

# Synthese

## The Poetics of Physics

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# The Poetics of Physics

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## Keywords

Thermodynamics; info-entropy; ontology; epistemology; palaeo-Hebrew; poetry

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# The Poetics of Physics

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## Abstract

Physics has been thought to truly represent reality since at least Galileo, and the foundations of physics are always established using philosophical ideas. In particular, the elegant naming of physical entities is usually very influential in the acceptance of physical theories. We here demonstrate (using current developments in thermodynamics as an example) that both the epistemology and the ontology of physics ultimately rest on poetic language. What we understand depends essentially on the language we use. We wish to establish our knowledge securely, but strictly speaking this is impossible using only analytic language. Knowledge of the meanings of things must use a natural language designed to express meaning, that is, poetic language. Although the world is really there, and although we can indeed know it truly, this knowledge is never either complete or certain but ultimately must rest on intuition. Reading a recently discovered artefact with a palaeo-Hebrew inscription as from the first century, we demonstrate from it that this ontological understanding long predates the Hellenic period. Poetic language is primary, both logically and temporally.

## Epigraph: “*Ku wown biyuke*”

Ku wown biyuke  
 nikwe ukanuhwan amin madikte arikna inurikyene,  
 (warukma, kamuw, kayg)  
 hawwata ukannuhwan umin wis amadgaya inin,  
 (uhiyakemni akak uwakemni)  
 in ka ekkepka akisyavrik akiw  
 ewka awen wownavrik.

Ku wown biyuke  
 nikwe madikte amadgaya inin,  
 (parahwokwa, warik, puwiknebdni akak ahavwi)  
 in ka kinetihwaka nimin akiw,  
 akak uhiyakemni payak akak uwegewni  
 mmanawa in kuwis menwe.

Ku wown biyuke  
 in ke wotbe pahayku lapot sabukwiyebe.  
 Nikwe hiyeg amedgenevwi inin  
 awetuvye pukuha  
 ku samah wowskawni ay amadga inin.

Ku wown biyuke,  
 unetni adah kiyathaki akak amnihka  
 unetni adah kayahka akak batekka  
 wavan, westwa, unetni, uvigyepkawni,  
 amekenegben gikehnikis  
 in ka kinetihwakati nimin akiw.

Ku wown biyuke,  
 — aa, ka aynsima iwit kuwis biyuke,  
 ka aynsima iwit biyuknene akiw,  
 kewa pahak waruwbe bekbetepka aritnanyuvwi —  
 nikwe wahawkrivwiy gikuvimnakis  
 tinwohawsepka adah avavyekwa  
 in ke igiskabe ku pariye wis biyukse adah avavyekwa.

If our language is lost  
 then all our knowledge of things above  
 (stars, sun, and moon)  
 and the knowledge of us humans on earth  
 (our thoughts and our deepest feelings)  
 will not be properly expressed again  
 when our language is gone.

If our language is lost  
 then everything in the world,  
 (seas and rivers, animals and plants)  
 may never again be spoken  
 with our understanding and insights  
 for these will have already vanished.

If our language is lost  
 it will be as though a door were closed  
 to the peoples of the world  
 and they will never understand  
 how we lived here on earth.

If our language is lost  
 our words of respect and love,  
 our expressions of pain or fondness  
 our songs, our stories, our talk, our prayers,  
 the accomplishments of our ancestors  
 will never be spoken of again.

If our language is lost  
 — oh, many languages have already been lost  
 and many more are almost lost,  
 like mirrors forever shattered —  
 then our ancestors' voices  
 will be silenced forever  
 and a great treasure will be forever lost to us.

after Miguel Leon-Portilla: *Cuando Muere Una Lengua* (1998)

© 2016 Aldiere Orlando, by permission (*translation from the Palikur language*: Diana Green © 2020)

See Supplementary Materials for the audio file of the poet speaking the poem in *Palikur* (and for its *Portuguese* translation), also for the *Náhuatl* original of *Cuando Muere Una Lengua* (and its translation into *English* from the *Spanish*).

## 1. Introduction

This essay has in mind Marshall McLuhan's idea, "*The Medium is the Message*" (McLuhan 1964): our epigraph and epilogues are *poems* because the very purpose of the work is to establish the idea that we always *mean* more than we *say*; an idea that is true even in – perhaps *especially* in – doing physics. So the canonical textbooks of physics are notoriously brief (for example Landau & Lifshitz 1940). Why are they brief? Because the students are supposed to *grasp* the material, and fill in the "trivial" (actually very challenging) gaps in the treatment for themselves. It is this activity of *grasping* that we will focus on here.

We will seek to prove that the terms which we use to *understand* any material, here especially including the material of mathematics and physics, is rooted in a poetic use of language in which ambiguity cannot be eliminated. The very terms used for our opening and closing poems, *epigraph* and *epilogue*, make use of the ambiguity of the Greek prefix ἐπι (*epi*) which can mean (among other things) either "upon" (that is in this case "before") or "in addition" (that is in this case "after").

The renowned physicist Carlo Rovelli has been dubbed "*the poet of physics*" by Richard Webb in his review of one of Rovelli's popular science books, which Webb calls "*enriching, illuminating, eclectic*" (Webb 2020). This present paper is "eclectic" since it ranges over subjects not usually considered together (physics, poetry, palaeo-Hebrew); but then the issue is reality itself, and the boundaries we erect around our disciplines are merely for our own convenience. For example, the DDT molecule behaves the way it behaves completely independently of whether we are considering the applicable quantum mechanics, or its enthalpy of formation, or the chemical and process engineering needed for its industrial production, or the regulatory issues related to its safe use, or the political issues raised seminally by Rachel Carson who took her title "*Silent Spring*" (Carson 1962) from a poem by Keats (1819).

Tom McLeish opens his book (McLeish 2019) with a "*powerful list of words*", that is: "*Creativity, Inspiration, Passion, Imagination, Composition, Representation*" (the capitalisation is his), which he proceeds to argue apply to the sciences just as much as to the humanities. He quotes Karl Popper saying, "*A great work of music, like a great scientific theory, is a cosmos imposed on chaos – in its tensions and harmonies inexhaustible even for its creator*" (Popper 1976). McLeish asks, "*Is a dualistic division into arts and science really faithful to our history, our capacities and needs?*" arguing that we should not "*reinforce the well-worn narrative*" of the "*Two Cultures*" (Snow 1959).

We believe that our account of *science* should acknowledge the seminal contribution of *Inspiration* to the process of gaining knowledge, and this essay is an attempt to do this. We wish to know *what things are* (that is, their ontology), and we also wish to know *how we know* what things are (that is, their epistemology). We seek here to explore the idea of *knowledge* itself, and to do this we will have to go beyond the usual Hellenocentric accounts that lead us to believe that philosophy started with Socrates (or at least, with the pre-Socratic Greeks)<sup>1</sup>.

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<sup>1</sup> So A.N.Whitehead is famous for saying, "the safest general characterisation of the European philosophical tradition is that it consists of a series of footnotes to Plato" (Whitehead 1929, ch.1§1). Everyone (including Whitehead himself) who comments on this aphorism hedges it about with qualifications, but nevertheless the Socratic analytical style is thought to be properly "philosophical" where the poetical (or "mystical" or "religious") styles of other ancient peoples is not. We think this is misleading, and will adduce evidence for this long pre-dating the Hellenic period.

*Knowing* is a characteristic human activity that in all the ancient societies we know of has been linked to *seeing* (which is why the wise were called “*seers*”), and the “*blind seer*” is an ancient archetype<sup>2</sup>. We will explore the roots of our ideas of knowledge since it is obviously a fundamental error to think that true things could have been known only in modern times.

The trouble with this is that there exist today widespread prejudices not only that for knowledge to be “true” it must be “scientific” (with poets operating somehow on a different plane), but also that any talk that may be called “religious” is necessarily irrelevant to science, even though what we now think of as “religious” ideas pervaded all ancient poetry. However, no-one has a monopoly on talking nonsense, and in any case we insist on the unity of truth. We are investigating *how we come to know* new things, and our discussion will range from the details of modern developments in thermodynamics to the ancient poets composing in an ancient Hebrew: the fact that this poetry is now pigeon-holed as “religion” here concerns us not at all. Instead we wish to point to the characteristic humanity of both the poetry and the science: we will show that the knowledge of both the poet and the scientist is, ultimately, the *same sort of thing* (even if they use vastly different methods). After all, both the poet and the scientist want to explain reality, which may be seen in multiple different (but complementary) ways.

It is also often thought today that scientific concepts are not constructed in a “natural” language, being higher order abstractions, and therefore that other accounts (such as the present one) are simply irrelevant. It is of course certainly true that modern physics is normally discussed by physicists in eye-wateringly sophisticated mathematical terms (and the thermodynamics we will describe is no exception), nevertheless we will demonstrate that at the foundations of every field of physics (with thermodynamics as our example) is a “natural” language explanation of how to *grasp* (or *see*) the phenomena of interest. Mathematics is required to expose logical consequences, but words are required to illuminate meaning.

## 2. Meaning as Poetry

In what way can a scientist be like Shakespeare? Tom McLeish recently quoted Shakespeare’s 100<sup>th</sup> Sonnet (“*Where art thou Muse ...*”) saying, “*it has never been easy to speak with clarity about moments of imaginative conception*” (McLeish, 2019, p.7), and we will also quote Dante Alighieri speaking of his Muse (§5.4). McLeish eloquently discusses a variety of cases showing how scientists *imagine* reality before they are able to establish their new theories, and how these imaginative (creative) approaches are actually central because of “*new patterns and connections that they offer for specific creative demands*” (McLeish, 2019, p.331). Seeing new things requires imagination!

Almost a century ago Owen Barfield famously spoke of “*poetic diction*”, that is: “*the language of poetic compositions*” (Barfield, 1928, III:5):

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<sup>2</sup> So Odin plucked out an eye to gain knowledge, and when Jesus said, “*seeing they see not*” (Matthew 13:13 *passim*; 1<sup>st</sup> century CE) he was quoting the pre-Hellenic seer (Isaiah 6:9f; 7<sup>th</sup> century BCE) who wanted the people to “*understand with their hearts*”. This saying of Jesus is one of the few attested in all four Gospels, underlining its central importance in European culture of the last two millennia: this attitude to *seeing* also underlies (almost invariably tacitly) the European philosophical tradition.

At one point in a detailed monograph on unconscious and/or unexamined bias, Jessica Nordell says, “*It may be that I did not even see [the operation of bias]*” (Nordell 2021, p.51). We see only what we believe, to an extent that is surprising (and often shocking). In another place she comments: “*We have to develop the ability to truly recognize what we see*” (*ibid*, p.164, citing Kahneman & Klein 2009).

When we start explaining the language of famous scientists as examples of ‘poetic diction’ ...  
[it is no] waste of time [if it helps anyone to be convinced] how essentially parochial is the  
fashionable distinction between Poetry and Science as modes of experience

Owen Barfield, *Poetic Diction* VIII:6 (1928)

seeking to establish, like McLeish, that epistemologically there is little distinction between artists and scientists: they are all similar in how they come to know new things.

If I say (with Parker & Jeynes, 2019), “*information has calculable entropy and obeys physical laws*”<sup>3</sup>, what do I mean? And how can you understand me? Barfield says that “*the poet’s relation to terms is that of maker*” (VIII:4)<sup>4</sup>; *information* and *entropy* here are terms referring to certain aspects of physical reality and it is clear that the terms are made by the physicists: are they (as both Barfield and McLeish outrageously seem to say) in some sense thereby *poets*?

We do not think that physicists ought to be poets, nor even that at least *some* physicists should! We regard such a position as absurd. But we do think that *ultimately*, physicists cannot avoid using language “poetically”: that is, using a “natural” language<sup>5</sup> (together with its unavoidable ambiguity) to set up the models proposed for the phenomenon in view. As an example of this we will explore the specific case of how we address the scientific concepts of *entropy* and its close companion *information*, which together represent difficult ideas in a currently very active (and contentious) field of research. We point out that the very close relation between information and entropy is now well established (Parker & Jeynes, 2019) by workers who articulate this relation in mathematical detail as a “new” concept of *info-entropy* within the overall theory that they call “Quantitative Geometrical Thermodynamics” (QGT).

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<sup>3</sup> The ontology of “*physical law*” is well-trodden ground (*e.g.* Bird, 2005) and out of our present scope.

<sup>4</sup> Barfield says of this dictum: “The *use* of them [the terms] is left to the Logician, who, in his endeavour to keep them steady and thus fit them to his laws, is continually seeking to *reduce* their meaning. I say seeking to do so, because logic is essentially a compromise. He could only evolve a language, whose propositions would *really* obey the laws of thought by eliminating meaning altogether. But he compromises before this zero-point is reached” (*ibid.*, italics original). This is entirely consistent with our view, *mutatis mutandis*.

In a subtle work now largely overlooked Barfield also investigates the “modern” attitude to *hypotheses* (Barfield 1957) in a treatment close to ours here in certain important respects. He says that the post-Copernican attitude is that “*if a hypothesis saves all the appearances it is identical with truth*” (*ibid.* Ch.VII) where of course his debt to Pierre Duhem (1908) is clear and explicit in his treatment. Much has happened since 1957 (including the establishment of the reality of both black holes and the cosmic microwave background), and this description of *hypotheses* (which characterisation does not adequately represent the breadth of Barfield’s argument) is clearly a version of naïve realism, which is no longer tenable (if it ever was). In our terms he claims that the modern (post-Copernican) view confuses the formalism with the reality (for further on “reality” see below, *note#24*).

Moreover, his gloss on the Hebrew Scriptures, not only regarding the (temporal) priority of Hebrew thought over Greek, but also underlining both the *otherness* of the Hebrew mode of thought and the metaleptic nature of the Christian (Greek) Scriptures’ dependance on the Hebrew Scriptures, is entirely consistent with our view (see §6 below).

<sup>5</sup> We will quote Thomas Piketty (2019) saying “*there is nothing ‘natural’ about language*” (§3): by “natural language” we mean the language we use every day without any special technical vocabulary. This is the same language used for novels and the same language used for poetry, although in both cases the authors or poets may use a register of language that can hardly be called “everyday”. We always compose (or write) for an audience: this will determine our style. But composition for a general audience cannot use any special language. We will call this, for want of a better term, “natural” language.

Note that this is *not* a “definition”, and is not intended to be one. We are not attempting to construct any sort of “analytical metaphysics” (on “metaphysics” see *note#10* below). Formal definitions use analytic (not poetic) language, but we are here only explaining informally which meaning we intend.

Using these test cases, explicitly using one of the first papers on entropy (Clausius 1854), we seek to show how the development of scientific ideas necessarily depends in the first instance on an intuitive understanding that relies on intrinsically poetic language. We emphasise that “poetic language” is not restricted to poetry! Even in 1928 Owen Barfield recognised that “famous scientists” used “poetic diction”. The basic ideas of any theory have to be “negotiated” (Edwardes 2019<sup>6</sup>) using some sort of “natural” language, and any subsequent mathematical representation is only a formal method of displaying the logical consequences of these ideas.

This assertion is disturbing since it is widely thought today that there is a sharp distinction between the “hard sciences” in which things are known certainly (or at least, pretty much certainly for practical purposes) and the humanities which (supposedly) prize feeling above thought. Supposedly, everyone agrees in science, but no-one agrees in politics, philosophy and religion. But we point out that knowledge is fuzzy: the “hard sciences” are not as hard as we might like them to be. The old joke goes, “*two Jews, three opinions*”, but the Jews themselves point to the value of debate in “*an atmosphere of civility and mutual respect and a willingness to concede one's original position in order to achieve the truth*” (Weinreb 2021). Who would disagree with that? It turns out on closer inspection that the “scientific method” is more poetic than we might have expected.

Summarising the programme of this essay: before a scientific concept can be understood it must be articulated, and language is essential to articulate scientific ideas: we cannot *know* anything without being able to *say* what it is we know (without language we have inchoate *feeling*, not *knowledge*). Science is effected by humans acting humanly – that is, using language! Stones don't know things: people do. Our knowledge of the world is necessarily based ultimately on intuition<sup>7</sup>, and the articulation of intuited knowledge is ultimately the business of poets. Before it is anything else, natural language is poetic.

Saying that *knowledge is necessarily mediated by words* sounds like the *linguistic determinism* famously proposed by Benjamin Lee Whorf (1941). We do not take this position, but rather that of the “*relay results*” advocated by McLeish who relies on Jacques Hadamard's *The Psychology of Invention in the Mathematical Field* (Hadamard 1945):

... James Clerk Maxwell would urge mathematicians to formulate their thinking in ‘words without the aid of symbols’, not because he would sympathize with the lingualists, but because he knew the creative force of communicating ideas

Tom McLeish *The Poetry and Music of Science* (2019) p.243

We note that McLeish explicitly considers the parallels between scientific creativity and the (wordless) creativity of painters and musicians: that is, there does exist a “knowledge” that is

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<sup>6</sup> Martin Edwardes treats the idea of “negotiating meaning” at length, but for convenience we summarise it here with an example. If, driving down a single track road, I meet another car, who has priority? We both have right of way, but neither of us has priority, and we have to “negotiate” who backs up to the nearest passing place. Without agreement we cannot move. If I want to say something straightforward so that you understand me, we already know how to do that. But if I want to say something new, you may not at first know what I mean: then we have to together “negotiate the meaning” until you are satisfied.

<sup>7</sup> Kahneman & Klein in their classic paper investigate this *intuition* in detail: “*expert intuition is sometimes remarkably accurate and sometimes off the mark*” (Kahneman & Klein 2009), of course they are considering real technical (“expert”) knowledge. They explicitly point out that the cues experts use to make their judgments “*involve tacit knowledge [which is] difficult for the expert to articulate*”. On tacit knowledge of course see Polanyi 1958 (and our discussion below). On the proper use of (and limits to) *expertise* see also Collins & Evans (2007).

*not* mediated by words, but we consider this wider view of knowledge as outside our present scope. Michael Polanyi also considered such knowledge, which he called “*tacit*”<sup>8</sup>. We here only consider scientific knowledge from the point where it becomes crystallised in words:

The formulation of the fruitful question, posed in the right way, constitutes the great imaginative act in science  
Tom McLeish *The Poetry and Music of Science* p.10 (2019)

We are also distinguishing sharply between “*information*” (which is physical) and “*knowledge*” (which is mental). *I know* precisely because *I am informed*. Stones incorporate *information* from which geologists can glean *knowledge*.<sup>9</sup>

The thesis of this paper is that where physics must use *analytic* language, metaphysics<sup>10</sup> must involve irreducibly *poetic* language. Language is intrinsically metaphorical: all our words have concrete referents but none of them is *merely* concrete, they all come with a cluster of connotations. Iris Murdoch (1967) observed long ago of metaphors:

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.  
Iris Murdoch, *The Sovereignty of Good over other Concepts* (1967)

A “*metaphor*” (after the ancient Greek *μεταφέρειν*, to transfer) can be thought to *translate* (or transfer) between elements of this connotation cluster, and this idea of “*translation*” is essential

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<sup>8</sup> see Part II – “*The Tacit Component*” – of his *Personal Knowledge* (Polanyi 1958). See also Mary Jo Nye’s recent assessment of Polanyi (Nye 2017).

<sup>9</sup> We are not here concerned with how much animals know: so far as we are aware, science is human. Here we are interested only in how *we* know things, not in how other creatures may possibly know things.

<sup>10</sup> We use “*metaphysics*” as a term cognate to (e.g.) “*metanarrative*”, “*metamathematics*”, “*metadata*”: that is, a “*natural*” language (see *note#5*) in which one may speak of the underlying features of the language or activity in question (the art of narrative, mathematics, the structure of the dataset). So here we use “*metaphysics*” to mean “*the metanarrative of physics*”. See below §5.2.

We do *not* intend the conventional (often pejorative) range of meanings normally associated with “*metaphysics*”. In particular we will in this essay directly address (as “*ontology*” or “*epistemology*”) what is usually spoken of as *metaphysics*, the first meaning of which is given by the Oxford English Dictionary: “*The branch of philosophy that deals with the first principles of things or reality ... theoretical philosophy as the ultimate science of being and knowing*” (OED 3<sup>rd</sup> Edition 2001).

As Rasmus Jakslund points out “*there is no univocal definition of metaphysics*” (Jakslund 2021), although he proceeds on the basis that metaphysics ought to be “*naturalised*” with a subject matter essentially indistinguishable from physics proper (except that the proper physical treatment has not yet become clear). We think that this approach is overcomplicated as well as apparently begging the basic ontological and epistemological questions: even the scaled back proposal of “*Moderately naturalistic metaphysics*” (Morganti & Tahko 2017) acknowledges that “*metaphysics*” (in the OED meaning) may explore “*a basic possibility space in such a way that the grounds for the interpretation of scientific theories are laid*” in just the way we will describe here. We wish to speak of *metaphysics* simply as the (“*natural*”) language used to set up the model of the physical system (with *entropy* as an example: §4.1).

Therefore, we think that James Ladyman’s suggestion that “*The first task of the metaphysician, like the scientist, is to construct a hypothesis that accounts for the phenomena in question*” (Ladyman 2012) is beside the point. It is the job of the scientists to account for the phenomena, but what terms are available to them? New terms for the new science must be constructed (“*negotiated*”, Edwardes 2019) out of existing language in a way comparable to how Clausius did it for “*entropy*” in 1854 (see §4.1). In any case, “*the primary ontological unit is the phenomenon*” (Barad 2007, p.333). We will discuss this further in §5.1 below.

to our thesis<sup>11</sup>. We will show (using the particular case of *entropy*) that the narrative of physics is only established in the context of a metanarrative (in this case called “metaphysics”) which constructs the meanings of the ideas to be used in a natural language as unambiguous as possible. This metaphysical step is usually carefully ignored by philosophers of science: Nicholas Maxwell’s “*aim-oriented empiricism*” approach (predicated on the *metaphysical priority* of unified theories) is a welcome exception (Maxwell 2020). But *standard empiricism* glosses over the idealistic foundations of how we *interpret* observations.<sup>12</sup>

There is a complexity here. We believe that Maxwell’s insistence on the *idealistic* nature of physics (since we always prefer unified theories, however wrong they might be) does not affect the common view of physicists that successful theories are *true*. That is, physicists are usually both realists and idealists. Logically, these two attitudes appear to be mutually exclusive: how then can they be compatible (if indeed they are)? We acknowledge that the naïve realist<sup>13</sup> and the naïve idealist positions are both untenable, but we will argue here for the truth that the physicist needs an *idealistic* approach to recognise a promising theory, while depending on a philosophical attitude that regards the world as real, rational, and comprehensible in principle (that is, being some sort of *realist*). And formally, this philosophical attitude must be couched in a ‘natural’ language (however tacitly), there being no alternative. Of course, one’s underlying philosophical attitudes are rarely made explicit.

Note that natural language is always ultimately poetic, especially where new meanings are being created. Meaning is always *negotiated* between speakers, and poets find new and resonant ways of doing this: Martin Edwards (2019) has shown how this *negotiated meaning* must be central to ontology. When scientists establish new concepts they must “negotiate the meaning” of the terms they use for these new concepts. We will show here how this works in the case of *entropy* (and *info-entropy*).

Understanding physical concepts therefore always involves an intuitive leap in meaning from the concrete to the metaphysical, which we could also arguably (and nearly equivalently) call the *spiritual*. The very word *spirit* exemplifies this intuitive leap. Today the English word *spirit* has a range of metaphysical connotations, but in the original Latin it also carried the concrete meaning *wind* (which English word has an Anglo-Saxon etymology). So for example, there is a Greek record of Jesus’ saying (John 3:8):

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<sup>11</sup> Our thesis is very restrained: it uses only the English, Palikur, German, Italian, Latin, Greek and Hebrew languages. The comparative linguistics, which are pregnant with ontological implications (Perunović 2021), are here only hinted at. These implications exist even for “simple” data handling (Forkel 2018).

<sup>12</sup> “Standard empiricism”, believed to be “objective”, has its usual meaning (Maxwell 2020). Maxwell shows how the usual treatment smuggles our own *ideas* in in the same way that Polanyi (1958) shows that knowledge is personal (the unavoidable subjectivity is smuggled in by how we speak of “simplicity” – see §3). That is, our understanding is *idealistic*: it depends on our own personal (or “subjective”) ideas.

Note that *measurement* itself is now acknowledged by the metrologists to have an irreducibly subjective element, see in particular §5.1. Note also that the subjectivity of our knowledge does not undermine it in any way, since it is socially validated by the peer review system (Hicks 2016).

<sup>13</sup> One sort of “naïve realist” might be what Timothy Lyons (2006) calls the “*deployment realist*” who says essentially that scientific theories are true because they work. Lyons explains in detail the multiple problems of this view, also confronting the literature at length.

Textus Receptus (<70 CE<sup>14</sup>): το πνευμα οπου θελει πνει ... που υπαγει ουτως εστιν πας ο  
γεγεννημενος εκ του πνευματος

*transl.* Jerome (c.400 CE): Spiritus ubi vult spirat ... sic est omnis qui natus est ex spiritu

*transl.* Tyndale (1526): The wynde bloweth where he listeth [where it wills] ... so is every  
man that is boren of the sprete [born of the spirit]<sup>15</sup>

Note that cognates of the same word are used in both Greek and Latin (πνευμα, πνει, πνευματος / *spiritus, spirat, spiritu*) where three different words are needed in English (*wind, blow, spirit*). Translation of nuance is irreducibly creative: both Jerome and William Tyndale had poets' ears.

Returning to the original question, what is *entropy* and what is *information*? These are ontological questions. How do we understand entropy and its relationship to information? These are epistemological ones. To answer these questions we have to translate from the concrete to the general; that is, from specific observations to an articulation of a coherent theory. We will proceed to explore these issues, taking as examples the meanings of “*information*” and “*entropy*”. Our thesis is that moving from the concrete observation of physical reality to the general articulation of a physical theory we cannot avoid brushing with the spiritual (in the sense explained above, which in this context would also usually be called “*metaphysical*”).

Barfield already knew a century ago that there is no clear line between *poetry* and *prose*: in reality these are undefinable categories, strictly speaking. But there is a clear distinction between poetic language and the analytic language that scientists must use. The poet relishes ambiguity<sup>16</sup>, which is fundamental in language and essential to poetry. But the point of analytical language is to reduce the inherent ambiguities as far as possible.

To be explicit here (since we will systematically contrast *poetic* and *analytic* language), poets have a free hand to use words any way they choose to invoke meaning to the hearers, making as full use as they like of the range of connotation (the *ambiguity*) of the words used. If the poet is successful then the hearer perceives meaning in the poem. On the other hand, scientists must *analyse* the ideas they wish to develop into components that are specified and combined as unambiguously as possible. But where do the scientists' ideas come from in the first place?

It should not be thought that because the use of 'natural' language is inescapable (and therefore that fundamental ambiguities necessarily remain in our theories), our knowledge of the world is thereby undermined. We will here underline what is common sense: all knowledge is ultimately incomplete – that is, we cannot know *everything* about anything. We wish to underpin our knowledge by giving a more correct account of it. No knowledge is absolute, and it is time to give a more nuanced account of the basis of our epistemology. Ultimately, we cannot avoid ambiguity: therefore, let us – like poets – start to treat it positively.

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<sup>14</sup> We give dates for the *New Testament* texts (conveniently but anachronistically reproduced in a miniscule Greek script with word spacing) as authoritatively discussed by John Robinson (1976).

<sup>15</sup> Tyndale's translations were printed in a blackletter font, but for convenience we transcribe here in a Latin font.

<sup>16</sup> *Ambiguity* has been explored in detail in an important monograph (Anthony Ossa-Richardson, 2019), showing that although our modern appreciation of poetic ambiguity can be traced back to William Empson's seminal work (Empson 1930), it has a long prehistory in Europe reaching back to Augustine and the Christian understanding of the Hebrew Scriptures. Ossa-Richardson underlines our point here when he quotes Eugen Bleuler (1914) approvingly as “*seeing in ambivalence ... 'one of the most important mainsprings of poetry' [Die Ambivalenz is eine der wichtigsten Triebfedern der Dichtung]*” (*op.cit.* p.373), commenting that Robert Graves would later agree with this judgment.

The analytical narrative must be encased in a metanarrative (as we will show); moreover, poetic perception cannot be spoken of analytically. The early Wittgenstein famously said, “*Whereof one cannot speak, thereof one must be silent*”<sup>17</sup>, but the later Wittgenstein changed his mind, saying instead, “[*in most cases*] ... *the meaning of a word is its use*”<sup>18</sup>. In our terms, he switched from believing that analytic language was sufficient, to recognising that poetic language was ontologically indispensable<sup>19</sup>. Something similar can be said of Richard Rorty: in 1982 he famously said (citing William James) that truth is “*a compliment paid to sentences that seem to be paying their way*” (Rorty, 1982); but in 2000 he says: “*it was a mistake on my part to go from criticism of attempts to define truth as accurate representation of the intrinsic nature of reality to a denial that true statements get things right*” (Rorty, 2000). Bruno Latour said something similar in his influential essay (Latour 2004). Of course, we argue here that it is a *logical* mistake to try to “*define truth*”.

Our epigraph touches both ontic and epistemic issues. It is composed (after a poem in *Náhuatl*, an autochthonous Mexican language) in *Palikur*, a northern Arawak language spoken by less than four thousand people living in the Brazilian state of Amapá and in French Guiana. There is a Palikur-Portuguese dictionary (Green, 2010) and the language displays *ways of knowing* that differ markedly from modern European ones (Green, 2013). The way we think – our very identity – is inextricable from our *language* (and the *Náhuatl* and the *Palikur* poems both express how horrible its loss would be<sup>20</sup>). What we *know* is inexpressible without language<sup>21</sup>. Benjamin Lee Whorf (1941) drew attention to the converse of this: “... *people act about situations in ways which are like the ways they talk about them*”, but this only serves to underline our point. If we cannot say it we cannot know it: this is true for all aspects of reality (but see *note#3*).

But first we must consider “reality” itself. The paper is constructed as an essay on ontics and epistemics: what things *are* and how we *know* them. We start by exploring the *thinginess of things* (§3), that is, the rational structure both of reality itself and of our knowledge of it. We then, separately, summarise the surprising development of the ideas of *entropy* and *information* (§4) as a specific example of how meaning is negotiated in physics. We underline (§5) this *negotiating of meaning* in the development of knowledge as being an exercise that necessarily involves poetics. The whole essay revolves around the recognition of *language* as the primary and essential medium of knowledge, and we give an example of this (§6) that uses a detailed analysis of an artefact that is demonstrably a mnemonic of a very sophisticated view of *knowledge* long predating the Hellenic schools of philosophy. We gather the threads of the argument together (§7) and finally conclude (§8).

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<sup>17</sup> “*Wovon man nicht sprechen kann, darüber muss man schweigen.*” (Wittgenstein 1921, §7)

<sup>18</sup> “*Man kann für eine große Klasse von Fällen der Benützung des Wortes »Bedeutung« - wenn auch nicht für alle Fälle seiner Benützung - dieses Wort so erklären: Die Bedeutung eines Wortes ist sein Gebrauch in der Sprache*” (Wittgenstein 1953, §43; emphasis original). This is translated as “*For a large class of cases—though not for all—in which we employ the word “meaning” it can be defined thus: the meaning of a word is its use in the language.*” Wittgenstein died in 1951: the *Philosophical Investigations* was published posthumously.

<sup>19</sup> ... although Wittgenstein is usually spoken of either as a positivist (early) or a pragmatist (late) of the sort that Iris Murdoch takes aim at. So he says, “*Wie haben wir denn die Bedeutung dieses Wortes (»gut« zum Beispiel) gelernt? An was für Beispielen; in welchen Sprachspielen?*” (Wittgenstein 1953, §77) but Murdoch specifically attacks this point of view in her essay “*On ‘God’ and ‘Good’*” (Murdoch 1966).

<sup>20</sup> Course & MacMillan (2021) have similarly observed, speaking of the threatened loss of the Gaelic language: “*The culture, the people, everything would disappear forever*”.

<sup>21</sup> This is strictly correct if we include the *language* of music or art (McLeish 2019), and if we note that Polanyi’s “tacit knowledge” is predicated on students picking up this tacit knowledge in the lab by doing things in collaboration with (and *talking with!*) supervisors and colleagues (Polanyi 1958).

### 3. The Thinginess of Things

Michael Frayn (2006) has memorably spoken of the “*thinginess of things*”<sup>22</sup>, that is, the sure ontological grasp that reality appears to have on us. Things *are!* This has long been resonant with the poets: for example, Wallace Stevens (1954) spoke specifically of “*A new knowledge of reality*”. Also, Iris Murdoch is quoted as saying, “*I’m glad we live in a thingy world*” (Jordan, 2012); her novels are shot through with this philosophical attitude. In her first published novel (Murdoch, 1954) she makes one of her heroes observe that the “*activity of translating*”, central to our thesis here, is “*an act so complex and extraordinary that it was puzzling to see how any human being could perform it*”. Why is this? Because every thing is “*astonishing, delightful, complicated and mysterious*” (*ibid.* ch.4, p.62).

*Thing* is a very ancient word with a surprisingly wide range of connotation (including *parliament*), and which is thought to be related to the Indo-European root of the Latin word *tempus*, time. Of course, material things only exist – can only exist – in time<sup>23</sup>: Frank Wilczek (2021; ch.6, p.159) points out that this underlies Augustine of Hippo’s (426 CE) elegant proof that the Christian doctrine of Creation entailed the creation of *time* along with matter. For, Augustine said, we only know time by the movement of things (he fixed their ontology by calling them “creatures” – that is, things made by the Creator); therefore, if there are no things then neither can there be time:

procul dubio non est mundus factus in tempore, sed cum tempore ... nullum autem posset esse  
praeteritum, quia nulla erat creatura, cuius mutabilibus motibus ageretur

verily the world was made with time, and not in time ... no time passed before the world, because no  
creature was made by whose course it might pass. But it was made with time, if motion be time's  
condition  
Augustine, *City of God* XI:6, 426 CE

There is also a similar statement in a lengthy and acute discussion in Book XI of the *Confessions*. Thus Augustine anticipates the conclusion of the *Gravitational Singularity Theorem* (that *time* had a beginning) by a millennium and a half (Hawking & Penrose, 1970).

All physicists operate on the assumption (not usually explicitly acknowledged) that the thinginess of the phenomena they investigate is ontologically secure: that is, the world is real.<sup>24</sup> Philosophically and historically this ontological security ultimately derives from the assertion of Creation by the monotheist religions<sup>25</sup>, even if most physicists today assume it tacitly merely as a pragmatic

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<sup>22</sup> “*Thingification*” is an interesting word whose first usage the Oxford English Dictionary (OED) attests in 1935; the OED lists *thinghood* as used by A.N.Whitehead, but sadly does not list the (better) synonym *thinginess* (philosophers might speak instead of “*reification*”, a Latinist neologism of the mid-19<sup>th</sup> century). The OED also attests all of *thingly* (adjective), *thingy* (both as a noun and an adjective), *thingness*, and *thingliness* (respectively 1450, 1787, 1891, 1840, 1662). Bruno Latour (2004) also spoke of “*thinginess*”. We are not much concerned here with Bill Brown's “*Thing Theory*” (Brown, 2004), which is interested more in *our relation with things* than the things-in-themselves.

<sup>23</sup> Of course Augustine was thinking about “massive” things, not mass-less ones like the photon. It is an elementary result of special relativity that the closer one’s speed is to the speed of light the slower “time” passes: thus for photons “time” stops altogether. This very simple and straightforward result is entirely counter-intuitive which remains very shocking however familiar it is: see further on the individuality of things in general (and electrons in particular: *note#63*).

<sup>24</sup> “*Real*” is another nice word whose extensive cluster of connotations includes *royalty* – well-known today by the many followers of premier-ranked *Real Madrid*: monotheists would say that the idea of *reality* derives from God the ‘King of kings’ (that is, God the Creator). See also the discussion of “Wigner’s friend” scenarios in *note#27*.

<sup>25</sup> This point of view was famously proposed by Herbert Butterfield in his *The Origins of Modern Science* (1957), which remains important as is discussed (for example) by Regis Cabral (1996) and

precondition. Interestingly, Gerry Schroeder (1997) has shown *both* that the Hebrew Creation story successfully resists scientific criticism, *and* that its interpretation is as subtle and elusive as any poetic text. And Iris Murdoch is not the only philosopher to comment on “*the infinite elusive character of reality*” (Murdoch 1962).

It is important to realise that the thinginess of things is *ontologically axiomatic*, as Frayn effectively acknowledges in a long discussion (Frayn 2006). Our ultimate epistemological reliance on *personal guarantee* is documented by Richard Bauckham (2006) in the context specifically of historical events: ultimately, we know things only through *eyewitness testimony*:

The testimony of Holocaust survivors is the modern context in which we most readily recognise that authentic testimony from participants is completely indispensable to acquiring real understanding of historical events, at least events of such exceptionality. Bauckham, 2006 §18 (p.499)

We can of course subject *testimony* to the standard critical tests but, more often than not, in the end we have to decide whether or not to trust the witness. In the end we simply have to *choose* what to believe. Note that “*personal guarantee*” also underlies the peer review system, which cannot operate without good faith. Thus, *testimony* also underlies the epistemology of scientific knowledge.

All scientists are effectively realists of some sort, whether or not they believe this philosophically. If they didn’t implicitly believe a) that the world is *there*, b) that *laws of nature* existed, and c) these laws are *discoverable* by us; then they wouldn’t get up in the morning for another frustrating day in the lab: they would find something else more lucrative to do. But realists do not have to be naïve! So the fifth chapter of the dense book by Karen Barad (Barad, 2007) is titled “*Getting Real: Technoscientific Practices and the Materialisation of Reality*” and has an epigraph by Michel Foucault (renowned as a postmodern structuralist critic even if he himself did not like these labels). Barad’s book is an extended, detailed and subtle investigation of “*Reality*” and the “*Ontology of Knowing*” (these terms are taken from the book’s chapter headings) in the light of the ontological puzzles forced on us by a deep look at the fundamentals of quantum mechanics. Barad knows not only that the Universe is *there*, but also that our usual naïve ways of thinking about this are false – our grasp of reality is often uncertain and unreliable: the book title (“*Meeting the Universe Halfway*”) is a line from Alice Fulton’s poem “*Cascade Experiment*” (Fulton, 1989) which opens: “*Because faith creates its verification ...*”<sup>26</sup>

However, reality is elusive. Is knowledge objective? are the things that science describes and explains really there? Alessandro Fedrizzi & Massimiliano Proietti (Fedrizzi & Proietti 2019) gloss their paper (Proietti *et al.*, 2019) as “*Objective Reality Doesn’t Exist, Quantum Experiment Shows*”. The paper reports an elegant three-photon-pair implementation of a “Wigner’s friend experiment” demonstrating a violation of the associated Bell inequality<sup>27</sup>. This means that in this case the results

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Cunningham & Williams (1993). Butterfield’s style of argument may appear dated, but it seems to remain uncontroversial that his substantive points remain valid.

<sup>26</sup> It is today a commonplace that *we see only what we believe* (see for an experimental example of this Zhaoping 2007). Of course this is an exaggeration, but it is always an effort to allow for our biases (and we never completely succeed). So in the line after “*meeting the universe halfway*” Alice Fulton says (as it were in explanation), “*nothing will unfold for us unless we move towards what looks to us like nothing*.” We creep towards knowledge in ignorance. But however fallible and incomplete, our knowledge still is real. Fulton concludes: “*let my glance be passionate towards the universe and you*.” Note that for the poets knowledge is *always* personal.

<sup>27</sup> Such “Wigner’s friend” scenarios mean that observer-independent “facts” cannot be determined in these cases, but this does *not* mean that these experimenters are thereby not realists! Just because the idea of

observed are not “objective” (that is, 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)

Michael Polanyi in his “*Personal Knowledge*” (1958) insists that ultimately we have only *personal* guarantees of whatever knowledge we think we possess: strictly speaking, *objective knowledge* is an oxymoron<sup>28</sup>:

... the intuition of rationality in nature [must] be acknowledged as a justifiable and indeed essential part of scientific theory. That is why scientific theory ... [can be] represented as a mere economical description of facts ... or as a working hypothesis ... [but these are] interpretations that all deliberately overlook the rational core of science.

... great theories are rarely *simple* in the ordinary sense of the term. Both quantum mechanics and relativity are very difficult to understand; it takes only a few minutes to memorize the facts accounted for by relativity, but years of study may not suffice to master the theory and see these facts in its context.

... We understand the meaning of the term ‘simple’ only by recalling the meaning of the terms ‘rational’ or ‘reasonable’ or ‘such that we ought to assent to it’, which the term ‘simple’ was supposed to replace. The term ‘simplicity’ functions then merely as a disguise for another meaning than its own. It is used for smuggling an essential quality into our appreciation of a scientific theory which a mistaken conception of **objectivity** forbids us to acknowledge. Polanyi, 1958, §1:4

where here by “rational” Polanyi means to imply *our* application of reasoning: it is *people* who do the reasoning! Knowledge is irreducibly personal; the “*rational core of science*” entails reasoning people<sup>29</sup>. So we prefer the Copernican theory over the Ptolomaic one precisely because we think that “*its excellence is, not a matter of personal taste on our part, but an inherent quality deserving universal acceptance by rational creatures. We abandon the cruder anthropocentrism of our sense – but only in favour of a more ambitious anthropocentrism of our reason*” (*ibid*, §1:1).

How do we know that nature is rational (and therefore amenable to scientific description)? We intuit it. Prior to our rationalisations is our belief that rationalisations exist. And in speaking of

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“objective reality” can be shown to be illusory in at least some cases does *not* mean that reality is illusory, just that our ideas of it may be mistaken! As Karen Barad has pointed out, such experiments are seriously difficult and to successfully carry them out one must be pretty sure that Nature is there and will play ball. Barad says, quoting from Greenstein & Zajonc (1997): “*it is not trivial to detect the extant quantum behaviour in quantum eraser experiments. The experimenters must be clever enough to design an experiment that can detect the entanglement*” (Barad 2007 p.348). But asserting (in our terms) that the *thinginess* of the phenomena being investigated is ontologically secure is *not* asserting even that we can know it! So Barad asserts, citing Bohr himself, that “things” cannot be taken as “*ontologically basic entities*” (Barad 2007, p.138). The thinginess of things is ontologically secure precisely because it is *phenomena* that are “*ontologically primitive*” (Barad 2007, p.333).

<sup>28</sup> “Subject” and “object” are primarily terms of grammar. In the phrase “objective knowledge” the adjective “objective” is being used as a (grammatical) metaphor which we here regard as empty: with Polanyi, we regard the philosophical conception of “objectivity” as being essentially mistaken. To minimise confusion we will therefore avoid the use of the terms “subjective” and “objective”.

<sup>29</sup> Jessica Nordell (quoting Erica Klarreich, 2017, saying “*Anybody who does mathematics knows this*”) insists that this applies to maths too: “*Math after all, is personal, emotional*” (Nordell 2021, p.245)

rationality here, Polanyi is also referring to the primacy over common sense scientists commonly give to idealistic thought – we have already mentioned Maxwell’s “aim-oriented empiricism” (Maxwell, 2020). Polanyi asks:

What is the true lesson of the Copernican revolution? Copernicus gave preference to man’s delight in abstract theory, at the price of rejecting the evidence of our senses, which present us with the irresistible fact of the sun, the moon, and the stars rising daily in the east to travel across the sky to their setting in the west. Polanyi, 1958, §1:1

The fact may appear psychologically “irresistible”; nevertheless, Polanyi points out that behaving rationally we systematically do resist it. We may “intuit” that the sun goes round the earth; but at a deeper level we intuit that the relation of sun to earth is lawful, and analytically we recognise that the simplest expression of the law has the earth going round the sun. We intuit the existence of the rationality that underpins this lawfulness. It is the business of poets to articulate intuition<sup>30</sup>.

Of course, Polanyi is aware of the logical necessity of this attitude to rationality, which becomes clear (as he explains) when Kurt Gödel’s *Incompleteness Theorem* (1931) is understood. Quoting S.C.Kleene’s *Introduction to Metamathematics* (1952), Polanyi says,

Rules have been stated to formalise the object theory, but now we must understand without rules how those rules work. An intuitive mathematics is necessary even to define the formal mathematics. Polanyi, 1958 (*op.cit.*), 8:8

This “intuitive mathematics” is called “metamathematics” by everyone – Polanyi, Kleene, Gödel – just as we call the comparable “intuitive physics” by the cognate word “metaphysics”. Every narrative has its metanarrative, without which it cannot make any sense.

Gödel’s achievement was to demonstrate by construction that his formula (which we can express in words as “*this sentence is undecidable*”) was not meaningless. His demonstration was rather involved, but indicates the processes of mind required to establish this cornerstone of epistemology. We display its flavour with this brief extract from his Introduction (here  $K$  is the set of “Gödel numbers”  $q$  representing *unprovable* formulas):

Die Analogie dieses Schlusses mit der Antinomie Richard springt in die Augen; auch mit dem „Lügner“ besteht eine nahe Verwandtschaft, denn der unentscheidbare Satz  $[R(q); q]$  besagt ja, daß  $q$  zu  $K$  gehört, [das heißt] nach (1), daß  $[R(q); q]$  nicht beweisbar ist. Wir haben also einen Satz vor uns, der seine eigene Unbeweisbarkeit behauptet.

<sup>13</sup>) Man beachte, daß „ $[R(q); q]$ ” ... bloß eine metamathematische Beschreibung des unentscheidbaren Satzes ist.

The analogy between this result and Richard’s antinomy leaps to the eye; there is also a close relationship with the “Liar”, since the undecidable proposition  $[R(q); q]$  states precisely that  $q$  belongs to  $K$ , that is according to Eq.1,  $[R(q); q]$  is not provable. We are therefore confronted with a proposition that asserts its own unprovability.

(footnote #13) Note that “ $[R(q); q]$ ” ... is merely a metamathematical description of the undecidable proposition. Gödel, 1931<sup>31</sup>

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<sup>30</sup> Poets that is, and anyone using poetic language such as the novelist: “*We must be ruled by the situation itself and this is unutterably particular. Indeed this is something to which we can never get close enough, however hard we may try to as it were crawl under the net.*” (Murdoch, *Under the Net*, 1954, ch.6; Vintage Classics 2019 edition p.90). This is “Annandine” (Hugo’s alter ego) speaking. The novelist (who identifies with Hugo’s point of view) makes her point by indirection: going “*under the net*”.

<sup>31</sup> German texts were printed in a blackletter font (known in German as “*Fraktur*”) until it was discontinued in 1941. We transcribe texts by Gödel and Clausius (§4.1) into a more convenient Latin font.

Richard's paradox was stated in 1905, but the Liar Paradox is ascribed to Epidemides of Crete, alluded to by St. Paul (Titus 1:12, 57 CE<sup>32</sup>), and investigated at length among others by the 14<sup>th</sup> century John Buridan, who conditioned Galileo's theory of *impetus* (Read, 2002).

It is well-known that Gödel later became fascinated by Anselm's comparable *Ontological Argument* for the existence of God (*Proslogion*, 1078 CE). Anselm asserted that the idea, "*aliquid quo maius nihil cogitare potest*" ("*that than which no greater can be thought*") was not unthinkable, and therefore God (than which no greater can be thought) must exist in fact. Starting from this premise of "*thinkability*", Anselm actually gave a proof that in its self-referencing form<sup>33</sup> anticipated Gödel's proof by a millennium:

Et certe id quo maius cogitare nequit, non potest esse in solo intellectu. Si enim vel in solo intellectu est, potest cogitare esse et in re, est in solo intellectu: id ipsum quo maius cogitare non potest, est quo maius cogitare potest. Sed certe hoc esse non potest.

And surely *that-than-which-a-greater-cannot-be-thought* cannot exist in the mind alone. For if it exists solely in the mind even, it can be thought to exist in reality also, which is greater. If then *that-than-which-a-greater-cannot-be-thought* exists in the mind alone, this *that-than-which-a-greater-cannot-be-thought* is *that-than-which-a-greater-can-be-thought*. But this is obviously impossible. Anselm, 1078, II

The elegance of Anselm's Latin is noticeable. And one can hear an attenuated echo of this ontological argument in Descartes' famous dictum "*cogito ergo sum*", which George Berkeley (1710) modified to "*esse est percipi*" deliberately to contrast the idealism of the scholastic nominalists with the new materialist schools. Anselm goes on to comment on the relation between believing (ontics) and understanding (epistemics) that is central to our present work:

Gratias tibi, bene dominum, gratias tibi, quia quod prius credidi te donante, iam sic intelligo te illuminante, ut si te esse nolim credere, non possim non intelligere.

I give thanks, good Lord, I give thanks to you, since what I believed before through your free gift I now so understand through your illumination, that [even] if I did not want to *believe* that you existed, I should nevertheless be unable not to *understand* it. Anselm, 1078, IV

This is reminiscent of Augustine's dictum "*nisi crederis non intelligis*" ("if you do not believe you will not understand": *City of God*, XII:17; quoting a version of Isaiah 7:9). But Anselm has recognised how the increase of knowledge works – first we *see*, then we *understand* – which is equally true for painters, for poets, and for physicists. First one grasps the *idea*, then one works out the details. Just because the devil is in the detail does not mean that the initial illumination is dispensable. Just because many ideas turn out to be incoherent does not mean that the fruitful ideas do not originate with illumination. One is reminded of Eric Dodds' comment (1951, in his Preface): "*time and the critics can be trusted to deal with the guesses; the illumination remains*".

We are not here saying that we reliably grasp things by intuition – everyone knows this is not the case! To test the reliability of our ideas we have to do science in the usual way. But where does the idea itself come from? Its origin is the "*illumination*" discussed by Anselm<sup>34</sup>. We *discern* truth: nevertheless, uncertainty cannot be eliminated.

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<sup>32</sup> Using the conveniently definite dating of Robinson (1976).

<sup>33</sup> This recursive form remains of interest today (Leonard, 2021)

<sup>34</sup> And we may grasp this illumination by the "*leap of faith*" (properly, the "*leap by faith*" over Lessing's "ditch") proposed by Søren Kierkegaard explicitly in his "*Unscientific Postscript*" (Kierkegaard 1846) and implicitly in his discussion of Abraham's faith in "*Fear and Trembling*" (Kierkegaard 1843). It has been heavily debated ever since Kierkegaard, who was very influential in 20<sup>th</sup> century philosophy: earlier we called the same thing an "*intuitive leap*".

Both Gödel's and Anselm's sentences are self-referencing, and have logical properties entirely due to this recursiveness. Gödel's sentence is proved "*not meaningless*" by construction (and therefore true, by a metamathematical argument), but because of its wider scope Anselm's sentence has resisted such construction<sup>35</sup>.

Gödel's proof was a revolution, not only in its overturning of the expectation of the mathematicians that arithmetic could be proved *both* consistent *and* complete<sup>36</sup>, but also in its entirely novel style of proof, relying explicitly on a *metamathematical* argument. It is interesting not only that Anselm anticipated Gödel, but also that he understood the logical status of his argument, which he did not present analytically but poetically (as a prayer). Ultimately, ontic knowledge is, and can only be, intuited. How else can one understand Paul of Tarsus writing in 57 CE (Robinson, 1976) about God, who:

καλουντος τα μη οντα ως οντα (Romans 4:17, *Textus Receptus*)  
calleth those things which be not as though they were (transl: Tyndale, 1526)

We have a complementary view of the necessarily intuitive nature of the knowledge of thinginess, expressed in a different context by Thomas Piketty (2019). In a section titled "*On the Complementarity of Natural Language and Mathematical Language*", Picketty says:

This book will rely primarily on natural language (about which there is nothing particularly natural) ... There is no substitute for natural language when it comes to expressing social identities or defining political ideologies. ... Those who believe that we will one day be able to rely on a mathematical formula, algorithm, or econometric model to determine the "socially optimal" level of inequality are destined to be disappointed. ... I do not contend that "truth" is found only in numbers or certainty only in "facts".  
Picketty, 2019, *Introduction*

To be clear: we are distinguishing between the *analytic* language required for scientific work, and the *natural* language we use every day (see *note#5*) together with the *poetic* language needed to express deep meanings; there is no sharp boundary between "poetic" and "natural" language just as there is no sharp boundary between poetry and prose.

Picketty encloses "facts" in quotes since these are always contentious in economics: one person's verity is always another's heresy, and Picketty authoritatively displays the *ideological* nature of such "facts". But it turns out that physics is also ideological in a similar way and for similar reasons<sup>37</sup>. Of course, this is not entirely unexpected: our present essay here could be thought of as merely a footnote to Thomas Kuhn's seminal book of a generation ago (*The Structure of*

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<sup>35</sup> To be precise, where Gödel proves a tautology (all theorems are formal manipulations in logic) Anselm asserts something about the real world. I think nobody believes that the reality of any thing can be established merely by "*the analysis of concepts*" (Ward 2008, ch.6), however, as Keith Ward points out, the Ontological Argument "*shows that God is either necessary or impossible (that is, either cannot fail to exist, or that the concept is incoherent). But we cannot, simply by thinking, establish which.*" (*ibid.*) Here we are interested in the analysis and epistemology of concepts in general (including scientific concepts), but not in the theological or ethical discussion of them. Such discussion is of course important, but outside our present scope.

<sup>36</sup> "consistent" means that no false proposition can be proved in the system; "complete" means that there exists a proof in the system for every true proposition. Gödel cites the 1925 edition of Russell & Whitehead's monumental work *Principia Mathematica*, and also David Hilbert's work in arithmetic (Russell & Whitehead 1910, Hilbert & Ackermann 1928).

<sup>37</sup> where by "ideological" we intend to mean merely "of ideas". Of course there is a difference between the ideology of economics (which is highly political), and the ideology of physics (which is mostly philosophical). We are *not* here alluding to the politics of science, which is not our present focus important though power relationships are in the development of science.

*Scientific Revolutions*, 1962). We proceed to explore this ideology specifically in relation to the development of ideas of entropy since the mid-19<sup>th</sup> century.

## 4. Entropy and Information

As a specific phenomenological example of the scientific method in action, leading to new knowledge, we will now tell the strange and intricate story of the development of the idea of “*entropy*”, starting as a neologism of Clausius in analogy to “*energy*” (an exactly similar Hellenic word). The early work established the idea (§4.1); then Boltzmann and others developed its implementation in statistical mechanics (§4.2); then we consider information, and the Shannon entropy (§4.3); then we consider the extraordinary case of black hole entropy and the Bekenstein-Hawking equation (§4.4); then we apparently come full circle considering the “geometrical” entropy of Parker and co-workers, which clearly exhibits a true *isomorphism* between entropy and energy, and not merely an “analogy” (§4.5); and lastly we consider some implications of this discussion for the very meaning of “causality” (§4.6).

### 4.1 Early work on the concept of Entropy

*Entropy* is a slippery concept. Edwin Jaynes (1965) says about it, in a paper explaining some fundamental aspects of the (19<sup>th</sup> century) treatments of Josiah Willard Gibbs and Ludwig Boltzmann:

It is interesting that, although this field [entropy] has long been regarded as one of the most puzzling and controversial parts of physics, the difficulties have not been mathematical. ... It is the enormous *conceptual* difficulty of this field which has retarded progress for so long. Jaynes, 1965 (emphasis original)

The Oxford English Dictionary (OED) is very helpful. Rudolf Clausius introduced the term *entropy* in 1865 specifically as a Hellenistic neologism: from *έν + τροπή* (transformation; literally ‘turning’: all the connotations of *trope* are also present in English). The OED comments:

Clausius assumed that (German) *Energie* literally meant ‘work content’ (*Werkinhalt*) and devised the term *Entropie* as a corresponding designation for the ‘transformation content’ (*Verwandlungsinhalt*) of a system. Oxford English Dictionary, 3<sup>rd</sup> Edition (September 2018)

And then, in sense 1a (“*Physics & Chemistry*”), the OED elaborates:

Entropy was first defined by the German physicist Rudolf Clausius (1822–88). Scottish physicists Peter Guthrie Tait (1831–1901) and James Clerk Maxwell (1831–79) were the first to interpret entropy as *a measure of the unavailability of energy for work*.

The modern mathematical definition of entropy, in terms of the possible microstates ... of a thermodynamic system, first appears in the work of Austrian physicist Ludwig Boltzmann (1844-1906), who viewed entropy as *a measure of the disorder of a system*.

[Sense 3 “*Statistics and Information Theory*”] ... mathematician Claude Shannon (1916-2001) coined the term in the context of information theory (see sense 3b)

Oxford English Dictionary, 3<sup>rd</sup> Edition (September 2018)

The OED gives a variety of definitions, three related to scientific concepts. (We will show below that these do not exhaust the meanings assigned to the term.) This is not merely a philological variety, but a real scientific discrepancy that has led to much confusion. It is still not entirely clear whether the multiple definitions do actually refer consistently to a coherent idea. But the confusion has certainly resulted in error. Indeed, as Jaynes noted near the end of his life, regarding his variational approach to providing an underlying principle to entropy: “...*the long confusion about order and disorder (which still clutters up our textbooks) is replaced by a remarkable simplicity and generality*” (Jaynes 1992).

The very logical status of the Second Law of Thermodynamics has long been debated, as hinted at above. Is it a fundamental Law? or is it a consequence of the other Laws, which are all time-reversible (except for the CP-violation by K-mesons discovered by Cronin & Fitch)? Either way, consistency is a problem. How can time reversibility be consistent with time irreversibility (see below on the “Arrow of Time”, §4.6)? Clausius first clearly stated a version of the Second Law in 1854:

es kann nie Wärme aus einem kälteren in einen wärmeren Körper übergehen, wenn nicht gleichzeitig eine andere damit zusammenhängende Aenderung eintritt.

heat can never pass from a colder to a warmer body without some other change, connected therewith, occurring at the same time. Clausius, 1854

In the same 1854 paper, Clausius also recognised (before he had introduced the term) that entropy remains unchanged for reversible cyclic processes (“*umkehrbaren Kreisprocesse*”), calling the identity  $\int dQ/T = 0$  the “second law of the mechanical theory of heat” (“*des zweiten Hauptsatzes der mechanischen Wärmetheorie*”). Of course, the “first law” was  $Q = U + A \cdot W$ , where  $Q$  is the total quantity of heat (“*die ganze Wärmemenge*”),  $U$  is how much heat is in the system before work is done on it,  $W$  is the external work (“*die äufsere Arbeit*”), and  $A$  is the factor converting work to heat (“*das Wärmeäquivalent für die Einheit der Arbeit*”, literally: “the heat equivalent for the unit of work”). It is instructive to see how Clausius reasons here:

Bei dieser Bestimmungsweise kann man den Satz von der Aequivalenz von Wärme und Arbeit, welcher nur einen speciellen Fall der allgemeinen Beziehung zwischen lebendiger Kraft und mechanischer Arbeit bildet, kurz so aussprechen:

**Es läfst sich Arbeit in Wärme und umgekehrt Wärme in Arbeit verwandeln, wobei stets die Gröfse der einen der der anderen proportional ist.**

... Betrachten wir nun die bei einer Zustandsänderung gethane innere und äufsere Arbeit zusammen, so können sich beide, wenn sie von entgegengesetzten Vorzeichen sind, theilweise gegenseitig aufheben, und dem Reste mufs dann die gleichzeitig eintretende Aenderung der Wärmequantität äquivalent seyn. Für die Rechnung aber kommt es auf dasselbe hinaus, wenn man für jede von beiden einzeln eine äquivalente Wärmeänderung annimmt.

Sey daher  $Q$  die ganze Wärmemenge, welche man einem Körper, während er auf einem bestimmten Wege aus einem Zustande in einen andern übergeht, mittheilen müfs, (wobei eine entzogene Wärmemenge als mitgetheilte negative Wärmemenge gerechnet wird), so zerlegen wir diese in drei Theile, von denen der erste die Vermehrung der wirklich in dem Körper vorhandenen Wärme, der zweite die zu innerer und der dritte die zu äufserer Arbeit verbrauchte Wärme begreift.

Von dem ersten Theile gilt dasselbe, was schon vom zweiten gesagt ist, dafs er von der Art, wie die Veränderung stattgefunden hat, unabhängig ist, und wir können daher beide Theile zusammen durch eine Function  $U$  darstellen, von der wir, auch wenn wir sie sonst noch nicht näher kennen, wenigstens soviel im Voraus wissen, dafs sie durch den Anfangs- und Endzustand des Körpers vollkommen bestimmt ist.

Der dritte Theil dagegen, das Aequivalent der äufseren Arbeit, kann, wie diese selbst, erst dann bestimmt werden, wenn der ganze Weg der Veränderungen gegeben ist. Nennen wir die äufsere Arbeit  $W$ , und das Wärmeäquivalent für die Einheit der Arbeit  $A$ , so ist der Werth des dritten Theiles  $A \cdot W$ , und wir erhalten daher als Ausdruck des ersten Hauptsatzes folgende Gleichung: (I)  $Q = U + A \cdot W$

With this means of determination, one can now concisely express the relation between the equivalence of heat and work (which is only a special case of the general relationship between active power and mechanical work) by the following saying:

**Work can be turned into heat and vice versa heat can be turned into work, so that the magnitude of the one is always proportional to the other.**

... Let us now consider, in the event of a change of state, the internal and external work together. These both, taken together, can partially compensate each other if they are of opposite signs. Then the remainder must be equivalent to the change of the quantity of heat that occurs at the same time [i.e.

during the change of state event]. For the calculation however, it comes back to the same thing, if one assumes an equivalent change in heat from the two separate entities [i.e., for each of internal work and external work separately, one takes the heat equivalent].

Let  $Q$  be the entire quantity of heat that must be imparted to a body, while going on a certain path from one state to another (where heat removed is counted as a negative quantity of heat imparted) [this is in the context of the Carnot cycle]. This can be broken into three parts, of which the first is the increase of heat actually present in the body, the second is the heat used for internal work and the third the heat used for external work.

Of the first part one can say the same as has already been said about the second part: that it is independent of the way that the change of state happened. We can therefore combine both parts together into a function  $U$ , for which we know in advance (regardless of how little knowledge we otherwise have) that it is completely (sufficiently) defined by the initial and final states of the body.

On the other hand, the third part, i.e. the equivalent of the external work, can only be calculated when the whole path of change is given. We call the external work  $W$ , and the heat equivalent for the unit of work  $A$ , so that the value of this third part is the product  $A \cdot W$ , and we come into view of the resulting first law in the following equation: (I)  $Q = U + A \cdot W$  Clausius, 1854 (emphasis original)

It is plain that the equation,  $Q = U + A \cdot W$ , derives its meaning from the previous discussion, which is in a “*verschachtelt*” (literally “*nested*”) German that is both syntactically and semantically complex: it defies a literal translation and it is hard to translate into a comprehensible English. Clausius is trying to describe the effect of *entropy* without knowing its explicit existence or name (he only coined the term in his 1865 paper), hence the apparent confusion and inarticulacy of this complex text of 1854. We leave the linguistic analysis as an exercise for the interested reader, but we conclude that Clausius is carefully “*negotiating*” (Edwardes, 2019) or constructing meanings for the terms he wishes to manipulate mathematically in just the way that Barfield says is characteristic of poets.

This is a rather clear example of metaphysical priority in a physical argument. We will discuss the logical properties of metanarratives later (§5.2): here we see Clausius using a natural language replete with its natural metaphors and ambiguities, but intending to restrict the unavoidable ambiguity as much as possible. It is only by using natural language that we can say anything at all, but then if we care about the meanings we are constructing we have to also address the formal poetics. Of course, usually this step is tacit, but we are here drawing attention to it.

Physicists tend to think that they can manipulate the behaviour of *phänomena* symbolically (since we all believe that the symbols truly represent reality), but in fact they only symbolically manipulate the *ideas* they have constructed of those behaviours<sup>38</sup>. Whence arise the ideas? And what relation (both ontic and epistemic) has the idea to the *phänomenon*?

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<sup>38</sup> So Roger Penrose speaks specifically of “*the principles that actually underlie the behaviour of our physical world*” (2004, Preface). Clearly, if pressed everyone will say that the reality is one thing and our ideas of it are something else, but in actual practice we do not tend to distinguish the two things very sharply. This becomes very obvious when string theorists (and others) speak of “before the Big Bang” as a sensible idea, or of “inflation” or “dark matter” (or the “multiverse”) as reality. So here Penrose has apparently made a reality of the *principles*, where strictly speaking our formalisms cannot ever completely capture reality. And Penrose’s book is a brilliant and seminal *tour de force*!

Also, Carlo Rovelli believes of “*the world*” that it “*does not exist in space and does not develop in time*” (Rovelli 2014, ch.13). Instead he speaks, rapturously and persuasively (like a “poet” – see note#12), of a “*world made up solely of interacting quantum fields the swarming of which generates – through a dense network of reciprocal interactions – space, time, particles, waves and light*” (*ibid.*). He does not explicitly distinguish the reality itself from our ideas of it, even if he does emphasise that our ideas may be mistaken. Ordinary readers (also including most scientists!) are not in a position to

## 4.2 Entropy and Statistical Mechanics

All students of thermodynamics start today with the model of the ideal Carnot cycle, which establishes the ideas of “waste heat” and “maximum thermodynamic efficiency”. Clausius depended on the Carnot cycle to model his idea of “entropy” as the accessible useful work available in some quantity of heat – in his time the steam engine powered the world: is it any wonder that (as we shall see) the ideal gas laws should be the natural exemplar of heat engines?<sup>39</sup>

It is by considering the ideal gas as a model for heat engines that today’s students learn the basics of statistical mechanics, first developed with great brilliance by the mid-nineteenth century giants of physics: Gibbs, Boltzmann and Maxwell. Ludwig Boltzmann is remembered by his eponymous constant  $k$ , and by the formula engraved on his tombstone (which in this form is due to Max Planck)<sup>40</sup>:

$$S = k \log W \quad (\text{Eq.1})$$

It is now also well-known that this “simple” treatment ignores or obscures a number of severe difficulties. The usual definition makes entropy an *extensive* quantity, yet it is known that this is an approximation that is appropriate only in certain circumstances:

Entropy is just as much, and just as little, extensive in classical statistics as in quantum statistics ...  
entropy stands strongly contrasted to energy. Jaynes, 1992

Strictly speaking, entropy is an *intensive* quantity<sup>41</sup>, as Jaynes observes in a penetrating discussion in the same place of the so-called *Gibbs Paradox*:

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judge the strengths and weaknesses of Rovelli’s position, and therefore how Rovelli himself may be mistaken (and what shape a more correct view might take).

Then Frank Wilczek (2021) says in his *Afterword*: “*I have been at pains to be clear that science teaches us what is ...*” This really sounds like an ontological statement. I am sure that Wilczek himself distinguishes the reality from our formalisms, but it is too easy for the ordinary reader to slide from a strict view into a comfortable (and mistaken) approximation.

As examples of (apparent) confusion between symbols and reality, I have mentioned three books by renowned physicists (two of them Nobel prizewinners), all with “*Reality*” in their titles. Physicists really do believe that they touch reality: we are here enquiring into what this means. A correct view turns out not to be very simple.

<sup>39</sup> Actually, Carnot’s seminal treatment relied on the false idea of *caloric*: it was Clausius who found the correct interpretation we still use (see Paul Sen, 2021). It was also Clausius who recognised that the *change* in the internal energy  $U$  of the system is path-independent and therefore that  $U$  is what we would now call a “function of state” (for a close discussion of this see Jennifer Coopersmith, 2015).

<sup>40</sup> The symbol “ $S$ ” (denoting *entropy*) originated with Clausius, possibly indicating the integral (“*Summe*”:  $\int dQ/T$ ) he introduced to define the “second law”. In modern terms  $S$  has the unit Joules per Kelvin (energy/temperature), where the idea of “*absolute temperature*” was clear to Clausius who already knew in 1854 that  $0^\circ\text{C} = 273\text{ K}$  (accepting the 1848 value of William Thomson – later Lord Kelvin). “ $W$ ” (supposedly from “*Wahrscheinlichkeit*”, probability) denotes the number of different states the system can have. From this formula Boltzmann could derive the ideal gas law in what is now a textbook treatment.

<sup>41</sup> This statement appears to be controversial since conventional (simple) physics treatments hold that entropy is *extensive*. However, it is very clear that this is an error. Entropy may indeed be extensive but only for certain sorts of systems. In principle it is *intensive* in general, as explained in detail by Walter Grandy (2008, ch.5: “*The Presumed Extensivity of Entropy*”), who points out (as we also do) not only the anthropomorphic (“subjective”) nature of the Partition Function, but also the necessity of considering the indistinguishability of *states* (not *particles*). This latter is also asserted by Karen Barad who insists (from an entirely different point of view) that “*the primary ontological unit is the phenomenon*” (Barad 2007, p.333).

Grandy also points out, citing Wolfgang Pauli’s famous Lectures at ETH Zurich (Pauli c.1952), that Boltzmann’s equation for entropy (see Eq.1 and *note#42*) is determined up to  $f(N)$ , an arbitrary *function* (not merely a constant) of the number of states  $N$  in the state space: “ $S = k \{\ln W + f(N)\}$ ”.

[Gibbs] had perceived that, when two systems interact, *only the entropy of the whole is meaningful*. Today we would say that the interaction induces correlations in their states which makes the entropy of the whole less than the sum of entropies of the parts; and it is the entropy of the whole that contains full thermodynamic information. This reminds us of Gibbs' famous remark, made in a supposedly (but perhaps not really) different context: "*The whole is simpler than the sum of its parts.*" How could Gibbs have perceived this long before the days of quantum theory? Jaynes, 1992 (emphases original)

Jaynes earlier had made an astonishing statement of the *subjectivity* of the concept of entropy in his acute comparison of the Gibbs and Boltzmann formulations:

... not only in the well-known statistical sense that it measures the extent of human ignorance as to the microstate [but also] *[e]ven at the purely phenomenological level, entropy is an anthropomorphic concept*. For it is a property, not of the physical system, but of the particular experiments you or I choose to perform on it. Jaynes, 1965 (emphasis original)

The point here is that the result of the entropy calculation depends on how the Partition Function of the system is specified, that is, which particular measurements are being contemplated. The Partition Function describes how phase space (which enumerates all of the *microstates*) is specified. Then the observables are specified by the *macroscopic parameters*, which can hopefully be calculated from the thermodynamics. Roger Penrose (2010) puts this quite sharply:

... we can ... appreciate ... [that] Boltzmann's formula ... put forward in 1875 ... represented an enormous advance on what had gone before ... There are, nevertheless, still certain aspects of vagueness in this definition, associated, primarily, with the notion of what is to be meant by a "macroscopic parameter". Penrose, 2010, §1.4

Carlo Rovelli (2017) made essentially the same point very recently when he argues that "*we are blind to many variables [that are] at the heart of Boltzmann's theory*", adding:

Thermodynamics ... is a description of *these* variables of the system: those through which we assume we are able to interact with the system Rovelli, 2017 (ch.10, n.4; *emphasis original*)

However, it was Max Planck who in 1900 first recognised "Boltzmann's constant" *per se* (see Eq.1) as fundamental to entropy in the seminal paper (Planck 1901) in which he explains black body radiation in terms of quantised resonators; and where he gives the quantisation constant,  $h$ , in units of action correct to almost 1%<sup>42</sup>.

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Note that the *entropic* Liouville Theorem still applies (Parker & Jaynes 2021a), meaning that  $N$  does not necessarily have to be defined in statistical mechanics terms: it may instead be defined in terms of "degrees of freedom" which may also apply to small systems.

Grandy says, "*The effect ... is to convince us that a proper definition of entropy should at bottom be theoretical ... It is not an empirical question but a conceptual one*" (Grandy 2008, p.68). There are of course many incorrect ways to think, but there is no mechanical method of finding a correct way.

<sup>42</sup> His argument involves a calculation of the *entropy* of the system of resonators, and therefore also involves Boltzmann's relation (which he gives correctly, that is, up to a constant factor and using the natural logarithm: " $S = k \ln W + \text{constant}$ "). He obtains the values of both eponymous constants (the "Planck" and the "Boltzmann" constants,  $h$  &  $k$ , which he calls "universal" or "natural" constants) by considering the accurate measurements of what we now call *Wien's displacement constant*,  $b = 2.94$  mm.K, that had then recently appeared: he obtains  $k = 1.346 \cdot 10^{-23}$  J/K and  $h = 6.55 \cdot 10^{-34}$  J.sec. Today's accepted values are,  $b = 2.90$  mm.K;  $k = 1.381 \cdot 10^{-23}$  J/K;  $h = 6.63 \cdot 10^{-34}$  J.sec. Note that Planck recognised that  $\hbar c/k$  has the same unit as  $b$  (where  $\hbar \equiv h/2\pi$  is Dirac's "*reduced*" Planck constant and  $c$  is the speed of light), and in fact  $\hbar c/kb \approx 1$ .

### 4.3 Information

We go into apparently arcane details in this section following Lars Lundheim’s useful review (Lundheim 2002), not only because the details are both surprising and very interesting, but also because it is the emergence of the Shannon *information entropy* that has enabled the proliferation of today’s high speed networks, a technology that would otherwise be inexplicable.

The first transatlantic “telegraph” cable was laid in 1858 but only operated for three weeks. A lasting transatlantic connection was established in 1866. In addition to its technical triumph, this was commercially very valuable (and expensive) technology, and the search for efficiency naturally attracted great scientific attention. The first message was transmitted (by Morse code, in 1858) at 10 minutes per word. The second (1866) cable already operated almost two orders of magnitude faster, at 8 words per minute; but the transmission speed (that is, the *bandwidth*) was necessarily slow because of frequency dispersion in the cable: this was already understood in principle by William Thompson (later Lord Kelvin) who published his analysis in 1854 and was closely involved with the enterprise.

However, although practical development (telegraphy with time- and frequency-division multiplexing, telephony, radio) was very rapid, little advance was made on what we would now call *informatics* until the 1920s, when it became clear that “*bandwidth limitation sets a fundamental limit to the possible information transfer rate of a system*” (Lundheim 2002). And the very idea of *bandwidth* depends on the understanding of electrical ‘*band pass*’ filters, which were not patented until 1917.

The additional problem of *signal-to-noise* dominated telecommunications science as soon as more reliable long distance signalling was allowed by usable amplifiers (i.e. valves, exploiting the vacuum tube technology which had originally been developed for the incandescent light bulb). But in the 1920s there was still no standard scientific understanding of noise: Norbert Wiener’s work on stochastic noise (Brownian motion) was published between 1920 and 1924, and Harry Nyquist’s mathematical model of thermal noise was only published in 1928. The vacuum tube amplifier had been introduced around 1910, but the high gains obtainable by cascading amplifiers had to wait until the feedback principle was patented in 1928. And then noise became important to control, being a limiting factor to transmission systems: “*by the 1930s ‘signal-to-noise ratio’ had become a common term among communications engineers*” (Lundheim, 2002).

It is this century of prior telecommunications history that set the scene for Claude Shannon’s breakthrough paper of 1948 (Shannon 1948) in which he re-used the term *entropy* to give a measure of “what rate information is produced” in a communication channel. In this work he showed quantitatively how the maximum bit-rate depended both on the noise in the channel and on its bandwidth, and he also established that completely error-free information exchange was possible, as long as the data rate in the channel was below a certain value (the “channel capacity”).

When one compares the generality and power of explanation of Shannon’s [1948] paper “*A Mathematical Theory of Communication*” to alternative theories at the time, one can hardly disagree with J.R.Pierce [1973] who states that it “came as a bomb”. Lundheim, 2002

Shannon used the term *entropy* as referring to “quantities of the form  $H = -\sum p_i \log p_i$ ” which “*play a central role in information theory as measures of information, choice and uncertainty*” specifically because it had the same form as that “*defined in certain formulations of statistical mechanics*” (citing Richard C. Tolman’s magisterial *Principles of Statistical Mechanics*, 1936), and it is now known as the “information entropy”, or the “Shannon entropy”. Shannon used the symbol  $H$  to invoke “*the H in Boltzmann’s famous H theorem*” (possibly “ $H$ ” originally denoted the Greek letter  $\eta$  –  $H, \eta$ ).

Responding to Shannon, Leon Brillouin considered “information” in 1953 as negative entropy: *negentropy* (Brillouin 1953); and Edwin Jaynes’ seminal work of 1957 (Jaynes 1957) amplified Shannon’s observations on probability distributions saying, “*the development of information theory has been felt by many people to be of great significance for statistical mechanics, although the exact way in which it should be applied has remained obscure*”; but then adding:

In this connection it is essential to note the following. The mere fact that the same mathematical expression  $-\sum p_i \log p_i$  occurs both in statistical mechanics and in information theory does not in itself establish any connection between these fields. This can be done only by finding new viewpoints from which thermodynamic entropy and information-theory entropy appear as the same *concept*.

Jaynes, 1957 (emphasis original)

Jaynes went on to establish the congruence of the ideas of thermodynamic and information-theoretic entropies, demonstrating that using a probability distribution that *maximizes the entropy* (subject to certain constraints) justifies making inferences from that distribution. Following Jaynes, the powerful “Maximum Entropy” (“MaxEnt”) methods are now very widely used across a large variety of technical disciplines.

Rolf Landauer famously drew specific attention to the entropy cost of computation, originally in 1961 (Landauer 1987), insisting that *computation is physical*. Although many of the steps in a computation can be carried out reversibly, information *erasure* is necessarily irreversible, and carries an inescapable entropy cost, as was emphasised by Charles Bennett (2003):

Landauer’s principle, while perhaps obvious in retrospect, makes it clear that information processing and acquisition have no intrinsic, irreducible thermodynamic cost whereas the seemingly humble act of information destruction does have a cost, exactly sufficient to save the Second Law from [Maxwell’s] Demon.

Bennett, 2003

Today, as Parker & Jaynes (2019) have pointed out, citing significant recent work in network theory (Parker & Walker, 2014): the entropic treatment of information is standard in the analysis of the efficiency of communications networks in the presence of noise; also, applying Landauer’s Principle<sup>43</sup> to a computation involves the transfer of information and therefore also results in a rise in entropy (Parker & Walker, 2007). They go on to show that information and entropy should be considered (*contra* Brillouin) not as *opposites*, but as *complementary* (that is, orthogonal in complex Minkowski 4-space). And indeed, they use the Shannon information entropy explicitly to discuss the stability of fullerenes: “*So for example, for C<sub>60</sub> ... we can calculate an entropy ... using the Shannon fragmentation metric*” (Parker & Jaynes, 2020).

#### 4.4 The Entropy of Black Holes

The Bekenstein-Hawking equation for  $S_{\text{BH}}$ , the entropy of black holes, is due to seminal work by Jacob Bekenstein (1973) where he showed that the entropy of the black hole is proportional to its surface area (that is, the area  $A$  of its event horizon). Stephen Hawking (1976) gave an argument for the value of the constant of proportionality, leading to the celebrated equation,

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<sup>43</sup> It is germane to mention that there remains an ongoing technical debate surrounding the meaning of Landauer’s Principle, which John Norton alleges to be “unproved”, and indeed based on “circular reasoning” (Norton 2013). The issues are intricate, but involve debate over the applicability to fluctuation theory and to systems not representable by statistical ensembles (such as black hole event horizons). The latest summary of this debate (Ladyman & Robertson, 2014) criticises Norton’s results but also allows that at least some of his analysis appears to be valid. However, everyone believes that Maxwell’s Demon fails, and the the Second Law remains valid (whether or not it is fundamental).

$S_{\text{BH}} = \frac{1}{4}Ak^3/(G\hbar)$ , where as usual  $k$ ,  $\hbar$ ,  $c$  and  $G$  are respectively Boltzmann’s constant, the reduced Planck constant, the speed of light and the gravitational constant.

Again in this formula, as for Planck’s treatment of the black body radiation, it is the ratio  $h/k$  that is significant: Planck recognised that this was directly fixed by the Wien displacement constant  $b$ , and that  $hc/kb$  was dimensionless ( $c$  is the speed of light as usual).

Bekenstein explicitly uses the Shannon information entropy in his derivation, specifically in the sense of the “*inaccessibility of information about [the black hole’s] internal configuration*”, thereby also implicitly employing Brillouin’s concept of “negentropy”:

[here] we attempt a unification of black-hole physics with thermodynamics. In Sec. II we point out a number of analogies between black-hole physics and thermodynamics, all of which bring out the parallelism between black-hole area and entropy. In Sec. III, after a short review of elements of the theory of information, we discuss some features of black-hole physics from the point of view of information theory. We take the area of a black hole as a measure of its entropy – entropy in the sense of inaccessibility of information about its internal configuration. Bekenstein, 1973

Stephen Hawking’s discovery of his eponymous radiation (Hawking, 1974) confirmed Bekenstein’s 1973 suggestion that black holes have a “temperature”; as indeed does any object having a finite entropy. Hawking demonstrated that the black hole behaves as though its event horizon is a (typically very cold) black body with a temperature inversely proportional to the black hole mass (for the central supermassive black hole of the Milky Way this works out as 15 fK). But at the event horizon of a black hole there is no matter that is not infalling: clearly, the idea of “temperature” is here used in a very different sense from normal temperatures, which always refer to a statistical (macroscopic) property of some sort of particle ensemble.

Parker & Jeynes (2019) showed how the Bekenstein-Hawking expression for the black hole entropy can be used to determine the virial mass of the (heavily idealised) Milky Way galaxy from the known mass of the supermassive black hole at the galactic centre. The galactic virial mass (which includes both the observed stellar mass and the inferred “dark matter” mass) is the galactic mass that can be inferred by the motion of its stars. Their derivation of the virial mass was a simple application of their recasting of the *maximum entropy* condition into an entropic Lagrangian/Hamiltonian formulation of equilibrium thermodynamics (the so-called *Quantitative Geometrical Thermodynamics*, QGT), in which the *double-helix* and the *double logarithmic spiral* are proved to be holomorphic structures conforming to maximum entropy geometries.

The double logarithmic spiral is a good zeroth order model for (idealised) spiral galaxies and QGT offers an explanation for the MaxEnt *stability* of a spiral galaxy without needing “dark matter”, but of course galaxies are necessarily structures that are far from equilibrium<sup>44</sup>, and the calculation of galactic virial mass has a number of as yet unresolved associated problems<sup>45</sup>.

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<sup>44</sup> In fact, Parker & Jeynes (2021b) have used the QGT formalism to show (i) that this (idealised) system conforms to the *entropic* Euler-Lagrange equations; (ii) that the *entropy production* is therefore Noether-conserved; and (iii) that for the double-logarithmic spiral (which is an eigenfunction of the entropic Hamiltonian, and treating the galaxy as well-modelled by it) the entropy production is non-zero, having two components: with one component small and comparable to the Hawking radiation of the supermassive black hole at the galactic centre, and the other component many orders of magnitude larger (and presumably comparable to the entropy created by the accretion behaviour of the black hole).

<sup>45</sup> These include problems in the definition of the (presumed) holographic “surface” of the galaxy (see Parker & Jeynes 2019). That is, how *big* it is supposed to be. The astrophysicists treat this problem heuristically, by calculating how much “dark matter” is required as a function of distance from the galactic centre. However, it should be noted that the *stability* of spiral galaxies (which are ubiquitous in the Universe) is an

However, recently Parker & Jeynes (2021a) have shown in the framework of QGT how the Bekenstein-Hawking expression itself is a consequence of Liouville's Theorem<sup>46</sup>, expressed in entropic terms.<sup>47</sup>

Black holes are extremely simple objects which are specified by only four parameters: mass, charge, angular momentum and the "Planck length" (Frank Wilczek omits the scale of "elementary particles" when he characterises them as those having only mass, charge and spin: Wilczek 2021, ch.3, p.73). It is because black holes are so simply specified that they are so definitely known to be ontologically simple: their property of being maximum entropy (MaxEnt) objects is also related to their ontological simplicity. Parker *et al.* (2021) have shown, using a QGT formalism, that alpha particles are also ontologically simple.

However, even though black holes (like alpha particles) are very simple MaxEnt objects, nevertheless (unlike alpha particles) they are not in thermodynamic equilibrium. They necessarily accrete mass. As yet, although it has been extended by Parker & Jeynes (2021b) to idealised spiral galaxies to yield an expression for the *entropy production* (a Noether-conserved quantity), the QGT formalism has not yet been systematically extended to express the evolution of MaxEnt objects in time. But it is already clear that such an extension would be natural to the formalism since an expression for "entropic force" is available (Parker & Jeynes 2019, eq.23).

#### 4.5 Geometric Entropy: Holography and Entanglement

The holographic properties of black holes have long been recognised, together with the non-local consequences. So Raphael Bousso (2002) said, in a review originating in developments in quantum gravity:

The holographic principle ... implies that the number of fundamental degrees of freedom is related to the area of surfaces in spacetime. Typically, this number is drastically smaller than the field theory estimate. Thus the holographic principle calls into question not only the fundamental status of field theory but the very notion of locality. ... Quantum gravity has imprinted few traces on physics below the Planck energy. Among them, the information content of spacetime may well be the most profound. Bousso, 2002

What is striking about the treatment of Parker & Jeynes (2019) is the *non-local* properties of the entropy, so that the spiral galaxies have their shape (on this account) as a consequence of the holomorphism of the double logarithmic spiral, which is a primary *geometric* property, even if it can also be shown in standard treatments to emerge from the kinematics. They say:

we have shown that the [double logarithmic spiral] structure of the ... Milky Way ... is consistent with a holomorphic representation in geometric algebra. In particular, we have shown that the [calculated] galactic shape, aspect ratio, and structural stability (which are all highly constrained by the algebra) are

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immediate consequence of QGT. This geometrical stability is not easy to account for in standard treatments since the distances involved ( $10^5$  light years for the Milky Way) preclude normal feedback mechanisms. But QGT is defined in *hyperbolic* space, and non-locality is built into it – see §4.5.

<sup>46</sup> Joseph Liouville obtained a result whose importance was subsequently recognised (Liouville 1838): in 1844 Augustin-Louis Cauchy proved the related result for complex analysis that every bounded entire function must be constant, which follows from the fact (important in QGT) that holomorphic functions are analytic. But it was J.W.Gibbs who was the first to recognize the importance of this equation as the "fundamental equation" of statistical mechanics (Gibbs 1884)

<sup>47</sup> Arno Keppens (Keppens 2018) also independently derives the Bekenstein-Hawking expression by considering the consequences of the underpinning of Raphael Bousso's "holographic principle" (Bousso 2002) by the quantisation of space-time.

consistent with observation; and we have also shown that the total galactic [virial] mass is also consistent with observation. Note that this is a simplified (“zeroth order”) analytical approximation to reality: ... the dynamics driving the galactic evolution [are neglected ... but] this treatment gives the proper weight to the effect of the [central supermassive] black hole entropy Parker & Jaynes, 2019

Parker & Jaynes (2020) also prove that the stability of Buckminsterfullerene ( $C_{60}$ ) is a *geometrical entropy* property fundamentally related to its representation as a holomorphic object. They say that the stability is:

[a property] of the thermodynamics of the system: [which is] a significant methodological advance since a detailed treatment of the energetics may be avoidable. ... The spherical  $C_{60}$  fullerene molecule therefore represents a least exertion or Maximum Entropy (most likely) topology ... For  $C_{60}$  the double-spiral trajectories have been proved holomorphic and maximum entropy in an exact Euler-Lagrange analytical treatment (given the approximation to a true spherical geometry). Parker & Jaynes, 2020

Parker & Jaynes (2021a) also demonstrate directly that the holographic principle itself is a consequence of the *entropic* Liouville Theorem:

The geometric entropy of both the sphere and the double-helix are clearly holographic in nature, since they are proportional to the surface areas of enclosed volumes. ...

... consideration of the geometric entropy of systems ranging ... from the molecular ... through to [cosmic] scales yields a common holographic interpretation ... The holographic principle itself ... is a consequence of the holomorphism ... of the objects considered.

The close relationship between quantum mechanics ... and statistical mechanics ... is well known ... However, using geometric entropy and the entropic version of Liouville’s Theorem ... we have shown not only how the entropy of a MaxEnt system is holographic in nature, but also that there exists an associated entropic version of the uncertainty principle, based on the Boltzmann constant as the appropriate entropic counterpart to the Planck constant. Parker & Jaynes, 2021a

Further work has shown that the holographic principle is also effective at sub-atomic scales: Parker *et al.* (2021) express the nuclear sizes of the helium isotopes ( $^4\text{He}$ ,  $^6\text{He}$ ,  $^8\text{He}$ ) and the self-conjugate  $A = 4n$  nuclei ( $^4\text{He}$ ,  $^8\text{Be}$ ,  $^{12}\text{C}$ ,  $^{16}\text{O}$ ,  $^{20}\text{Ne}$ ,  $^{24}\text{Mg}$ ,  $^{28}\text{Si}$ ,  $^{32}\text{S}$ ,  $^{36}\text{Ar}$ ,  $^{40}\text{Ca}$ ) in terms of a single parameter, the “*holographic wavelength*” associated with the entropic geometry: all of these calculated values being entirely consistent with measurement.

In our present context, the point about holography is precisely that *each part represents the whole*, that is, it carries the implication of non-locality. It is of course well-known that “individual” electrons in an atom, or “individual” nucleons in a nucleus are strictly indistinguishable in a proper quantum treatment: this implies that in a holographic system all the “individual entities” are actually somehow mutually entangled<sup>48</sup>.

Entanglement at the microscopic scale is currently well understood. But the galactic scale also appears to us to have some properties which seem similar. It is clear that our idealised spiral galaxy, expressed as a (holomorphic) double-logarithmic spiral, is treated by the QGT formalism as an object whose entropy is given holographically, just like the entropy of its central supermassive black hole. But then, should the galaxy not also be considered as *entangled*, just as are quantum objects like atoms and atomic nuclei? After all, *entanglement* represents another

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<sup>48</sup> It is worth pointing out that Karen Barad approaches this from a fundamental point of view, by denying that “*objects have inherent properties*” (Barad 2007, p.293), explaining that this is a consequence of the BKS Theorem (Bell 1966, Kochen & Specker 1967). That is, “*individual entities*” do not really exist as such, even if it is often very convenient to pretend they do.

way to speak of *non-local influence*, and what could be more non-local than the symmetry of well-formed spiral galaxies, which are common in the Universe?<sup>49</sup>

#### 4.6 The Arrow of Time, and Teleology

Time asymmetry is a problem because all the laws of physics we know are apparently time-symmetrical, apart from the Second Law of Thermodynamics (and the CP properties of the K-meson). Whence then the Second Law? Is it independent of the other laws? In any case, how can it be consistent with the other laws considering that it is *not* time-symmetrical but almost all the other laws we know of *are*?

One approach to this adopted recently by widely disparate authors is to deny that the arrow of time is real: that is, time does not have a beginning. Carlo Rovelli (2017) claims that the reality is that the arrow of time is a matter of perspective (“*Time is Ignorance*”), justifying this by a discussion of Boltzmann’s statistical mechanics apparatus (a discussion amplified in detail with considerable subtlety by John Earman, 2006). Roger Penrose claims to have found a way of extending Time back beyond the Big Bang singularity with his detailed suggestion of *Conformal Cyclic Cosmology* (Penrose 2010). Ilya Prigogine claims that *Time Precedes Existence* (Prigogine 1996). All of these eminent scientists recognise that they here venture into “metaphysics”<sup>50</sup>, but we dissent from their conclusions essentially on physical grounds.

Robert Bishop (2004) discusses the problem of the arrow of time in the nonequilibrium statistical mechanics of Prigogine’s “Brussels–Austin Group” (Prigogine 1977): he considers “*the observed direction of time to be a basic physical phenomenon due to the dynamics of physical systems*” and continues:

One claimed virtue [of this approach] ... is the ability ... to provide time-asymmetry. ... Why then do we not observe [entropy decreasing]? To answer this question ... [and by] translating their conception of entropy into information-theoretic language [they] showed that their formulation of the second law requires infinite information for specifying the initial states of a singular distribution evolving in the negative [time] direction, but only finite information for specifying the initial states for evolution in the positive [time] direction.

This would render the initial conditions for systems to approach equilibrium along the negative *t*-axis physically unrealizable ... Since singular probability distributions are supposedly operationally unrealizable, they argue it is physically impossible for unstable systems to evolve to equilibrium in the negative [time] direction. Hence, their version of the second law acts as a selection rule for initial states.

This argument is supposed to show why anti-thermodynamic behavior in the real world is impossible ... Nevertheless, the argument is problematic. The most fundamental difficulty is that it conflates epistemic concepts (e.g., information, empirical accessibility of states) with ontic concepts (e.g., actual states and behaviors of systems). Bishop, 2004

Here again we see *entropy* (the subject of the Second Law) intricately tied up with *information*, a relation we have already explored above. We also have an explicit statement of how even the best minds can experience “fundamental” epistemological and ontological difficulties in this whole subject.

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<sup>49</sup> Note that QGT is defined in *hyperbolic* space: this is a necessary consequence of the logarithmic dependence expressed in Eq.1. It is hyperbolic space that generates the scale-independence of QGT expected from thermodynamics which must be true at all scales if it is fundamental to physics.

<sup>50</sup> Of course, none of these eminent scientists could have taken the recent developments in thermodynamics into account. But however eminent they are, no-one really believes them when they claim that the arrow of time is unreal! So Iris Murdoch, speaking of “*simple and obvious facts*” (and referring to the prominent philosophers John M.E. McTaggart and George E. Moore), observes that “*McTaggart says that time is unreal, Moore replies that he’s just had his breakfast*” (Murdoch 1964).

In this context we wish to point out the teleology apparently implicit in the *Principle of Least Action*. Photons “decide” which path to take on the basis of this Principle. That is, they can be represented as doing a variational calculation over all possible paths, and choosing the *least action* path. Of course, we know that such anthropomorphising language cannot be used properly of photons, but what precisely is it that constrains them to take the paths they do? They behave as though they had a purpose, and the consequence of the Second Law is that the universe behaves as though its purpose is to maximise entropy. But we exorcised teleology from science when we abandoned Aristotle in the 17<sup>th</sup> century.

It turns out that there is an entropic counterpart to the *Principle of Least Action*: the *Principle of Least Exertion*. Parker & Jeynes (2020) explain:

[Parker & Jeynes, 2019] have shown that the *principle of least action* has the entropic analogue of a *principle of least exertion*: where “action” is the path integral of the kinematic Lagrangian, “exertion” is the path integral of the entropic Lagrangian – which still satisfies the various canonical conjugate-pairing relationships. Roughly speaking, in the energy domain where the Hamiltonian represents the total energy of a system (that is, the sum of potential and kinetic terms), the Lagrangian represents an energy balance (the difference of potential and kinetic terms). The entropic Hamiltonian-Lagrangian treatment emerges from a consideration of information as the orthogonal complement to entropy

Parker & Jeynes, 2020

(although the two Principles are mathematically *isomorphic* and not merely “counterparts” or “analogues”).

It seems that a proper consideration of *entropy* (implying the arrow of time) is intimately linked up on the one hand with the physical quantity *exertion* and the variational *principle of least exertion*, and on the other hand with holographic properties of objects which can be at any scale, from sub-atomic to cosmic (entropy being essentially scale-less, as is witnessed by the logarithm in Eq.1). And these holographic properties are essentially non-local, giving those wedded to mechanical cause-and-effect modes of thought the impression of teleology.

Michael Stöltzner (2003) has investigated the teleological aspects of the *Principle of Least Action* (the **PLA**), showing that the logical empiricists (such as Moritz Schlick, Hans Hahn and Philipp Frank) ignored the PLA on account of these apparently teleological aspects even though Max Planck and David Hilbert emphasised it, and Jennifer Coopersmith has recently underlined its fundamental nature in an elegantly deep and wide-ranging treatment (Coopersmith 2017). Planck considered “*the PLA as formal embodiment of his convergent realist methodology*”, and Hilbert “*took the PLA as the key concept in his axiomatizations of physical theories*”; serving “*one of the main goals of the axiomatic method*”, that is, “*deepening the foundations.*” Stöltzner points out that for Planck and Hilbert and their schools, the PLA did not have the theological connotations ascribed to it by Maupertuis (for example). He says:

Both its staunchest advocates and those remaining silent about the PLA shared the conviction that final causation, material or organismic teleology, and analogies with human behavior had to be kept out of physics.

Stöltzner, 2003

Just so! Aristotelian teleology was simply a baleful error that proved far too influential. We could however note here that Stöltzner cautions: “When it comes to philosophy, the German word *Zweckmäßigkeit* is notoriously difficult to translate. *Teleology*, *finality*, and *purposiveness* capture only part of it”. The question of what precisely is the intended meaning of the words we use obtrudes persistently, even in a technical or scientific context. Stöltzner continues:

Moreover, none of the protagonists of the debate under investigation considered the PLA as an instance of backward causation. The history of physical teleology might alternatively suggest a relationship between the PLA and the problem of determinism. ... neither PLA-advocates nor logical empiricists contemplated any relation between the PLA and the second law of thermodynamics [except Boltzmann]. Rather, they explicitly restricted the validity of the PLA to reversible phenomena regardless of their views on causality. Stöltzner, 2003

It seems to us that we need to revisit this debate since the heroes of physics at the beginning of the 20<sup>th</sup> century knew nothing of *exertion* and the *Principle of Least Exertion (PLE)* that Parker discovered (Parker & Jeynes 2019), and which is demonstrated both complementary to the PLA and also emerging from the QGT formalism. He has shown that this QGT formalism is general, that is, it is also valid for non-equilibrium (irreversible) systems, like (idealised) spiral galaxies whose entropy production has been derived analytically from QGT (Parker & Jeynes 2021b).

The new (QGT) treatment of *info-entropy* is entirely consistent with standard ideas of causality: its treatment of *information* presupposes this. We should point out that QGT has surprising and surprisingly far-reaching consequences, such as the demonstration that DNA must be right-handed because of the Second Law (Parker & Walker 2010), a result later formally proved in a general treatment (Parker & Jeynes 2019, Appendix A).

However, we suspect that apparent causality paradoxes observed in the past associated with the PLA should instead be viewed as *entanglement* effects of the non-locality. This may have very wide-ranging ramifications, including putting David Bohm's "pilot wave" proposal (Bohm 1952) in a new light, as Parker *et al.* (2021) comment:

It is worth pointing out that Bohm's recognition of a "quantum-mechanical" potential  $U(x)$  exerting a "quantum-mechanical" force "*analogous to, but not identical with*" the conventional strong force on a nucleon ([Bohm 1952] his Eq.8), can now be understood to be a prescient anticipation of our *entropic force*, familiar from our previous discussion of galactic geometry ([Parker & Jeynes 2019, their Eq.23]. Parker, Jeynes & Catford (2021)

Bohm's proposal is considered by Rovelli to violate his *Hypothesis 2* (completion) of his *Relational Quantum Mechanics* (Rovelli 1996). However, neither Bohm nor Rovelli take account of Parker's *Principle of Least Exertion* (Parker & Jeynes, 2019) in any way, even though both of them give significant weight to the (physical) quantity *Information* in their different treatments. But Parker has shown that a physical system cannot be treated completely unless its *info-entropy* is also considered.

Alastair Rae has observed: "*If, as a result of the modern work on irreversible processes, we were to be led to a fundamental physics that took as its central theme the idea that time really does flow in one direction, I at least would certainly welcome it*" (Rae 1986). Parker's info-entropy formalism presupposes the arrow of time, since it treats the Second Law of Thermodynamics as axiomatic. And since the fundamental nature of the variational Principles is uncontroversial (and since the info-entropy formalism naturally generates the PLE as the entropic isomorph of the PLA), it seems that Rae's desire is satisfied.

## 5. Knowledge of Meaning

We are arguing in this essay that "knowledge" has to *mean* something, and that this meaning must be *grasped*. Understanding is not a mechanical process: on the contrary, we commonly experience understanding "dawning" on us. Understanding is by illumination. This process cannot be adequately spoken of in analytical language.

In this section we explore these things. We first make some observations about the properties of *Definitions* (§5.1); then some remarks on the properties of *Metanarratives* (§5.2); then we discuss the properties of *rationality* (§5.3); and finally we point out some consequences for poetics, using as an example some canonical poetry (§5.4).

Both *knowledge* and *meaning* are very ancient words in English<sup>51</sup>, with roots in ideas that have always exercised humans as far back in time as we can tell. We have already shown that our modern knowledge of physics is rooted in our humanity: but we wish to underline that *knowledge is personal*, and always has been. We have a tendency to be dazzled by the huge advances in both mathematics and philosophy by the ancient Greeks, but in truth human interest in (and knowledge of) these things long predated the Greeks.

### 5.1 The problem of Definition

Things are what they are: ultimately they are ineffable (except to poets): things-in-themselves are hard to speak of, and they *cannot* be defined. We can only define the ideas we have of things, not the things themselves. But to speak coherently about things we *must* define the ideas we have of them. We cannot speak of any thing without having some more or less clear idea of what it is. It should be obvious that although the ontology of the thing (its thinginess) and its epistemology (how we know it) are intrinsically separate ideas, yet in any specific case the two must be inextricably bound together. We cannot know anything about the thinginess of the thing without also knowing how we know. This is true despite the fact that this knowledge is almost invariably implicit (or “tacit”).

The problem then is the propensity we have of confusing our idea of the thing with the thing itself. We think that because we have a satisfactory idea of the thing, we know the thing in itself. If I ask, *What is entropy?*<sup>52</sup> you may answer, with early Clausius: *It is a measure of how much work is available in a quantity of heat*; or with later Clausius: *It is a closed line integral of the change in heat of a body at the absolute temperature of the body at the time of the change*; or with Boltzmann (as later interpreted by Planck):  $S = k \ln W$ ; or with Shannon  $\{S = k \sum p_i \ln p_i\}$ ; or with Parker & Jaynes: *the maximum entropy of a holomorphic body is a holographic property of its geometry*.

All of these answers are correct in their own terms, but an observer could be forgiven for thinking that they do not all describe the same thing: the “thermodynamics” used by Parker and co-workers might be almost unrecognisable by Clausius and Boltzmann. Is it the same? Is Parker’s “entropy” the same as Clausius’ “entropy”? Both use a recognisably similar mathematical apparatus, but does this establish identity? We have already quoted Edwin Jaynes (1957) on this: *“The mere fact that the same mathematical expression occurs both in statistical mechanics and in information theory does not in itself establish any connection between these*

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<sup>51</sup> Although in Biblical Hebrew there is no equivalent impersonal word for “*meaning*”: [בִּינָה] (*bî-nāh*) is invariably used specifically of someone’s *understanding*; it is used only once in the Hebrew Bible as syntactically impersonal at Daniel 8:15 (translated “*meaning*” by Geneva 1560), but even in this late text it refers semantically to Daniel’s *understanding* of the vision.

<sup>52</sup> Ariel Caticha (2021) takes an entirely different line here, commenting that the “*search for the meaning of entropy has proved so elusive*” precisely because we do not need to “*know what ‘entropy’ means—we only need to know how to use it*”. In fact he says that “*entropy needs no interpretation*” (italics original). Also, Caticha treats “*information*” not as something strictly physical, as we do here, but effectively in anthropological terms, that is: as “*defined in terms of its effects on the beliefs of rational agents*”. From our point of view here, this underlines the complexity of the philosophical position; the general addressing of Caticha’s position needs a careful technical treatment outside our present scope.

fields.” But Jaynes went on to show that in fact statistical mechanics (Boltzmann’s achievement) and information theory (Shannon’s achievement) really are both truly thermodynamics. And Parker’s entropy is too, since his achievement is firmly built on Jaynes’. This conclusion is clearly a real semantic development in word usage, as well as being a startling development of the mathematical apparatus.

The very word *thing* itself was originally used of immaterial things, as we have seen. In fact, the first group of meanings listed in the Oxford English Dictionary are entirely of immaterial things (“A meeting, or the matter or business considered by it, and derived senses”): only the second group of meanings (§§8-17: “An entity of any kind ... in the most general sense, in fact or in idea”) concerns material things, and then only in a secondary way. It is only in sense §11 that the word is used to denote explicitly *material objects*. It is clear that in standard English usage a property of a thing is also itself a (different) thing. The curious fact appears to be that *things* are no less thingy for not being concrete. In which case one can hardly be surprised if things turn out to be hard to tie down. Indeed, in 1991 Landauer wrote a popular paper “*Information is Physical*” on the thermodynamics of information erasure (Landauer 1991) which precisely emphasised the *thinginess* of a quantity that most people assumed was too abstract to be a thing!

Recently, rather similar and highly relevant observations have emerged in a different context. Mari *et al.* (2013) have drawn a careful philosophical distinction between *being a quantity*, and *being measurable*. They point out that this distinction is an *ontological* one, and moreover, that “*measurement is primarily an epistemic process*”! Underlying this treatment is the recognition that “*knowledge is constructed by humans*”: that is, as we have already insisted above, ultimately knowledge is *personal*. This position is explored in more detail by Maul *et al.* (2016) who deprecate “*the appearance of rigor and objectivity [achieved] by reducing abstract ideas to observables*”. Knowledge, being constructed by humans, is necessarily and intrinsically ideological: these authors we cite are metrologists who include a member of the JCGM<sup>53</sup>, a committee of the BIPM.

The recognition that *knowledge is personal* is widespread: we have noted the positions of Michael Polanyi and the metrologists above and we will consider *gnosis* in more detail below, but it is worth underlining the generality of this observation by mentioning the comment of Oliver Sacks (1985) on a case of clinical agnosia he describes in detail:

... our mental processes, which constitute our being and our life, are not just abstract and mechanical, but personal, as well – and, as such, involve not just classifying and categorising, but continual judging and feeling also. Oliver Sacks, *The Man who mistook his Wife for a Hat* (1985; Postscript to 2015 edition)

Sacks considers that *knowledge* is not merely an abstract philosophical idealism, it is actually what allows us to *live*!

It is important to emphasise that the desire for “objective” (that is, *impersonal*) knowledge is a form of chasing the rainbow. When we cast our ideas in mathematical terms *we do not remove ambiguity!*

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<sup>53</sup> JCGM: Joint Committee for Guides in Metrology; BIPM: Bureau International des Poids et Mesures (International Bureau of Weights & Measures). The JCGM is responsible for the GUM (the *Guide to the Expression of Uncertainty in Measurement*: JCGM 2008) and the VIM (the *Vocabulaire international de métrologie*: JCGM 2012). The essentially human nature of *measurement* is underlined by the insistence in the latest revisions of the GUM and the VIM that the measurement is not aimed at determining the “*true value*” (whose very existence is philosophically debatable) but instead seeks to specify a “*process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity*” (JCGM 2012). This makes it very plain that, as Karen Barad says, it is the *phænomēnon* (not the presumed entity) that is ontologically primitive (Barad 2007, p.333)

The mathematics beloved of physicists is their way of thinking clearly (and unambiguously) about seriously complex ideas. Ideally, mathematical methods do not *introduce* ambiguity, but neither can they *remove* the fundamental ambiguities implicit in the basic ideas. Reality itself is elusive!<sup>54</sup>

## 5.2 Metaphysics and metanarratives

We have already noted that we will use “*metaphysics*” neither in its standard philosophical usage, nor with its usual (normally pejorative) ordinary meaning, but as a term cognate with “metanarrative”, “metadata”, “metamathematics” etc. (see *note#10*).

In the proof of the Incompleteness Theorem Gödel himself explicitly makes parallel use of two strands of argument, the mathematical and the *metamathematical*. He says (Gödel 1931):

Der im System PM unentscheidbare Satz wurde also durch metamathematische Überlegungen doch entschieden.

So the proposition which is undecidable in the PM system yet turns out to be decidable by metamathematical considerations Gödel, 1931

where “PM” here refers to Russell & Whitehead’s axiomatisation of arithmetic in *Principia Mathematica* (Russell & Whitehead 1910, 2<sup>nd</sup> ed. 1925). Note that Whitehead himself said of this work (Whitehead 1929, p.8), “*even in mathematics the statement of the ultimate logical principles is beset with difficulties as yet insuperable*”. Whitehead goes on to comment acerbically that “*peccant premises*” in incorrect philosophical arguments are notoriously hard to locate (*ibid.*).

Aristotle’s book τὰ Φυσικά (*The Physics*) has a title perhaps most helpfully translated *Natural Philosophy*. Similarly, the title of his τὰ μετὰ τὰ Φυσικά (*The Metaphysics*) might be *Beyond Nature*. The one deals (largely) with material things, the other mainly with the immaterial. There is a widespread prejudice today that the immaterial has little or no real existence. The way Gödel proved his Theorem, by the formal use of a *metamathematical* argument, demonstrates that such an assumption is without foundation. It seems that strict materialism is irrational<sup>55</sup>. Be that as it may, it seems logically inescapable that every narrative necessarily has its metanarrative without which it can make no sense. And this is true also in pure physics, as we have seen by showing how the metaphysics is implicit in the history of the idea of *entropy*.

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<sup>54</sup> There is a very large literature on “realism” which we can only touch on here. Barad (2007) is as good an entry as any into the philosophical literature since the book opens with a detailed account and discussion of Bohr’s physics-philosophy. But “reality” is regularly presented as a preoccupation of leading scientists: “*Process and Reality*” (Whitehead 1929), “*The Road to Reality*” (Penrose 2004), “*Reality is not what it seems*” (Rovelli 2014), “*Fundamentals: Ten Keys to Reality*” (Wilczek 2021). Although all these authors are realists, none of them are “naïve realists”: as Rovelli observes, reality is not what it seems – it is elusive!

<sup>55</sup> It might be thought that an argument from mathematics cannot be used for or against any doctrine of materialism. But Gödel proved what Whitehead suspected, that not even maths is a strictly *necessary* thing (since it is Gödel-incomplete). Nevertheless, maths is indispensable to our knowledge of physics (and much else besides). The strict materialist would claim knowledge is ultimately thought, and thought must ultimately be physical (neurons firing and suchlike) since nature is all there is. But this position looks irrational, given that our knowledge is necessarily Gödel-incomplete. Materialists should claim instead that “*thought may (or may not) ultimately be physical*” (and they *believe* that it is physical). But we suspect not only that mind is immaterial, and also that that such a position accords best with the evidence.

The obvious question then arises, what is the meta-metanarrative of the metanarrative?<sup>56</sup> and the meta-metametannarrative of that (and so on)? It is clear that Clausius uses a ‘natural’ language (see *note#5*) for what we have called his metaphysics, even if his German is of a rather special sort: this type of 19<sup>th</sup> century academic German is known as “*verschachtelt*” (that is, “complex” or “nested”). But the metalanguage of this *verschachtelten Deutsches* is still only German: a natural language is its own metalanguage. Anselm already recognised this recursiveness of language, and Gödel only formalised it mathematically.

### 5.3 Ambiguity and Coherence

We have seen Clausius carefully constructing or “*negotiating*” (Edwardes 2019) unambiguous meanings for the terms he wishes to manipulate mathematically – using linguistic means. Strictly speaking, this is specifying the physics by means of a metaphysical discourse. Philosophers of science have tended to obscure this step as much as they can, but it is *explicit* even in the proof of the Incompleteness Theorem, as we have seen. Even to do fundamental mathematics we are forced to recruit the help of metamathematical methods: is it then surprising that at the fundamentals of physics also lurk metaphysical methods?

But rational speech is not limited to analytical speech. Poetic speech derives any power it may have from its internal coherence: and coherence is a property of rationality. The epistemology of physics rests on the foundation of socially verified personal testimony, which is a form of poetic speech<sup>57</sup>.

Form and the knowledge of form are both prior to all scientific knowledge. Prior to all rationalisation is the knowledge of the possibility of rationalisations. Rationality itself is a poetic, not an analytic property.<sup>58</sup>

Three millennia ago the Psalmist underlined the rationality of the (necessarily intuited) knowledge of God, insisting (in Hebrew) that the epitome of rationality – that is, the regularity of the heavens – was specifically a pointer to the knowledge of God, saying (and we give the ancient Greek translation of the Hebrew<sup>59</sup>):

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<sup>56</sup> This usage of “*meta*” and “*metameta*” is analysed logically in some detail for this context: it “plays a fundamental role when we define formal systems such as logical and computational calculi” (Sato 2003).

<sup>57</sup> The Ontological Argument (Anselm 1078) has puzzled philosophers for a millennium, and was written as a *prayer*, which is also a form of poetical speech.

<sup>58</sup> E.R.Dodds’ influential idea of “*irrational intuition*” in his famous book of a generation ago (Dodds 1951, p.217 *passim*) in our terms is quite mistaken since it is *rationality* itself that guides, structures and mediates intuition (see for example Polanyi 1958).

<sup>59</sup> We give the ancient (*koine*) Greek text rendering the ancient Hebrew (Hebrew Bible c.500 BCE; see §6 and *note#55*) because the Hebrew original (with its vocalisation remembered separately) was not a *text* as we now understand it: the *Masoretic text* (“MT”: essentially the “pointed” Hebrew text of Samuel ben Jacob) was only completed in modern times (1010 CE: the “*Leningrad Codex*”). The unpointed (original) Hebrew text is an *abjad*, that is, a very highly compressed mnemonic (consonantal) text: the vowels are preserved by the oral tradition (known as the *Masorah*). The MT encodes this vocalisation into the text itself by a sophisticated “pointing” system.

The Greek translation of the Hebrew (the *Septuagint*, “LXX”) was started in the 3<sup>rd</sup> century BCE by the Jewish scholars in Alexandria at the request of the Pharaoh (Ptolemy II, 285-247 BCE), and probably essentially finished by the 2<sup>nd</sup> century BCE. Note that the chapter numbering varies between the MT and LXX for *Jeremiah* and *Psalms*. The LXX is itself a canonical text for Christians since the *New Testament* quotes it *verbatim* in many places.

We use the English of the *Geneva* translation (1560) since this was widely reprinted and used up to and beyond the Restoration of Charles II (1660), remaining very influential through the substantial

The heuens declare the glorie of God ... the law of the LORD is perfite [perfect], conuerting the foule ...  
the ftatutes of the LORD are right, and reioice the heart Ps.19:1,7,8 (Geneva, 1560)

οι ουρανοι διηγουνται δοξαν θεου ... ο νομος του κυριου αμωμος επιστρεφων ψυχας ... τα δικαιωματα  
κυριου ευθεια ευφραινοντα καρδιαν Ps.18:2,8, 9 (Lxx, c.250 BCE)

Some four centuries after the Psalmist, the prophet Jeremiah took up the same idea, insisting that the *rationality* of God was an earnest of the *dependability* of God:

Beholde, the daies come, faith y<sup>e</sup> LORD, that I wil mak a newe couenant with the houfe of Ifraél, and  
with the houfe of Iudáh ... Thus faith the LORD, which giueth the funne for a light to the day, and the  
courfes of y<sup>e</sup> moone and of the ftarres for a light to the night ... If thefe ordinances departe out of my  
fight, faith the LORD, then fhall the feed of Ifraél ceafe from being a nation before me, for euer.

Jeremiah 31:31,35,36 (Geneva, 1560)

ιδου ημεραι ερχονται φησιν κυριος και διαθησομαι τω οικω ισραηλ και τω οικω ιουδα διαθηκην  
καινην ... ουτως ειπεν κυριος ο δους τον ηλιον εις φως της ημερας σεληνην και αστερας εις φως της  
νυκτος ... εαν παυσωνται οι νομοι ουτοι απο προσωπου μου φησιν κυριος και το γενος ισραηλ  
παυσεται γενεσθαι εθνος κατα προσωπον μου πασας τας ημερας

Jeremiah 38:31,36,37 (Lxx, c.3<sup>rd</sup> century BCE)

Whence the laws of physics on whose nature all physicists depend? Today the tendency would be to say something equivalent to: never mind the ontic antics, shut up and calculate! But it seems that much that we are interested in is non-calculable, that is, it “*inherently is non-algorithmic and, therefore, cannot be surrogated and simulated in a Turing machine*” (Rubin & Crucifix, 2021).

Until quite recently, the standard answer to the ontological question “*whence natural law?*” would have been to point to Jeremiah’s *καινη διαθηκη* (*new testament*) which underlies European civilisation in the last two millennia. And Jeremiah asserts that this “new testament” is a covenant guaranteed by the testimony of the very heavens: “*if ever these laws (νομοι) depart from before my face (προσωπου) ...*”!

These ancient poets were *poets*, not scientists: even Jeremiah predated the peak of Hellenic science with Thales being his younger contemporary. The later Alexandrian scholars responsible for the Greek text we display could not help interpreting the Hebrew, but even their Greek is a complex text with multiple ambiguities; ambiguity which is clearly intended by the poet, and which is enhanced by the *coherence* of the text.

How then does the little *cohere* with the large<sup>60</sup>; the early *cohere* with the late<sup>61</sup>? We have said that thermodynamics (that is, entropy) is scale-less: and this must apply to both of the conjugate

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dependence on it of the King James Version (1611) which became the dominant text in English until the mid-20th century. The 1560 Geneva Bible was printed in a clear Latin (*not* blackletter) font. The *New Testament* of both *Geneva* and KJV are heavily dependent on Tyndale’s 1526 *New Testament*.

<sup>60</sup> Parker & Jeynes (2019) correctly calculate an energy of  $1.2 \times 10^{-15}$  J required to transform a DNA molecule to a different form: they also correctly calculate an energy-equivalent galactic mass of the Milky Way as  $2.3 \times 10^{59}$  J, an energy 74 orders of magnitude larger. Parker *et al.* (2021) also correctly calculate nuclear sizes: the atomic nucleus is some nine orders of magnitude smaller than the DNA molecule treated previously. But exactly the same (thermodynamic) methods are in use, as expected since the Laws of Thermodynamics are expected to apply at all scales.

<sup>61</sup> The scalelessness in time has not yet been explicitly demonstrated in quantitative examples by QGT methods: these very new methods have not yet been developed to treat dynamical systems. However, Parker *et al.* (2021) point out that radioactive decay (the beta-decay process, which is logarithmic in time) is apparently correctly accounted for in their heuristic treatment of <sup>6</sup>He decaying to <sup>6</sup>Li.

quantities, time and energy<sup>62</sup>: energy is clearly the province of the physicists, but we regard time as the province of poets (as well as historians), and we wish to peer back into the mists of time provided we may do so securely (that is, where verifiably reliable records exist).

### 5.4 Meaning in Poetry

Lo giorno se n'andava, e l'aere bruno  
toglieva li animai che sono in terra  
da le fatiche loro; e io sol uno

m'apparecchiava a sostener la guerra  
si` del cammino e si de la pietate,  
che ritrarra la mente che non erra.

O muse, o alto ingegno, or m'aiutate;  
o mente che scrivesti cio ch'io vidi,  
qui si parra la tua nobilitate.

The day was dying, and the darkening air  
Brought all the working world of living things  
To rest. I, only, sweated to prepare  
For war, the way ahead, the grind that brings  
The battler to hot tears for each yard gained:  
To bitter tears, and memories more real  
Than what was real and which is thus retained  
Unblunted, edged with even sharper steel.

My Muse, my schooled and proven gift, help me:  
It's now or never. Fortify my mind  
With the vivifying skills of poetry,  
For what I saw needs art of a great kind.  
I saw great things. Give them nobility.

Dante Alighieri, *Divina Commedia*, 1320 (transl. Clive James, 2013); Canto II

We quote Dante's masterpiece because, at the start of Canto II, the poet is thinking about how to say what he wants, and how hard it is. Also because the form of the work is untranslatable, as is most poetry (and the idea of "translation" is essential to this thesis). We have chosen Clive James' translation (James 2013) because he asserts that Dante's *terza rima* simply does not work in English: instead he uses quatrains, sometimes expanded, as here. And also because Dante deliberately makes use of a variety of poetic means to convey his meaning. James says:

Dante was one of the most educated men of his time even in the conventional sense, quite apart from the proto-scientific sense in which he was original without parallel. But [Byron and other translators] couldn't, or wouldn't, get down to the level where syllables met each other and generated force. That had to be the aim, impossible as it seemed; to generate the force, both semantic and phonetic: the force of both meaning and sound. Indeed, in the original, some of the meaning was *in* the sound. Unless the translator did something to duplicate how the poem sounded, he, or she, wouldn't get near what it meant.

James, 2013 (emphasis original)

The comment that James is pointing to the *thinginess* of Dante's epic is irresistible. Both poetry and ordinary language deliberately use multiple layers of meaning to express the *thing in view*. Ambiguity is built-in to poetic expression at a fundamental epistemological level: there is no unambiguous knowledge of a *thing in itself*. Scientists wish to speak unambiguously about the *thing* presently in view. But this is impossible in principle! What to do?

We have considered the example of the evolution of the idea of *entropy*, showing that at each stage the *thing in view* is replaced by an *idea* of the thing delineated in a natural language which aligns its salient features (that is, the properties of the thing then considered salient) with

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<sup>62</sup> "Conjugate quantities" are those related by the "Uncertainty Relations" (position & momentum, time & energy *etc.*). These relations are discussed in considerable depth by Karen Barad, both of the position/momentum ( $x$  &  $p$ ) and the time/energy ( $t$  &  $E$ ) conjugate pairs are given explicitly in terms of the Planck constant  $h$ :  $\Delta x \Delta p \geq h/4\pi$ ;  $\Delta t \Delta E \geq h/4\pi$  (Barad 2007, p.300: as Eq.2 and an inline equation). Note that Barad draws a sharp philosophical distinction between Heisenberg's "Uncertainty Relations" (which are epistemological) and Bohr's "Indeterminacy Relations" (which are ontological), although the distinction is in the interpretation of the  $\Delta$  operator.

mathematical (that is, well-defined) ideas. This is a well-known progression that is usually presented as a version of solipsism<sup>63</sup>, but that this cannot be the reality is demonstrated by the uniform belief of physicists that they are really describing the world as it is.

We have shown instead that although physics represents real knowledge about the real world, this knowledge is inaccessible in principle without the use of natural language, with all the ambiguity that entails. Ultimately, physics relies ostensibly on this “natural” language, but used (as natural language often is) with poetic overtones: that is, with the deliberate intention of creating new meanings, as we have shown Clausius doing (§4.1).

So Quentin Meillassoux (2006) asserts that the laws of nature are epistemologically *contingent*, not necessary (thereby escaping a number of otherwise intractable philosophical problems, although he sidesteps the problem of ontology altogether). So much is obvious from our previous discussion, but Meillassoux’s “demonstration” is entirely in an analytic language which in English sounds deeply obscure. Is this a problem of translation? I think not. In the terms of the present discussion Meillassoux has failed to acknowledge the necessity of using poetic language to express the ontological verities he sees, and the translator therefore has no warrant to write good English.

Unlike Meillassoux, Karen Barad asserts that the laws of nature are also *ontologically* contingent: “*phenomena are real material beings*” (Barad 2007, p.361). Like Meillassoux, much of Barad’s discussion is analytically intricate, however Barad explicitly anchors the discussion in the poetic, with the book’s title being a line quoted from Alice Fulton’s poem (Fulton 1989). Barad opens with a discussion of Michael Frayn’s play “*Copenhagen*” (Frayn 1989) specifically to introduce a close discussion of Niels Bohr’s “philosophy-physics”. The question in all this is, who was right? was it Werner Heisenberg saying that the Uncertainty Principle expressed merely our *epistemological* ignorance or was it Bohr’s view that it expressed a fundamental ontological *indeterminacy* of reality?<sup>64</sup> Barad’s assessment is clear that Bohr was right.

Meaning is elusive. Even in physics meaning is elusive. *What is an electron?* The simple answer is easy: *we don’t know!*<sup>65</sup> Which does not mean that we know nothing at all, nor that

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<sup>63</sup> If we only know our *ideas* of the thing (rather than the thing-in-itself) why should we believe that the thing-in-itself has any reality independent of us? Hence what is known as (some version of) “external world skepticism”. Grace Helton discussed this in detail, commenting: “*if solipsism is in fact refutable, it is at least not obvious what form its refutation might take ... My aim is ... showing that it is not a straightforward matter to see how these difficulties might be overcome, with the result that solipsism cannot be dismissed out of hand*” (Helton 2021).

<sup>64</sup> Barad criticises Frayn, but does not note that Frayn’s device of a *triple* rendering of the Heisenberg-Bohr meeting is a nod to Kierkegaard’s similar (*quadruple*) device in his terrifying account of Abraham and Isaac in *Fear and Trembling* (Kierkegaard 1843) that was so influential in the 20<sup>th</sup> century.

Kierkegaard was translated into English rather late (1930s and later). But he was translated into German repeatedly from the later 19<sup>th</sup> century. Christoph Schrempf had translated Kierkegaard’s complete works into German by 1922, but these were renowned as being rather free. Parts of *Fear and Trembling* and other works were published by Hermann Ulrich in 1925 in a much closer German rendering (Ulrich 1925).

<sup>65</sup> The reason that we cannot say what “an electron” *is* is that all electrons are entangled with each other (being indistinguishable) so that “an electron” does not exist at all as an individual entity. Karen Barad insists on this, observing (in the context of a discussion of the implications of Bell’s Theorem) “*that it is no longer possible to embrace the metaphysics of individualism*” (Barad 2007, p.292).

Surprisingly, this was underlined by the poet some three millennia ago, who asserted to God *silence is praise* “[דַּמֵּי-יָאֵה תְהִלָּה] *du-mî-yāh tē-hil-lāh*” (Psalm 65:2, using the Masoretic Text and following the English translation of Alter, 2007) in the context of God’s power both over his Creation (he “*stills the roar of the sea*”) and also over “*the tumult of nations*” (*ibid.* v.8) but starting with the

what we think we know is illusory, nor that truth itself is a mirage. No. But we cannot do without poetic language to *really* say what we mean.

## 6. Image and Knowledge: Seeing and Knowing

We know what we see, we see what we know. Reality is elusive and its epistemology is not easy to tie down. What we see is conditioned by what we know. And of course, what we know is informed by what we see. In any case, what is certain is that our knowledge is not only incomplete but also uncertain: we are fallible!

Therefore, we wish to widen our view into historical considerations. Physics is concerned with the *present* behaviour of the systems we are interested in, but if we take the complementarity of energy and time seriously (which physically speaking we must) then we need also to look into the past (the future being inaccessible to us). In particular, human knowledge is a property of humans, and humans develop in time and in societies that develop in time. We will now enquire into the most ancient knowledge available to us that we have reliable evidence on.

St Paul said in 55 CE<sup>66</sup>, ἀρτι γινώσκω εκ μερους (*now I know in part*: I Corinthians 13:12), but because we know things only partially does not mean we don't know any thing! Our survey of the idea of *entropy* has highlighted how partial our knowledge remains: even such a basic idea of physics remains controversial. However, even though the way we think of entropy has changed dramatically over the last century and a half, yet we can still obtain real and useful results. The fundamentals shifting beneath our feet is uncomfortable, but physicists are familiar with this feeling from the quantum revolution a century ago.

The idea of *knowledge* is ancient and has very deep roots for us, both ontic and epistemic. The English word “*knowledge*” is etymologically related to St. Paul’s γινώσκω, as the OED notes (even the Latin “*science*” appears also to be a derivative of the ancient Greek γινώσκειν): the word carries the strong connotation of *personal experience* or *first-hand acquaintance*, as is seen in the Gospel (“*I know not a man*”: ἀνδρα ου γινώσκω, Luke 1:34) echoing the *koiné* Greek rendering of the ancient Hebrew (“*Adam knew Eve his wife*”: אָדָם דֵּעַ עֵוָה עֵוָה אִתּוֹ, Genesis 4:1; LXX). The first (Hebrew) creation account in its present (unpointed) form dates from c.500 BCE, whose original written source is probably 7<sup>th</sup> century BCE (only a little later than Homer). But these

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poet’s own shortcomings (“*crimes*”) on which God is silent (he “*covers*” them: [תַּכְּפֶרֶם] *tə-kap-pə-rēm*, *ibid.*v.4). Here the personal and indeterminate nature of the ontology of knowledge is explicit, and the poem is undoubtedly early: David was c.1000 BCE and he or one of his musicians (also called “*seers*”) may well be the poet. Note that this is the indeterminacy (or *silence*) of the eloquent poet, not of the baffled philosopher (Wittgenstein 1921, §7).

This is not an isolated instance. Psalm 19 juxtaposes the wordless praise by the cosmos of the Creator (“*day after day they pour forth speech ... they use no words ... yet their line goes out into all the earth*”, v.3) with the delight of the poet in his law (“*the law of the LORD is perfect, refreshing the soul*”, v.7). The physicist knows the same delight. There are also other examples. The *via negativa* has ancient roots.

It is not only the ancient poets who notice the apparent entanglement of everything. Jessica Nordell, in the context of a discussion of police bias, also points out that people’s very health itself may be measurably compromised by an inability to recognise our entanglement with each other as social beings: “*Bias requires a firm division between the self and the other. But if the distinction between the concept of ‘I’ and the concept of ‘you’ is not so clear, bias loses its meaning.*” (Nordell 2021, p.128).

<sup>66</sup> For convenience we follow the dating of *New Testament* texts by J.A.T.Robinson (1976).

are themselves probably derived from written sources which may have been a millennium older, and which in turn probably remembered even more ancient oral sources<sup>67</sup>.

We have spoken above of the idea of Creation: in the Hebrew Creation account (Genesis 1:26; Hebrew Bible c.500 BCE<sup>68</sup>) the climax is about the creation of mankind (man-and-woman together; for convenience, the English indicates the four Hebrew words):

Hebrew (unvocalised)	נעשה אדם בצלמנו כדמותנו
ποιησωμεν ανθρωπον κατ' εικονα ημετεραν και καθ' ομοιωσιν	LXX, c.3 <sup>rd</sup> century BCE
Let-vs-make man in-our-image, according-to-our-likeness [ <i>likeness</i> ]	Geneva, 1560

It is interesting that the Greek of the second half of the line might be viewed in terms of formal Welsh poetry (Hopwood 2004) as (imperfect) *cynghanedd groes*: k-k-m-n / k-k-m-n (*kat eikona emeteran / kai kath omoiosin*). Note that the LXX scholars considered that they did not have to repeat ημετεραν (“after *our* likeness”: the possessive plural form is indicated in the Hebrew suffix) since the *cynghanedd* “sound” of the line allowed the hearer to imply it from the και. The Hebrew is already a consonantal text which can be transliterated as: *n’sh ’dm bšlmnw kdmwnw*, and vocalised as *na-’ă-šeh adam bə-šal-mê-nū kid-mū-tê-nū*. The second half of the line might be viewed as (imperfect) *cynghanedd draws*: m-n / m-(t)-n.

Of course, there is no virtue in pretending that Greek or Hebrew poetry can be forced into the formal rules of the Welsh *cynghanedd*: we here only wish to draw attention to the fact that, as for all poetry, the lines are composed with an ear to their *sound*, invoking both the *breath* and the *word* (and also, obviously, the *inspiration*). And the purpose of this iconic poetic composition – which has been heavily influential in European cultural history almost up to the present day – is precisely to address the *ontological* questions: what is man? what is woman? who am I?

We should note that the Hebrew knowledge long predated and may have underpinned the Greek: Eusebius, citing precisely the antiquity of the Hebrew alphabet, insisted that “*Moses taught Plato*” (*Praeparatio evangelica*, c.320 CE; see Barker 2003 ch.11). We have drawn attention to the antiquity of the roots of the ideas we have been exploring: the reason for introducing Hebrew texts is specifically that they are the most ancient remaining in current use.

It is known that the modern Hebrew script was preceded by a more ancient script, “palaeo-Hebrew” (Davies & Aitken 1991), in which the source documents for the modern text were probably written, and which is witnessed most famously by the “*Lachish Ostraca*”, confidently dated c.590 BCE: these are letters in carbon ink on clay “ostraca” that appear to be military

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<sup>67</sup> The Creation narrative in Genesis in the form we have it almost certainly dates from around the Temple reforms of Josiah in the 7<sup>th</sup> century BCE: see II Kings 23 and Margaret Barker’s gloss on this (Barker 1987, p.142). It uses a modern Hebrew script (introduced in the early 5<sup>th</sup> century BCE by Ezra the Scribe). It has been widely thought that this Creation narrative represented a theological innovation at that time, since comparable tropes had not been found in the surrounding cultures. But this position is certainly mistaken, since a reanalysis (Korpel & de Moor 2014, see Jaynes 2014) of two tablets from the Ugarit tell at Ras Shamra confidently dated late 13<sup>th</sup> century BCE show that the Ugaritic creation story has many remarkably close similarities with the Hebrew one. Therefore the traditional ascription of the Hebrew story to Moses (perhaps 16<sup>th</sup> century BCE or earlier) cannot be rejected out of hand.

<sup>68</sup> For convenience, and to be definite, we accept the traditional account of the genesis of the Hebrew text of the Hebrew Scriptures that we have in our hands as being the work of Ezra the Scribe working in Babylon around 500 BCE, although nothing much rests on this dating in this present work. Ezra introduced (or restored) the “Assyrian script” that is used to this day in Israel: previously the common (Canaanite) script was completely different. All this is discussed in detail in the **Appendix** (see **Supplementary Materials**)

communications in the campaign during which the city of Lachish was lost to the Babylonians. This palaeo-Hebrew script was used by Simon ben Kosevah (“Bar Kokhba”, leader of the second Jewish rebellion against Rome 132-135 CE, bloodily put down by Hadrian) on the coins he minted for “Free Jerusalem” (**Figure 1**). But so far as we know, it was never used subsequently.



**Figure 1: Bar Kokhba silver Shekel (134/5 CE).** *Obverse:* the Jewish Temple facade with the rising star, surrounded by [שמעון] ("Shimon"). *Reverse:* a lulav and etrog, the text reads: [לחירות ירושלם] ("to the freedom of Jerusalem") (the script is palaeo-Hebrew: see Supplementary Materials for more information)

*Image:* Classical Numismatic Group, Inc. <http://www.cngcoins.com>, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=2420146>; *Tracing:* Margaret Barker

Light may be shed on the modern Hebrew canonical Biblical text by referring to a gloss in palaeo-Hebrew that has recently been found in the so-called “lead books” (see **Figure 2**): curious traditional artefacts that have recently come to light from Bedouin communities in Jordan that are “pages” cast in an impure lead with a sophisticated pattern in relief. Many such pages can be found, usually “bound” together in a “book”. The presence of a form of palaeo-Hebrew on them indicates that the original design was passed down from the 2<sup>nd</sup> century CE at the latest, and probably earlier<sup>69</sup>. A characteristic page is shown (the “Menorah” page, Figure 2) not only because it comments directly on our Creation text (Gen.1:26) but also because it comments in a way that clearly indicates the ambiguity and allusiveness characteristic of poetic texts that we have emphasised here. This Menorah Page can be read as a sophisticated and very extensive gloss on various aspects of Temple theology, quite possibly remembering the time *before* Solomon’s Temple in Jerusalem was destroyed in 586 BCE by the Babylonians. We give only one very simple example of this gloss: there are many more which we will report elsewhere.

In the Creation text (Gen.1:26), the Hebrew word for “*after-our-likeness*” is [כדמותנו] (*kid-mū-tê-nū*) from the word [דמות] (*də-mūt*) which in this Page (Figure 2) is read from the three

<sup>69</sup> The alternative possibility that such artefacts were created for the antiquities market is considered in the **Appendix** (see **Supplementary Material**) and ruled out on the grounds that the palaeo-Hebrew is meaningful.

letters transliterated as [דמת]. The letter *waw* ([ו]) must be added to the transliteration following the rules known as *matres lectionis*: the original palaeo-Hebrew is a pure *abjad*, but modern Hebrew is slightly impure since some letters are used to indicate vowels. The Menorah Page (Figure 2) uses a modified palaeo-Hebrew, with Hellenised symbols as well as symbols indicating double letters: unfortunately, transliterating into a readable modern Hebrew script is not entirely trivial (see **Table 1** and **Supplementary Material**).



**Figure 2: “Menorah” page from a Lead Book**

*Image (left)* courtesy of Jean-Paul Bragard. *Tracing (right)* by Margaret Barker.  
See Supplementary Materials for more information.

#	Palaeo-Hebrew	Modern	Modern+ML	English
0	דמת	תמד מדת דמת	תמיד מדת דמותו	continually / garments / likeness
1	בצי	ישב צבא בצי	ישב בצבא בוצי	enthroned / army / fine linen
2	עצי	ישע שעו עצי	ישע שעו עצי	he who saves / gazing on / tree
3	צצי	יצץ צצי צצי	יצץ צצי צצי	bloom / flowers of / my flower
4	עצי	יעץ עצי עצי	יעץ עצי עצי	counsellor / my tree / delight
5	בצה	חשב שבח בצה	חשב שבח בצחיה	returns / praised / radiance
6	עצה	השע עצה עצה	השע עצה עצה	delight / gazes / on her tree
7	עצה	העץ עצה עצה	העץ עצה עצה	the tree / counsels / he who gazes
8	עבה	העב עבה עבה	העב עבה עבה	cloud / overshadows / enquirer
9	עבי	יעב עבי עבי	יעב עבי עבי	overshadow / my cloud / seeker

**Table 1: Reading the Menorah Page (see Fig.2 and text)**

Line #0 is the three letters transliterated [דמת] (*də-mūt*, “likeness”, Gen.1:26) with its permutations. This word occurs 9 times on the Page: lines ##1-9 are the corresponding mirror images (see **Figure A4** in **Supplementary Materials**). Hebrew is read right-to-left (the English is read left-to-right as usual). Readable modern Hebrew requires the addition of certain letters: the *matres lectionis*, see the column “Modern+ML”. The transliteration (including ML and grammatical prefixes and suffixes) is described in Supplementary Materials. An abbreviated indication of the English translation is also given.

This word *likeness* ([דמת] *də-mūt*) can be found nine times in the Menorah Page, and if each triple and its mirror image is taken in three of its six possible permutations, we obtain the 10-line “poem” shown in Table 1. The first line of this poem is formed from [דמת] permuted twice, and

the following nine lines are the nine mirror images, permuted the same way (see Supplementary Material for explicit details and discussion of the significance of reflections, especially **Figure A4**). There are of course other ways to read this mnemonic, but we have chosen the simplest coherent version available: a more extensive treatment is outside our present scope. It is interesting to note how the formal rules of modern information theory (involving the mathematical combinatorial and permutation operations) underpin the profound truths, as perceived by the creators of this ancient artefact.

The “reflection” operation that yields the poem of Table 1 has a general importance. We have seen how Buckminsterfullerene (Parker & Jeynes 2020), and DNA and the Milky Way (Parker & Jeynes 2019) all have Maximum Entropy geometries precisely because these all involve *holomorphic pairs*: the logarithmic double spiral for the spiral galaxy, the double helix for DNA, a spherical double spiral for C<sub>60</sub>, and also, presumably, a pair of holomorphically bound “deuterons” for the alpha particle (Parker *et al.* 2021). “*Holomorphic*” is used here in its full mathematical meaning but applied to real objects, which can therefore be realistically thought of as *unitary objects*. “Two” have become “One” for all of these, and the two entities that form the holomorphic pair are reflections of each other.

Then the whole poem can be tentatively interpreted in English as:

0.	Clothed perpetually in His likeness	תמיד מדת דמותו
1.	he is enthroned among the heavenly host in shining linen	ישב בצבא לבוש בצי
2.	delighting that I know he saves	יושע שעני עצי
3.	he establishes the flowering of my blooms	יצץ צצי צצי
4.	my Counsellor delights in me	יעץ עצי שעעני
5.	He returns in glory to praises	השב שבה בצחיה
6.	he delights who gazed upon Wisdom’s tree	השעע שענה עצה
7.	she blesses him with wisdom	העץ עצה שענה
8.	She overshadows the seeker	העב עבה בעה
9.	My cloud will overshadow him who enquires of me	אעוב עבי בעי
0.	Clothing him perpetually in the likeness	תמיד מדת הדמות

where we have also given the Hebrew original in a vocalised and slightly expanded version for the convenience of Hebrew speakers (see **Supplementary Material** for an extensive commentary).

This rendering interprets the literal text obtained from a simple 3-letter word (with its permutations and reflections), but indicates something of the mnemonic value of this Page. We have attempted to make the variety of allusions of the literal text explicit in the interpretation (see **Supplementary Material** for further explanations).

While exploring the meaning of *entropy* we have seen how we understand things. The ancient artefact shown in Figure 2 and interpreted above shows that such understanding is manifestly a property of our humanity that has been current for at least thirty centuries, where the underlying ideas date from at least a thousand years earlier. We are, and always have been, fundamentally curious about the ontological questions.

Physics uses analytical language, the language of mathematics, as central to the coherent definition and correct manipulation of complex ideas. But the activity of definition, essential to doing physics and a precursor to explicating meaning, is itself a delicate issue. We do not wish to fall into the error of Aristotle, who thought that his definitions had an ontic reality. But neither do we wish to fall into the opposite error of thinking that because we cannot define any real *thing* our definitions can have no reality at all. Indeed, although we cannot define real

things, we can define our *ideas* of them, and we can then test these ideas against reality to see how far they are true. And insofar as our ideas are proved correct we can without solipsism claim a (partial) grasp of reality itself, a grasp that is both ontic and epistemic.

But how can we “grasp ideas”? For this basic purpose analytic language cannot help. The strength and purpose of analytical language is to construct logically valid arguments: one can check the *consistency* of one’s premises (or axioms), but one has simply to *assert* their truth. How do we form ideas that we are willing to assert axiomatically? How do we speak of them, and how do we understand others’ ideas? When it comes to *seeing* and *knowing*, and for speaking of the *meaning* of things, we find that poetic language is indispensable.

## 7. The Poetics of Physics

Physics is the most definite and quantitative of all the sciences and, one might superficially think, the least *poetic*. Physics is the description of elemental matter – what could be simpler? what could be less poetical? Yet it turns out that we need poetry (or at least, poetic language) to be able to express our knowledge of what things are in themselves – especially such things to which common sense cannot apply – and it turns out that we also need this poetic language to discern how it is that we *know*. For prior to the sophisticated mathematical treatments that pervade physics is the *making of the terms* in which such treatments are done. Clausius said it in 1854: “*Bei dieser Bestimmungsweise ... bildet ...*”: we paint our picture (*Bild*) of things from our knowledge, and we try to make this knowledge as sure (*Bestimmung*) and as wise (*weise*) as we can (reinterpreting the meaning of Clausius’ text using the range of connotations audible in German and resonating with the Anglo-Saxon roots of much of modern English). Language always has a palette of meanings even if analysts (and physicists) try to eliminate the ambiguity that the poet relishes.

We have described the development of the idea of *entropy* over the last century and a half: entropy is a notoriously difficult concept, even though it is fundamental to modern physics. The different uses to which the idea of entropy has been put – the assertion of the impossibility of perpetual motion, the derivation of the ideal gas laws (and the design of steam engines), the design of telecommunications networks, the properties of black holes, the stability of galaxies – these all look so vastly different, and are thought of in such different ways that it is a great leap of the imagination to see any underlying common entity. In this essay we have tried to describe this imaginative leap.

Of course we do not assert that physics should be (or indeed can be) done by poets (even if some poets may also be physicists, and some physicists poets). All must look to their own business. What we assert is that in the end the *understanding* of physics – indeed, the understanding of *any* thing – depends on inspiration. Knowledge is unitary: physicists and poets know things in similar ways, we are not so different! And physicists along with everyone else depend ultimately on language: what if our very language itself is endangered, as the Palikur poet of our epigraph bewails?

Before it is anything else, language is poetic.

## 8. Conclusion

How do we sum up? We have drawn a distinction between poetic language, and the analytic language used for physics. We have shown that although analytical language is designed to be unambiguous, the ambiguity inherent in all language cannot be entirely eliminated but must emerge at the foundations of any scientific argument. This was illustrated by a discussion of the foundations of thermodynamics, and the meaning of the term “entropy” which has had

surprising development continuing to the present. This could be seen as an example of the ‘*integrated history and philosophy of science*’ recommended by Bobby Vos (Vos 2021).

Although *ideas* can be defined, real *things* defy definition: ultimately, our knowledge of them must be intuited, inevitably leaving space for ambiguity and incomplete understanding. Mathematics is a calculus of ideas, but even mathematics is not complete: the foundations of mathematics must be established with *metamathematical* methods!

For many scientific purposes we can avoid the basic ontological questions, like: “*What is entropy?*” Provided we know how to calculate the quantities of interest we can be satisfied for practical purposes. But questions of a different nature require a more developed philosophical approach: How secure is the knowledge our scientific advisors claim to have? Why should I trust scientific advice? How do I evaluate conflicting advice given by various technical experts? Such questions have become particularly salient during the recent COVID-19 pandemic.

We have already cited Iris Murdoch’s acknowledgement of the ethical importance of our understanding of *thinginess*: we here wish to refrain from venturing into ethics despite her insistence on a valid philosophical account of *goodness*:

The necessity of the good is then an aspect of the kind of necessity involved in any technique for exhibiting fact  
Murdoch, *On ‘God’ and ‘Good’*, 1966

where of course, in speaking of “*exhibiting fact*” she has our activity of science in mind. She says, “*we are moral agents before we are scientists, and the place of science in human life must be discussed in words*” (*ibid.*, emphasis original), and she says, sarcastically:

Let us consider the case of conduct. What of [Jesus’] command, ‘Be ye therefore perfect’ [Matt.5:48]? Would it not be more sensible to say, ‘Be ye therefore slightly improved’?

Murdoch, *On ‘God’ and ‘Good’*, 1966

What scientists writing a paper would be happy with a text they knew was barely adequate? We strive for perfection even as we know it is unattainable, strictly speaking. We take Murdoch’s position on “*the infinitely elusive nature of reality*” (Murdoch 1962), and note that she links the *good* firmly to reality: “*Good is indefinable ... because of the infinite difficulty of the task of apprehending a magnetic but inexhaustible reality*” (*ibid.*). And on “*science*”, we note that, in the context of the description of an unfortunate man in 1975 who remembered *nothing* after 1945, Oliver Sacks comments that “*Empirical science ... takes no account of the soul, no account of what constitutes and determines personal being*” (Sacks 1984). The knowledge of reality is irreducibly *personal*: and may not be adequately described by a limited (“*empirical*”) view.

In any case, any answers to the ethical, social and political questions hinted at above all depend on our basic understanding of what *knowledge* itself is. We have here sought to show how, at the very foundations of physics, we rely on a *poetic* handling of language even to define the terms we use to articulate the ideas we need to understand the world. Just as the foundations of mathematics are established with metamathematical methods, so the foundations of physics must be established with metaphysical methods.

And natural language is its own metalanguage: this is why ultimately we must rely on poetics. The *meanings* of things are always intuited: Leon Wieseltier has said, “*The knowledge of a thing is more decisive than the sight of it*” (Wieseltier 1999, p.22): note that we insist on the distinction between *information*, which is physical, and *knowledge*, which is mental. Formally, physics can treat only information: to treat knowledge we properly have to use metaphysics – or, ultimately, poetics. Wieseltier also said, “*The place of science in life cannot be scientifically established*”

(*ibid.* p.256), and McLeish (2019, p.28) quotes Shelley: “*Poetry is ... at once the centre and circumference of knowledge; it is that which comprehends all science*” (Shelley 1821).

We have explored the articulation of some basic ontological ideas with the help of a tangible artefact (the “Menorah Page”, Figure 2) whose design appears to be very ancient, remembering times long prior to the Hellenic schools of philosophy. We have reconstructed from this artefact a mnemonic that makes an exceptionally sophisticated poetic gloss on the idea of [דמיון] (*də·mūt: likeness*) which is a word in the Hebrew language with a similar set of connotations to Plato’s “forms”: that is, it is specifically concerned with the *knowledge* of things, underlining that the search by humans for knowledge and the desire of humans to grasp reality long predated the invention of what we now think of as “scientific” language.

How do we *know* things? Rationality itself is as fundamental to poetic language as it is to analytic language: the appreciation of poetry depends critically on the recognition of poetic *form*. We have interpreted this artefact (the “Menorah Page”) as a *mnemonic* of ideas looking back at least three millennia, probably much more: it focusses our attention on the *logical continuity between different sorts of knowledge*. We conclude that whether the knowledge is of concrete or numinous things, the *rationality* used to handle and articulate it is common.

Before anything else, language is poetic. The foundations of physics cannot in principle be established analytically: they must be constructed metaphysically, using the poetic properties of language.

## Epilogue

God is One

Man is two: woman is too

Love is three: binding mankind whole

Right is four-square: breath of man and breath of woman

Mercy is prime five: both two summed with three and one summed with four

Mankind’s number is six: love’s mutuality

God’s number is prime seven: the resting of creation

The first perfect cube conquers death: man and woman joining in life

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# Supplementary Materials Index: Read-Me

## The Poetry of Physics

22<sup>nd</sup> April 2021

The main paper (*The Poetry of Physics*) includes poems in *Palikur* (an autochthonous Amazonian language), *Hebrew* (classical Hebrew probably from over two millennia ago, probably remembering pre-Homeric times), and *Italian* (by Dante Alighieri; three stanzas from the *Divina Commedia*, Canto II). There are also extended quotes from great writers in German, post-classical Latin and Alexandrian Greek. Audio files are provided for all of these:

1. **ku wown biyuke-2020.m4a**; Poem in *Palikur* (Epigraph) read by the author, Aldiere Orlando. The opening sentence is: “*Ay pahat nopsesa iwit adahan wis ivegminene uhiyakemni amin wownavrik awaygyi ku aysaw in kote biyukte*” (“Here is a brief word to encourage us to think about the value of our language before we lose it.”)
2. **HebrewMnemonicPoem.opus**; Poem in *classical Hebrew* (Section §5) read by [רם זייצ'ק] (Ram Zajicek). The (voiced) text is given explicitly in **HebrewPoem-4Feb2021.pdf**.
3. **Genesis1,26-WA0005.opus**; Phrase from the Masoretic Text in *classical Hebrew* (quoted near the start of Section §5) read by [רם זייצ'ק] (Ram Zajicek). The (voiced) text is given explicitly in **Genesis1,26-22Apr2021.png**.
4. **Dante-20210215\_103247.mp4**; Poem in mediaeval Italian (§4.4) read by Silvia Calusi.

Aldiere Orlando's poem takes as its model a famous poem, “*Ihcuac thalhtolli ye miqui*” in *Náhuatl* (an autochthonous Mexican language) by Miguel León-Portilla. The *Palikur* poem is translated into Portuguese and English, and the *Náhuatl* poem with its Spanish and English translations are all given:

5. **If our language is lost x3.pdf**; *Palikur* and *Náhuatl* poems with their Portuguese, Spanish and English translations. Note that the English of the *Náhuatl* poem is a translation of the Spanish.

The *Appendix* to the main paper is referred to multiple times in the Paper, notably in Section §5 (Figures 1,2; Table 1 and other places). It elaborates the philosophical reasoning behind the Christian interpretation of the Hebrew poem (mnemonic) constructed in Table 1 of the Main Paper, with extensive references to Christian canonical texts (which include the Masoretic Text of the Hebrew Scriptures).

6. **PoeticsAppendix\_v9-Feb2021.pdf**; Philosophical justification of the English interpretation of the palaeo-Hebrew mnemonic shown in Table 1 of the Main Paper.

The Appendix also refers to two laboratory Reports from the University of Surrey Ion Beam Centre:

7. **LeadComposition-PIXEreport2012.pdf**; X-ray spectrometry determination of minor elements in the lead Page. Trace elements are hard to detect in Pb without special methods, not used here since the lead provenance was not the interest of the analysis. A known modern lead control sample had detectable Cr, quite a lot of Cu, some other transition metals, but no detectable Sn, Sb. The sample under test had no Cr but quite a lot of everything else. The report of the presence of small amounts of "Hg" is a measurement artefact.
8. **LeadMeasurements-July16.pdf**; alpha spectrometry determination of the age of the lead in the lead Page using the  $^{210}\text{Pb}$  isotope method. This Report shows only the raw data: the interpretation in the Appendix concludes that the lead is certainly older than 1950 (excluding modern forgeries subsequent to the discovery of the Dead Sea Scrolls which created a market for these forgeries).

[Click here to view linked References](#)

Poetics of Physics Appendix: Rev.11 (3<sup>rd</sup> January 2022)

# The Poetics of Physics (Appendix)

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## Abstract

The foundations of physics are always established using philosophical ideas. But physics has been thought to truly represent reality since at least Galileo. In particular, the elegant naming of physical entities usually determines the acceptability of physical theories. We here demonstrate (using current developments in thermodynamics as an example) that both the epistemology and the ontology of physics ultimately rests on poetic language. What we understand depends essentially on the language we use. Ultimately, knowledge is necessarily subjective; that is, although the world is really there, and although we can indeed know it truly, yet ultimately this knowledge is necessarily intuited. We wish to establish our knowledge securely, but strictly speaking this is impossible using only analytical language. Poetic language is primary.

## Summary

In this Appendix we justify the text of the main paper as it relates to the Figures.

We are interested in the characteristically human ways of speaking about things, which are irreducibly poetic. This assertion leads us to the most ancient witnesses we can find that are still in daily use, which are in Hebrew. We can interpret ancient Hebrew texts through the gloss on them found on an artefact whose original may date back to the first century CE or earlier, and which is written in a form of Hebrew (“palaeo-Hebrew”) that predates the modern Hebrew script, but that fell entirely out of use after the second destruction of Jerusalem in 135 CE.

We therefore have to explain not only the artefact itself, but also the palaeo-Hebrew which appears on it. We apologise for the inescapable intricacy. We will conclude that the artefact is an independent witness of a Hebrew tradition (possibly an early Jewish Christian one) that may (or may not) be independent of the present version of the Hebrew Scriptures.

The way that the validity of this gloss can be demonstrated turns out to be highly indicative support of our assertion of the essentially poetic nature of language, which is why it is worth going to so much trouble to make the point.

## The lead book Menorah page

Recently, some extraordinary artefacts have emerged from Jordan. These are “books” (that is, codices) made from several cast lead pages (typically about six) and bound together with leaden “cord”. These pages typically have more or less intricate patterns, cast in relief (see Figure A1).

A lead page from such a codex was analysed by PIXE (particle-induced X-ray emission, using a 2.5 MeV proton ion beam, see 2012 Report<sup>1</sup>). This showed a rather impure lead (98.7 wt% Pb) with a very inhomogeneous composition, but including large regions with 0.2 wt% of both Sb and Sn, and 0.4 wt% of both Fe and Cu. This composition suggests that antimony was introduced deliberately to harden the lead for robustness of the cast image. (The supposed presence of trace quantities of Hg mentioned in the Report is not real: it was

shown subsequently to be a measurement artefact introduced by poor modelling of the low energy tailing behaviour of the X-ray detector.)

There has been a question as to whether such artefacts were made in modern times for the antiquities market. There is no doubt that such “forgeries” do exist; however, there is also no doubt that many such artefacts are certainly not modern. We have checked these artefacts using the method of alpha-counting to determine the presence of  $^{210}\text{Pb}$  (with a half-life of 22 years: see Keisch, 1968<sup>2</sup>). We obtained a null result (see 2016 Report<sup>3</sup>), indicating that the measured artefacts were certainly older than about 1950 and almost certainly predate 1900. This definitely excludes forgery using new lead for the antiquities market, which itself only became established later in the 20<sup>th</sup> century (after the discovery of the Dead Sea Scrolls). This by itself is not sufficient to exclude the possibility that old lead was used to forge an “antiquity”, but we show here that the design of the Page uses authentic palaeo-Hebrew as a sophisticated mnemonic. The writing on the Page is not “gibberish” as has been alleged, quite the contrary: both the images and the lettering have been shown to carry substantial meaning of which we here show only a very small part. It seems incredible to ascribe such effort to a forger: where is the market pressure for such a sophisticated artefact in palaeo-Hebrew?



**Figure A1:** *A lead book still bound as a codex*

The pages have relief designs on them: an example is shown in Figure A1. These designs are intricate, detailed, and complex; they may include letters as well as pictures. For example, in Figure A2 there are three horizontal lines of 6 letters each, two vertical lines of seven letters each, and two further isolated letters (34 altogether). These letters are in a palaeo-Hebrew script, and the page uses only 17 of the 22 letters of that alphabet. There are 7 letters that are not in the regular palaeo-Hebrew alphabet but which are read as compounds. A further 3 letters are Hellenised forms.

The details of this design are beyond the scope of the present work: we will concentrate only on some isolated extracts. But these extracts are themselves the result of a highly sophisticated reading, the particulars of which cannot be justified except at some length.

It is fairly clear that these artefacts do continue to be made using traditional methods: they are used as cultic objects – now considered as good luck charms to “protect” the dwelling. But what is their origin? The presence of palaeo-Hebrew points to an early origin of the *design*, perhaps 1<sup>st</sup> century CE, since palaeo-Hebrew is not otherwise attested after 135 CE.



**Figure A2: Lead book “Menorah” page, with sketch of the design**

680mm x 560mm. Purchased from a registered dealer in Shobak, S Jordan. Original provenance not known. Image (left) courtesy of Jean-Paul Bragard. Sketch (right) by Margaret Barker.

The artefacts have come to us as “books”: pages with lead wire hinges, and bound shut with lead wire. The codex was a Christian innovation (or at least popularised by them) in the 1<sup>st</sup> century CE, and it is known that in the 1<sup>st</sup> century both Christians and Jews gave great weight to the book of Daniel, which ends with the injunction to “*seal the words*” (Dan.12:4). The Christians looked to the Risen Christ to “*open the book*” in the last times (Rev.5:2), so the fact that these lead books are sealed shut perhaps indicates Christians looking to the last times (“*Come, Lord Jesus*”, Rev.22:20). The fact that they are codices probably points to their being used by Christians even if not manufactured by them.

This page was originally treated as a separate tablet since the holes necessary to bind it as a codex have damaged the pattern and some letters are lost. The original letters have been restored by comparing other examples. The page shares a Christian understanding of Hebrew temple tradition, but the direction of influence cannot be independently determined. The original of this artefact is probably pre-Christian since its symbology is exceptionally intricate and displays an intimate knowledge and appreciation of First Temple theology and liturgy. (The First Temple was built by Solomon c.1000 BCE and destroyed by the Babylonians 586 BCE.) Examination of a number of these artefacts suggests that this page is typical, although it is unusually detailed and well-preserved.

## Palaeo-Hebrew

It is undisputed that the modern Hebrew script (the *ketav Ashurit*, the “Assyrian script”), is supposed to have been introduced c.5<sup>th</sup> century BCE by “*Ezra the scribe*” shortly after the Babylonian exile – hence the name “Assyrian”. This was preceded by another script, the

*ketav Ivri* (now called “palaeo-Hebrew”). Both scripts were known and used at least up to the final destruction of Jerusalem in 135 CE, as the coins minted by Bar Kochba witness.

Accounts of the history are recorded in the Babylonian Talmud (*B.Sanhedrin* 21b, 22a): this undoubtedly records ancient witnesses, but was put in its present written form only in the 5<sup>th</sup> century CE. This written form is known to have modified the original oral witness in at least some respects, and it is now notoriously difficult to obtain agreement about all details of the ancient versions.

We propose an account that seems reasonable to us, and is consistent with the evidence we now have. Other accounts are possible (and not excluded), but we wish to give at least some account to allow readers to form some coherent picture of a complex and deeply puzzling story.

In our account we assume the uniform tradition of the ancient witnesses that Moses engraved the second tablets of the Torah on the mountain (Ex.34:4; this account is of course hotly disputed) since we believe that use of Ockham’s Razor should lead one to deprecate the setting aside of ancient witness without good reason. For example, we believe that the view that makes the Creation Accounts late, on the grounds that no adequate parallels are to be found in contemporary cultures, has been refuted by Korpel & de Moor’s 2014 demonstration<sup>4</sup> of exactly such parallels in the Ugaritic tablets (reliably dated c.1290 BCE).

The ancient witnesses do not agree on what script Moses used: the Babylonian Talmud (*Sanhedrin* 21, 22) suggests both *Ashurit* and *Ivri*. “*Ashurit*” can also be translated “beautiful” and of course the writing on the tablets must have been beautiful. However, although it seems plain that the *ketav Ivri* script is more cursive inviting the thought that it is more suitable to a graphical technique (with pen and ink on scrolls) than a glyphic one (carving on stone), this may be misleading since, as is common with ancient scripts, both scripts can be graphic and either can be glyphic. Note that both scripts are read right-to-left.

The ancient witnesses do agree that the *ketav Ivri* script itself had a previous history, even if they do not agree what that history was. However, it may be that *Ivri* refers to what we might now call the “*Vulgate*”: the script of the common people, since until the Babylonian exile the Jews were referred to as “Hebrews” (*Ivri'im*). For example, the Talmud suggests in one place that perhaps the reason the scroll found by Hilkiyah (*II Kings* 22:10, c.641 BCE) had to be given to “*Shapan the scribe*” to read was because it was written in the generally unfamiliar older script, the *ketav Ashurit* (in other words, on this account Ezra the Scribe *re-introduced* the *ketav Ashurit*). It is known that the *ketav Ivri* script was effectively a variation of the Proto-Canaanite script used throughout Canaan in the Late Bronze Age, and a reason given by the Talmud that none of Belshazzar’s court could read the “writing on the wall” (except Daniel, *Daniel* 5:8) was because it was written in the *ketav Ashurit* (*Sanhedrin* 22). It is curious that in the second century CE, Simon bar Kochba used the *ketav Ivri* script on his coins. Was this a deliberate archaism?

## Features of the Menorah Page

Table A1 shows how to transliterate the letters on this Menorah Page into the *ketav Ashurit* script. Note that five letters of the *Ashurit* script are missing: these are *zayin* as in [זהר] (*zohar*, “brightness”, see Ezekiel 8:2; Daniel 12:3); *teth* as in [טהר] (*tohar*, “clearness”, that is, ritual purity, see Exodus 24:10; Psalm.89:44); *kaph* as in [כבוד] (*kabhôdh*, “glory”, see Isaiah 6:3); *samekh* as in [סנה] (*sə-neh*, “bush”, see the burning bush of Deuteronomy 33:16;

Ex.3:2,3,4); and *pe* as in [פאר] (*pā'ar*, “glorify or beautify”, see Isaiah 60:7). Note that Hebrew is read right-to-left.

Haggai 1:8 has a word for “glorify” ([ואכבדה], *wā'ek-kā-bə-dāh*) with different written ([כתיב], *ketiv*) and spoken ([קרי], *qere*) texts (*ketiv* and *qere* are Aramaic words). This text is given as “[ואכבדה=ק] [ואכבד=כ]”. The written (*ketiv*) text omits the final *heh* [ה].

Ancient witnesses gloss this missing *heh* (also used as the Hebrew numeral 5) in Hag.1:8 by saying that in the Second Temple *five* items were missing: this list of five (the list is given variously) might be the ark, the menorah, the fire, the Spirit of God and the cherubim. Ezekiel saw the Glory leave Solomon’s Temple (destroyed in 586 BCE: Ezek.10:18), and the Temple to which he saw it return (Ezek.44:4) was *not* the Temple that Ezra built in about 515 BCE (Ezra 6:14) under Haggai’s prophecy. The *ketiv* of Hag.1:8 is held by ancient commentators to be an explicit acknowledgement that the Glory has departed. Thus, “five” is the number of the *missing Glory*, and in this Menorah Page each missing letter represents one aspect of this missing Glory.

<b>Ashurit</b>	מ	ל	תו	הה	דג	ב	א'
<b>Ivri</b>	מ	ל	ת	ה	ד	ב	א
<b>Ashurit</b>	ק	קר	קד	שצ	ע	נ	
<b>Ivri</b>	ק	ק	ק	ש	ע	נ	

**Table A1: Transliteration between Ashurit and Ivri scripts**

All these *ketav Ivri* script characters appear on the Menorah Page (Figure A2). Note that multiple *Ivri* characters have two possible transliterations, and the *Ashurit* “kof” character is the transliteration of three different *Ivri* characters. The *Ashurit* “dalet” character is also the transliteration of three *Ivri* characters, one of which can be written two ways, both appearing on this Page (which also includes the Greek letter *omega* Ω).

## Reading the Menorah page as mnemonic

The Hebrew script is unpointed (“unvocalised”), meaning that most vowels are not written and there are no word dividers, so that it is intrinsically ambiguous. We start to show here how to read this “Menorah page”, how we demonstrate a coherent decoding of just one aspect of it, and how we rule out the possibility that this reading is arbitrary.

Figure A4 indicates at least nine different ways that *d<sup>e</sup>mûth* can be read from the letters d-m-t (using the usual transliteration). This in itself would be of no significance, but the triangles formed by the three letters can be read in three different ways: d-m-t; m-t-d; t-m-d (selecting only half of the six possible permutations). Moreover, the mirror image of the d-m-t triangle (shown as the dotted lines in Figure A4) can also similarly be read. Table A2 shows that this is coherent, and is therefore a plausible reading of this part of the Menorah page. We can also justify this use of the mirror image by citing the influential Jesus ben Sirach, writing in Jerusalem about 200 BCE (Ecclesiasticus 33.15): ‘*So look upon all the works of the most High; and there are two and two, one against another* (και ουτως εμβλεψον εις παντα τα εργα του υψιστου δυο δυο εν κατεναντι του ενος)’.

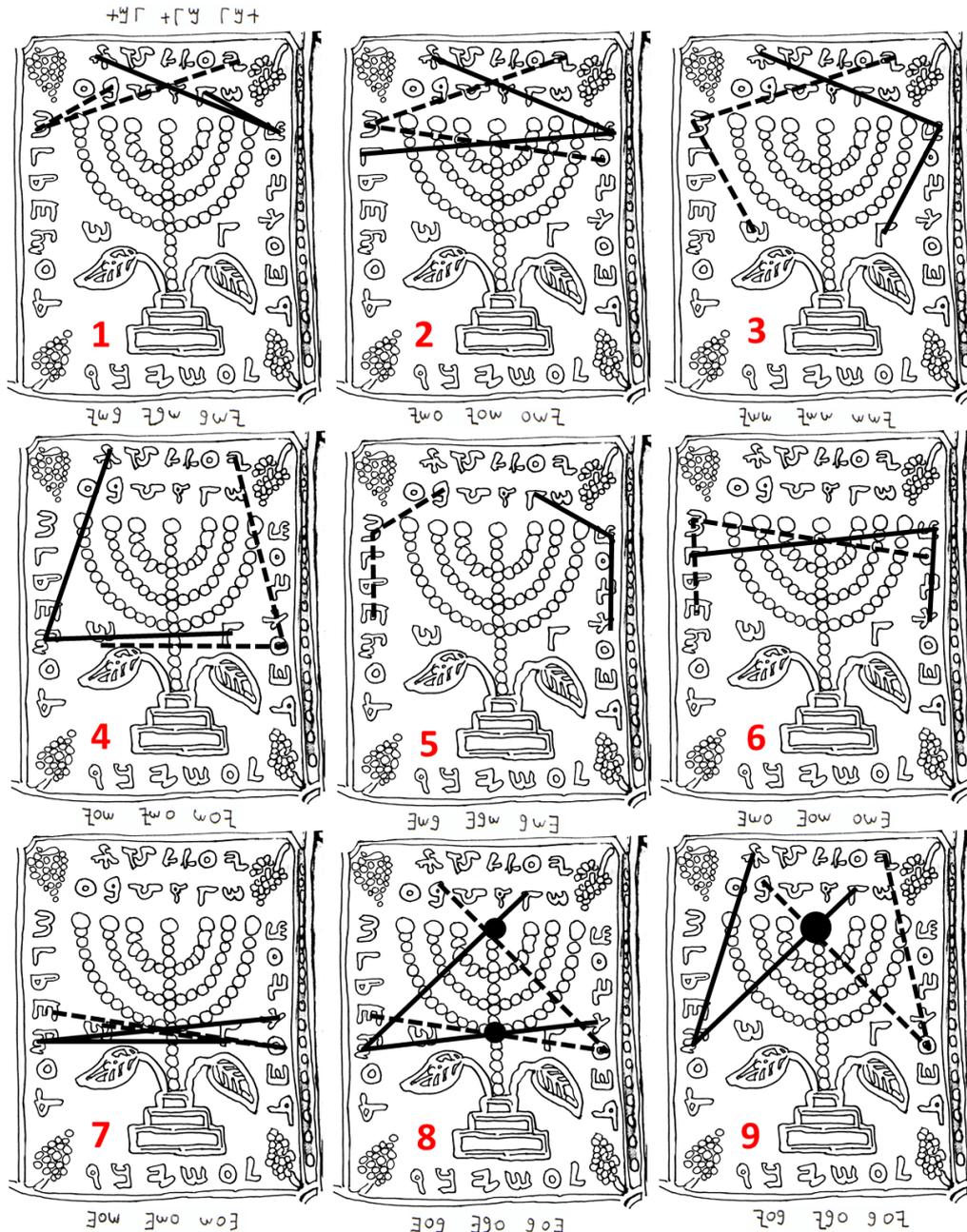
Summarising, we can read Table A2 as a double gloss on the text referred to by *d<sup>e</sup>mûth*, which occurs at the centrally important text, “*let us make man in our image, after our*

***likeness***” (*Genesis* 1:26). This is the first statement in the Bible about how the human being relates to God, and the patterns on the Menorah page show how this was expressed in the traditions and rituals of the temple in Jerusalem, Solomon’s temple. First, the Menorah page invites us to permute the three letters of the word three ways, to read: *be clothed continually in the garment of His likeness*, as the High Priest was when he went in to sacrifice in the Holy of Holies (see *Exodus* 28:29f; *Psalms* 34:1 etc).

Then secondly, the mirror image of each of the nine cases (with the corresponding permutations) can also be read: see Table A2, which makes one proposal for speaking the “poem”. The letters may be transliterated into “modern” Hebrew (the *ketav Ashurit*) a number of ways (our choice is shown in Table A3), and this text can be vocalised a number of ways (our choice is shown in Table A3 and summarised in Table A2).

We underline that this Page is a very sophisticated mnemonic design, of which we show only a very small and simple part (as can be seen in Figure A4). Such designs are intrinsically ambiguous, so that different people can see different things. In particular, the artefact appears to be a sophisticated Second Temple Jewish design remembering First Temple theology, but taken over (and doubtless reinterpreted) by a Christian community, as is witnessed by the Page being subsequently incorporated into a codex. Its interpretation as a Jewish artefact is rather esoteric, and certainly beyond our present scope, but we interpret it here more simply as an artefact used by Christians. However, we believe that both our transliteration and our vocalisation choices work for either interpretation, perhaps with some small changes for the vocalisation.

To modern ears the Hebrew poem will sound strongly archaic (even in modern pronunciation): this is because it is stylistically similar to Ugaritic materials, which were already very ancient in the 1<sup>st</sup> century CE (see [ref.4]: Ps.114 has similar stylistic features<sup>5</sup>, and so does Ps.29<sup>6</sup>).



**Figure A4: Interpreting “d’ mûth” in the Menorah page (see Table A1)**

In each case the solid line reads *tāmîdh* (or *d’ mûth* reading the other way), and the dotted line (the mirror image) interprets: see text. Note: Hebrew reads right-to-left. The solid line triangle is read three ways: first starting with the top left character, and then the two ways of ending with it. This reading (three words) heads the Figure. For each of the nine ways this word appears, the mirror triangle is read the same way: with the reading given below the corresponding image. For ##8,9 the black circles indicate where the reading and its mirror intersect the Menorah (the significance of which is outside our present scope). The images ##1-9 are ordered by row: so image #1 involves rows {1,3,2}, image #2 {1,3,4} etc. We consider the isolated characters above the Menorah leaves to be in row #6\*. Then images ##1-9 involve in turn rows {1,3,2}; {1,3,4}; {1,3,6\*}; {1,7,6\*}; {6,3,2}; {6,3,4}; {6,7,6\*}; {6,7,2}; {1,7,2}

#	abc / bca / cba	abc / bca / cba (vocalised)	English (abbreviated)
0	tmd / mdt / dmt	<i>tāmîdh / middōth / d<sup>e</sup>mûth</i>	continually / in the garments / of the likeness
1	asb / sba / bsa	<i>yōšēbh / b<sup>e</sup>šābhā' / bušî</i>	enthroned / amidst the angel host / in fine linen
2	asa / saa / asa	<i>yōšēa' / šā'ay / 'ēšî</i>	the Victor (Saviour) / gazes / on my tree
3	ass / ssa / ssa	<i>yīššas / šīššê / šīšay</i>	he will make bloom / the flowers of / my blossoms
4	aas / asa / saa	<i>yō'ēš / 'ēšî / šō'<sup>a</sup>î</i>	the Counsellor / of my tree / is glad
5	hsb / sbh / bsh	<i>haššōbh / šābhaḥ / beššāḥîḥ</i>	he who returns / praises / in the shining place
6	hsa / sah / ash	<i>haššō'ēa' / šā'āh / 'ēšāh</i>	he who delights / gazed / upon her tree
7	has / sah / ash	<i>hā'ēš / 'āšāh / šā'āh</i>	the tree / gave counsel / and looked with favour
8	hab / abh / bah	<i>hā'ābh / 'ābhâ / bō'eh</i>	with the cloud / she overshadows / the enquirer
9	aab / aba / baa	<i>'ā'ûbh / 'ābhî / bō'î</i>	I will overshadow / with my cloud / he who seeks me

**Table A2: Decoding “d<sup>e</sup>mûth” in the Menorah page (see Figure A4)**

This whole Table is read left-to-right. In column 2 “a” is used to “transliterate” both *aleph* and *ayin*;

“s” for *shin/sin/tsadi*; “h” for *heh/chet*; “t” for *tav*; “m” for *mem*; “d” for *dalet*; “b” for *beth*.

Vocalisation (like transliteration) is ambiguous: this version does not exclude other possibilities.

Table A3 indicates some resonances of the mnemonic in the Hebrew Scriptures (using only the Masoretic Text): these in turn have Christian resonances, also indicated.

line	#	Hebrew			English		Reference		
		Text	+ML	Root	Trans-lation	Trans-literation	MT	LXX	NT
0	1	תמד	תמיד	מוד	continually	<i>tāmīdh</i>	Ex.27:20	δια παντος	Heb.13:15
	2	מדת	מדת	מד	garments	<i>middōth</i>	Ps.133:2	ενδυμα	Matt.22:11f; 28:3
	3	דמת	דמות	דמה	of the likeness	<i>demûth</i>	Is.40:18	ομοιωμα	Phil.2:7; Rom.1:23; 6:5;
1	1	ישב	ישב	ישב	enthroned	<i>yōšēbh</i>	2Sam.6:2; 1Ki.22:19	καθημενος	Matt.24:3; Rev.4:10
	2	צבא	בצבא	צבא	angel host	<i>b'šābhā'</i>	1Ki.22:19	στρατια ουρανου	Lk.2:13; Rev.19:14
	3	בצי	בצי	--	in fine linen	<i>bušî</i>	1Chron.15:27	βυσσινος	Rev.19:8
2	1	ישע	ישע	ישע	Saviour	<i>yōšēa'</i>	Is.61:10	σωτηρ	Lk.2:11 etc.
	2	שעי	שעי	שעה	gazes on	<i>šā'ay</i>	Is.17:7	πεποιθως	2Cor.2:3; Phil.1:6,25;
	3	עצי	עצי	עץ	my tree	<i>'ēšî</i>	Gen.2:9	ξύλος	Rev.22:2
3	1	יצץ	יצץ	צייץ	he will make to bloom	<i>yiššāš</i>	Num.17:8 Is.40:6ff	ανθος ανθιζω	Jas.1:10f 1Pet.1:24
	2	צצי	צצי	צייץ	flowers of	<i>šiššē</i>			
	3	צצי	צצי	צייץ	my blossoms	<i>šišay</i>			
4	1	יעץ	יעץ	עץ	the Counsellor	<i>yō'ēš</i>	2Sam.16:23 (2Sam.15:12)	συμβουλος (βουλη)	Rom.11:34 (Eph.1:11)
	2	עצי	עצי	עץ	my tree	<i>'ēšî</i>	(as 2:3)		
	3	שעי	שעעי	שעע	is glad	<i>šō'a'î</i>	Ps.94:19	αγαπαω	Rev.12:11
5	1	חשב	חשב	שוב	the one who returns	<i>haššōbh</i>	Gen.3:19 Jer.31:18	αποστρεψω επιστρεψω	Acts 3:26 Matt.13:15
	2	שבח	שבח	שבח	praises	<i>šābhah</i>	Pss.145:4; 117:1	επαινει	Rom.15:11
	3	בצה	בצהח	צה	shining place	<i>beššāhîh</i>	Cant.5:10	[λευκος]	[Matt.17:2; 28:3]
6	1	השע	השעע	שעע	he who takes delight	<i>haššō'ēa'</i>	(as 4.3)		
	2	שעה	שעה	שעה	gazed	<i>šā'āh</i>	(as 2:2)		
	3	עצה	עצה	עץ	upon her tree	<i>'ēšāh</i>	(as 2:3)		
7	1	העץ	העץ	עץ	the tree	<i>hā'ēš</i>	(as 4.1)		
	2	עצה	עצה	יעץ	counsels	<i>'āšāh</i>	(as 4.1)		
	3	שעה	שעה	שעה	looked with favour	<i>šā'āh</i>	(as 2:2)		
8	1	העב	העב	עב	with the cloud	<i>hā'ābh</i>	Ex.19:9	νεφελη	Matt.17:5
	2	עבה	עבה	עוב	she overshadows	<i>'ābhā</i>	(as 9:1)		
	3	בעה	בעה	בעה	the seeker	<i>bō'eh</i>	Is.21:12	ζητων	Matt.6:33
9	1	אעב	אעוב	עוב	I will overshadow	<i>'ā'ūbh</i>	Lam.2:1	εγνοφωσεν	Heb.12:18
	2	עבי	עבי	עב	with my cloud	<i>'ābhî</i>	(as 8:1)		
	3	בעי	בעי	בעה	he who seeks me	<i>bō'î</i>	(as 8:3)		

**Table A3: Interpreting “d'mûth” in the Menorah page (see Table A2)**

This Table gives the roots of the Hebrew words, together with a suggested vocalisation for this reading (including the *matres lectionis*, “ML”, and an occasional grammatical prefix or suffix) and an indication of the translation. Representative allusions to the canonical text are given, using the LXX as a Hebrew-Greek lexicon. See text for discussion of Table.

The Hebrew text is highly suggestive and heavily allusive, and reading it with a Christian gloss (explicitly adding the vocalisation) we tentatively interpret it in English as:

0.	Clothed perpetually in His likeness	תָּמִיד מְדַת דְּמוּתוֹ
1.	he is enthroned among the heavenly host in shining linen	יָשָׁב בַּצִּבְאָה לְבוּשׁ בְּצִי
2.	delighting that I know he saves	יֹשֵׁעַ שְׁעֵי עֲצֵי
3.	he establishes the flowering of my blooms	יַצִּיץ צִיָּי צִיָּי
4.	my Counsellor delights in me	יַעֲזָר עִצִּי שְׁעֵעֵי
5.	He returns in glory to praises	הַשֵּׁב שִׁבְחָה בְּצִחִיָּה
6.	he delights who gazed upon Wisdom's tree	הַשְּׁעֵעַ שְׁעָה עֵצָה
7.	she blesses him with wisdom	הַעֲזָר עֵצָה שְׁעָה
8.	She overshadows the seeker	הַעֲבֵר עֲבָה בְּעָה
9.	My cloud will overshadow him who enquires of me	אֲעֹוֵב עֲבֵי בְּעֵי
0.	Clothing him perpetually in the likeness	תָּמִיד מְדַת הַדְּמוּת

## Glossing the Poem

It is not possible to give a literal reading of the Hebrew poem implied in Table A3 in any English version that would be accessible to modern ears, since the allusiveness of the text requires a deep familiarity with the canonical (and extra-canonical) texts very rare today. (The extra-canonical texts are far out of our scope and we do not here consider them.)

However, the book of *Revelation* (which is full of heavily Hebrew imagery) features prominently in a Christian gloss of the poem. So the “**shining linen**” in line#1 is the clothing of the saints (Rev.7:9) as already suggested by Jesus (Matt.22:11) and modelled by David dancing before the Ark (1Chron.15:27). There are “garments” in line#0 and “linen” in line#1, implicit in both is the word “clothed” ([לְבוּשׁ], *lābhūš*) which we have added to line#1.

In line#2 “**I know**” refers to the Tree, which is the Tree of Knowledge and the Tree of Life. After all, it is “*by his knowledge [that] my righteous servant [shall] justify many*” (Is.53:11). It is textually arguable that in Eden there was only one Tree, which was of both Knowledge and Life. Comparison with the Ugaritic Creation story [ref.4] would support this argument.

The Tree also refers to Aaron’s rod, which budded, blossomed, gave almond fruits, and was kept “*before the Ark*” (Num.17:8ff). Looking at the rod silenced the grumblers, just as looking ([וְהִבִּיט], *wə-hib-bîṭ*) at the brass serpent gave life (Num.21:9). “**Gazing**” is a reference to this holy looking: “*they shall look ([וְהִבִּיטוּ], wə-hib-bî-ṭū) upon me whom they have pierced*” (Zech.12:10) echoed by “*and every eye shall see him, and they also which pierced him*” (Rev.1:7). In Table A3, Is.17:7 (a prophecy against Damascus) seems rather obscure, and uses a different Hebrew word: “*At that day shall a man look ([יִשְׁעָה], πεποιθως) to his Maker ...*”, but both the LXX and the NT use the Greek word to mean “*confidence*” (this is part of the connotation of *looking* also in English: we *look for comfort*; we *look up* to people). Matt.27:43 also uses the same word (rendered “*trusted*” in English) clearly referring to Ps.22:8 (but changing the LXX ηλπισεν). The root of πεποιθως is πειθω, which is also related to πιστις (faith).

“**The tree**” [ξύλος] also refers to the Cross [σταυρος]: “*The God of our fathers raised up Jesus, whom ye slew and hanged on a tree*” (Acts 5:30). This is because the Jews heard the Torah here: “*Cursed is every one that hangeth on a tree*” (Gal.3:13; Deut.21:23). But of

course, in the end the Tree is the tree of life, “*and the leaves of the tree were for the healing of the nations*” (Rev.22:2).

In line#3, we have already seen that the “**flowering of my blooms**” alludes to Aaron’s staff. It also alludes to Is.40:6, the fading glory of the flowers of the field, echoed many times in the New Testament including Jesus: “*Consider the lilies ...*” (Lk.12:27) who is also alluding to the Song of Songs: “*I am my beloved’s, and my beloved is mine: he feedeth among the lilies*” (Cant.6:3). This in turn is the context of Jeremiah’s central prophesy: “*I have loved thee with an everlasting love*” (Jer.31:3) which he expands in the same place saying “*Behold, the days come, saith the LORD, that I will make a **new covenant** with the house of Israel, and with the house of Judah*” (Jer.31:31). And it was this *new covenant* that Jesus picked up and made into the central Christian symbol (Lk.22:20; 1Cor.11:25; Heb.8:8).

The “**return**” in line#5 is speaking about “*the consolation of Israel*” (Lk.2:25), where of course Israel is looking for the *Return of the King* (as Tolkien put it in *The Lord of the Rings*). Jesus referred to this obliquely in the parable (Lk.19:15) but the Jews knew that although they had “returned” from Babylon they were not yet fully returned from exile: not while the Glory was still absent from the Temple. (Ezra c.500 BCE and Nehemiah c.440 BCE had both confessed this: “*we are still slaves*”, Ezra 9:9; “*we are slaves today*”, Neh.9:36.) And earlier (c.720 BCE) Hezekiah had urged the people: “*turn again unto ... God ... and he will return to ... you*” (2Chron.30:6). Then c.600 BCE Jeremiah sees Ephraim, who is dead and gone a century since, “*bemoaning himself*” and saying to God: “*turn thou me, and I shall be turned*” (Jer.31:18). And John himself must *turn* in his vision to see Jesus (Rev.1:12).

In line#8 the “**cloud**” refers to the Glory of God (as in the *cloudy pillar*, Ex.13:21f; 33:9f etc). For us this is an obscure allusion, but it would have been crystal clear to both 1<sup>st</sup> century Jews and 1<sup>st</sup> century Christians who all had exactly the same understanding. This is plain in the New Testament as is shown by Table A3: the Greek word for “cloud” [νεφέλη] used at the account of Jesus’ Transfiguration is the same as the Greek word in the LXX used for the cloud on Mount Sinai.

Also, in the book of *Revelation* the Cloud (Rev.1:7; 10:1; 14:14) explicitly references the Cloud in Daniel’s vision of the Son of Man (Dan.7:13) that was demonstrably influential in the 1<sup>st</sup> century CE. It also explicitly references the Cloud as the promise of God in the Rainbow (Rev.10:1). This word [νεφέλη] is still standard Greek, but the word used for “overshadow” in the reference in the New Testament to Mount Sinai (Hebrews 12:18) is a cognate word (γνοφω, “blackness”) no longer common, and which was already archaic in the 1<sup>st</sup> century, as shown since the New Testament uses a different word [επισκιαζω] to render “overshadow” literally (Lk.1:35; 9:34). But the Hebrew word [עֹרֵב] here rendered “overshadow” is, literally, “overcloud” with all the connotations of the Cloud<sup>1</sup>.

Of course, the Cloud symbolises the Presence of God as well as the Glory and the Promise: first century CE Jews were looking for the Return of God, and for the Hope and Salvation of

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<sup>1</sup> Connotations of the Cloud: the rainbow Covenant, Gen.9:13ff; protection in the wilderness by day, Ex.13:21 *passim*; the Glory of the LORD, Ex.16:10; Mount Sinai, Ex.19:9 *passim*, Ex.24:15 *passim*; the second Tablets, Ex.34:5; the Glory in the tabernacle, Ex.33:9 *passim*, Ex.40:34ff, Lev.16:2,13, Num.9:15 etc. “Overcloud” [עֹרֵב] is an *hapax legomenon* at Lam.2:1.

Israel – prominent symbols in this poem which all reinforce each other: see on this the extensive historical survey of N.T. Wright (1992, ch.10 “*The Hope of Israel*”) <sup>7</sup>. Wright says:

... the “salvation” spoken of in the Jewish sources of this period has to do with rescue from national enemies, restoration of the national symbols, and a state of *shalom* in which every man will sit under his vine or fig-tree [cf. Jn.1:48; Mic.4:4 etc.]. “Salvation” encapsulates the entire future hope. If there are Christian redefinitions of the word later on, that is another question. ... “salvation” [is not] an easy and univocal term  
Wright, 1992, p.300

Of course, first century Christians were convinced that these things were a present reality: this is why the same poem works for both Jews and Christians.

In line #5 the **radiance** is an idea that permeates the whole poem (shining linen, the cloud) but the Hebrew Scriptures and the NT are not closely linked in this case by the LXX: the equivalent of [רָצַף] (*ṣah*) is κάυματος (see Is.18:4), but this has a somewhat different connotation in the NT (see e.g. Rev.16:9).

We now need only some final comments about line#0, of which all the other lines are a mirror. We have repeated the line at the end of the poem: this is because Figure A4 clearly shows a circular progression, ending where it starts. But we have interpreted a different pronoun referent at the start and at the end: this may be a specifically Christian gloss (the raw ancient Hebrew remains ambiguous). Who is “clothed”? At the start it is clearly the Son of Man (as in Dan.7:13), but at the end it is he who may enter the Cloud. For the Jews this would include the High Priest, but for the Christians it would include every Christian (we have already pointed out Rev.7:9).

We have underlined the importance of **clothing**: in the Temple liturgy many things were **continually** required, not only the sacrifices (see Rev.5:6) but also the continual incense (which is the “*prayers of the saints*”, Rev.8:3f), and also “*the lamps*” which are “*to burn continually*” (Lev.24:2; cp. Ex.27:20; see Rev.4:5). However, in line#0 the “*garments*” have a different connotation from the “*fine linen*” of line#1. The word is used most frequently in Ezekiel, of his visionary *measurements* of the Temple: the idea in line#0 is that our clothing measures our *extent* or delimits our *boundary*. (*Garment* and *measurement* are the same word in Hebrew.)

The **likeness** is a seminally important idea that is the basis of both Jewish and Christian ontology. Who are we? Made in the **image** and **likeness** of God (Gen.1:26)! The *image* is the physical representation: for the ancient peoples *idols* were *images* in this sense – the ideas are synonymous. But the *likeness* is that underlying reality which is represented: the closest idea in European philosophy is the *Platonic form*. Of course, Plato was later than any of the Hebrew canonical text, and it may well be that the “Platonic form” is an idea dependent on this Hebrew idea of *likeness*.

“*Likeness*” was also deeply important for 1<sup>st</sup> century Jews, being central in Ezekiel’s visions (occurring 10 times in Ez.1; and 4 times in Ez.10) and in the powerful and influential Isaiah passage (Is.40:18). It was also crucial for Christians: the early Christian hymn recorded in Paul’s letter to the Philippians declared that “*Christ Jesus ... was made in human likeness* [ομοιωματι ανθρωπων]” (Phil.2:7). Then “*continually in the garments of the likeness*” makes explicit the High Priest compassing the likeness of God in *time* and *space* (see Jer.31:22).

In any case, for the whole poem the subject (“he”) is masculine, indicating Wisdom’s son. Both faithful Jews and Christians would identify with this. It is Wisdom who is displayed in

many theophanies of the Hebrew Scriptures, and the *New Testament* is clear that Jesus is the Wisdom of God (explicit at 1Cor.1:30; Col.2:2).

## How Stable is this Interpretation?

The reader is entitled to wonder how compelling the interpretation of this Menorah Page actually is. Could not a determined interpreter read almost anything into it? However, apart from the essential ambiguity of the transliteration from the *ketav Ivri* script to the *ketav Ashurit*, and also the essential ambiguity of choosing a vocalisation for the unpointed text, once the triangular word of interest is chosen the 10-line “poem” in *ketav Ivri* follows unambiguously. The steps are as follows:

1. We found the triangular (3-letter) word [דמת] (*d'mûth: likeness*) multiple times in the Page. Of course, this in itself has little or no significance.
2. A set of 3 (“abc”) has 3! (=6) permutations: abc, acb, bca, bac, cab, cba. We choose half of these: abc, bca, cba. Applying these to [דמת] we obtain the line [תמד מדת דמת] as given (remember, Hebrew reads right-to-left). Clearly, this can be considered an arbitrary move.
3. For each of the nine occurrences of the triangular word [דמת] in the Page we take the mirror image triangle, and apply the permutations in #2 in the same order (see Figure A4). This move is *not* arbitrary. Given line#0, lines ##1-9 follow unambiguously.
4. The order of the lines ##1-9 is given by the patterns made on the Page. Figure A4 has a logical order independent of any meaning that might be assigned to the result.

The question now is, does the resulting 10-line text have any significance? We have found a reading that not only makes sense, but makes rather powerful sense in the context of the deep interest in Temple theology that we know both Jews and Christians had in the first century (20 centuries ago).

We can also comment that there is a precedent for considering as an enigma a line of three words with three letters each. The writing that appeared on the wall before Belshazzar was:

מנא תקל פרס

(“MENE TEKEL PERES”) which was interpreted by Daniel (Dan.5:25ff) as:

מנא מנא תקל ופרסין

(“MENE MENE TEKEL UPHARSIN”). Ancient witnesses (*B.Sanhedrin 22a*) proposed that the reason the Babylonians could not read this was precisely because it was written in the *ketav Ashurit* script which was unknown to all but the Jewish priests.

## Mirror Image: *e pluribus unum*

The crucial fact that has not been emphasised so far (except in step #3 above) is the importance of the mirror image. The idea that runs through the modern physics in the paper is of “holomorphism”: the integrity (unity) that results from binding two together into one. This is only a modern physics gloss on what is an ancient idea, but it is this same idea that tacitly pervades the reading given here from the Page.

We (and all mammals) are made with mirror symmetry: two eyes, two ears, two arms, two legs etc. The canonical Biblical text acknowledges this in many places, as does all Wisdom literature: a representative quote might be the Psalm of David (from 30 centuries ago):

One thing God has spoken; two things have I heard  
that strength is but God's; and yours, Master, is kindness Ps.62:11f (Alter, 2007 [ref.6])

God (being One) speaks univocally, but we (having two ears) hear multiple aspects of the same thing. The same thing is heard in the *New Testament*, which metaleptically refers to the seminal Hebrew Scripture (Gen.2:24):

[Jesus said] For this cause shall a man leave father and mother, and shall cleave to his wife:  
and they twain shall be one flesh Matt.19:5f; see also Mk.10:8; 1Cor.6:16; Eph.5:31

Mankind, made in the image of God, is dual: man and woman. And the idea of *two-becoming-one* in the sense of *reconciliation* is sharpest in the Christian (Greek) Scriptures: the word “*atonement*” was introduced by William Tyndale in 1526 specifically as an Englished synonym of the Latinist word “*reconciliation*”: *atonement* is, properly, “*at-one-ment*”. Tyndale even uses “*atone*”, meaning “*at one*”:

Therefore yff eny man be in Chrift / he is a newe creature. ... Neverthelesse all thyng<sup>f</sup> are of god / whych hath reconciled vs vnto hym fylfe by Jefus Chrift / and hath geven vnto vs the office to preache the atonement. For god was in Chrift / and made agrement bitwene the worlde and hym fylfe / and imputed not their fynnes vnto them: and hath committed to vs the preachynge of the atonment. ... So praye we you in Chriftes ftede / that ye be atone with God.

2Cor.5:17-20 (Tyndale 1526<sup>8</sup>)

In the Mosaic Law, Yom Kippur ([יום הכפרים]) is known in English as the “*Day of Atonement*” (Lev.23:27f), following Tyndale’s 1530 translation. Tyndale understood that God’s purpose for the sacrifices was specifically *reconciliation* (although the Hebrew word [כפר] refers to the idea of “*coverings*”: see Gen.6:14, Noah had to *pitch* the inside and the outside of the Ark).

## The Menorah Page as a Mnemonic

The artefact shown in Figure A2 is one of dozens of similar types of pages we have seen. It is only one of several we have analysed in depth. The analysis here, using a single 3-letter word that can be read nine times in this Page, shows how a powerful mnemonic can be constructed using the property of reflection (the mirror image). This is a general method: we have already found over a hundred other words with similar mirror-mnemonic properties on just this Page.

It has become clear that this Page is a very sophisticated artefact that depends on (and has stimulated) a much wider lexical knowledge of ancient Hebrew than remains extant in the Masoretic Text (see on this David Clines<sup>9,10</sup>). It may well prove to be a powerful research tool in its own right.

## References

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- <sup>1</sup> C.Jeynes & G.W.Grime, *Report on Report on the composition of two Pb samples*, For Roger Webb G469, Job #3172 (22<sup>nd</sup> May 2012), *LeadComposition-PIXEreport2016.pdf* (in Supplementary Materials)
- <sup>2</sup> Bernard Keisch Dating Works of Art through Their Natural Radioactivity, *Science* **160** (3826), 413-415. (April 26, 1968); <http://dx.doi.org/10.1126/science.160.3826.413>
- <sup>3</sup> C.Jeynes, *Report on  $\alpha$ -decay of two lead book pages*, For Matthew Hood, Jordan Codices Group G469, Job ##4405, 4475 (23<sup>rd</sup> August 2016), *LeadMeasurements-July2016.pdf* (in Supplementary Materials)
- <sup>4</sup> Marjo C.A. Korpel & Johannes C. de Moor, *Adam, Eve, and the Devil* (Sheffield Phoenix Press 2014)
- <sup>5</sup> C.Jeynes, *Review of "Adam, Eve, and the Devil" by Marjo Korpel & Johannes de Moor* (August 2014); <http://dx.doi.org/10.13140/2.1.3318.7203>
- <sup>6</sup> Robert Alter, *The Book of Psalms – a translation with commentary* (W.W.Norton & Co. Inc., New York, 2007)
- <sup>7</sup> N.T.Wright, *The New Testament and the People of God* (SPCK, London 1992)
- <sup>8</sup> William Tyndale, *The Newe Testamente* (Peter Schoeffer, Worms, 1526; facsimile of The British Library, London, 2008)
- <sup>9</sup> David Clines, *The Challenge of Hebrew Lexicography Today*, Congress Volume, Ljubljana 2007 (ed. André Lemaire; *Vetus Testamentum Supplements*, 133; Leiden: E.J. Brill, 2009), pp. 87-98
- <sup>10</sup> David J.A. Clines (ed.), *The Dictionary of Classical Hebrew*, vol. 6 (Sheffield, 2007)

[Click here to view linked References](#)



*Ion Beam Centre*



**The University of Surrey Ion Beam Centre**

*An EPSRC supported National Facility*

**The Ion Beam Analysis Laboratory**

**Report on the composition of two Pb samples**

**For Roger Webb, IBC**

**G469, Job No. 3172**

**22<sup>nd</sup> May 2012, C.Jeynes & G.W.Grime**

### ***Samples and Purpose of Analysis***

Samples arrived 18<sup>th</sup> May 2012 from Roger Webb. One sample may be from the Jordan Codices (??), the other is a convenient "modern" control sample; we are looking for characterisation, both with 5 MeV alphas from <sup>210</sup>Pb disintegration and from trace element analysis using PIXE. The PIXE is reported here.

### ***Conclusions***

Large amounts of Sb and Sn are detected in the "old" sample, with strongly enhanced transition metal content and heavy chloridation of the surface. For more details see the Appendix.

### ***Analysis***

Data were collected using OMDAQ, and fitted with WiNDF. The particle detector was not used.

NDFv9.3e was used to fit the data (N. P. Barradas and C. Jeynes, "Advanced physics & algorithms in the IBA DataFurnace", *Nucl. Instrum Methods Phys. Res., Sect. B*, **266** (2008) 1875-1879).

### ***Results***

(For experimental setup and detailed results and discussion, please refer to the Appendix).

## APPENDIX

### Depth Profiling by Ion Beam Analysis

This work was done using a 2MV Tandatron accelerator from High Voltage Engineering Europe, commissioned summer 2002 at the University of Surrey Ion Beam Centre. This machine is capable of generating proton beams up to 4MeV and alpha particle beams of up to 6MeV (Simon *et al*: Nucl.Instrum.Methods 2004: **B219-220**, 405)

Rutherford backscattering spectrometry (RBS) is an accurate, powerful and general thin film depth profiling technique typically carried out with 2 MeV He beams. Higher energy and proton beams are typically used for depth profiling thicker films, and for enhancing sensitivity to light elements with non-Rutherford elastic backscattering (EBS). Hydrogen can be depth profiled using elastic forward recoil spectrometry (FRS, also known as ERD: elastic recoil detection). Deuterium can also be depth profiled using nuclear reaction analysis (NRA) with a  $^3\text{He}$  beam. Particle induced X-ray emission (PIXE) has little depth resolution but can unambiguously identify elements and analyse for trace elements with detection limits approaching  $\mu\text{g/g}$ . Particle induced gamma-ray emission (PIGE) is a form of NRA particularly valuable for lighter elements present in bulk materials at a trace level: F, Na, Al, Si.

*The depth profiling beamline* is equipped with a 6-movement goniometer from Arun Microelectronics Ltd, commissioned autumn 2002. This instrument is capable of loading entire 100mm wafers through a load lock, of channelling in arbitrary directions on a single crystal, and of high depth resolution (glancing beam incidence geometry). Both backscattering and forward recoil detectors are fitted. The target chamber has a base vacuum below 1 nbar.

*The microbeam beamline* was commissioned summer 2002. It has a magnetic quadrupole triplet lens and associated equipment from Oxford Microbeams Ltd, and can focus the beam to about 1 micron. The beam can be scanned over about 2mm giving trace and minor element mapping with PIXE and 3D depth profiling with RBS/EBS using the OMDAC and DAN32 software (Grime & Dawson, Nucl.Instrum.Methods 1995: **B104**, 107) which is based on the GUPIX code (Blaauw, Campbell *et al*, Nucl.Instrum.Methods 2002. **B189**, 113) Various sample stages are available including a cold stage, a goniometer, and a stage suitable for ion beam induced current (IBIC).

*The external beamline* was commissioned May 2004 and also has a magnetic quadrupole triplet with a thin window so that a focussed and scanned ion beam can be passed into air to analyse large, delicate or wet samples by PIXE, RBS/EBS and PIGE.

*Depth profiles* can be extracted automatically from RBS, EBS, ERD and NRA spectra using the Surrey IBA DataFurnace software (Jeynes *et al* J.Phys.D, 2003: **36**, R97, [www.surreyibc.ac.uk/ndf](http://www.surreyibc.ac.uk/ndf)). We have validated the accuracy of this code against a certified standard sample (Boudreault *et al* Surf. Interface Anal. 2002: **33**, 478). The code is also validated by an international intercomparison (Barradas *et al* Nucl.Instrum.Methods 2008: **B266**, 1338). DataFurnace v9 (Barradas & Jeynes Nucl.Instrum. Methods 2008: **B266**, 1875), can also now handle PIXE data (with other IBA data) self-consistently (Pascual-Izarra *et al*, Nucl. Instrum.Methods 2007: **B261**, 426) and more correctly than GUPIX.

Where the DataFurnace fit is *good* the fitted profile is *valid* (but not necessarily true!). In the analyses we will point out the limitations of the results due to counting statistics, finite energy and depth resolution, and other systematic errors. Profiles are always given as layer structures. We systematically use *Occam's Razor* ("minimise your assumptions") to be objective about how much information is really in the data: in particular the extracted layer structures tend to be as *coarse* as the data will allow, and the discontinuous profiles we always show are due to the finite energy and depth resolution of the technique and can be seen as an expression of these.

Complete data sets are archived and can be re-analysed on request. In particular, a rigorous statistical evaluation of the uncertainty of the depth profiles can be obtained with the Bayesian techniques natural to the DataFurnace implementation. We have an interest in accurate work with rigorous evaluation of uncertainties, and are always interested in joint publication.

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tel: 01483 689829 (Mrs.Karen Arthur: 01483 686090)

July 2009

### ***Samples and Purpose of Analysis***

Samples arrived 18<sup>th</sup> May 2012 from Roger Webb. One sample may be from the Jordan Codices (??), the other is a convenient "modern" control sample; we are looking for characterisation, both with 5 MeV alphas from <sup>210</sup>Pb disintegration and from trace element analysis using PIXE. The PIXE is reported here.

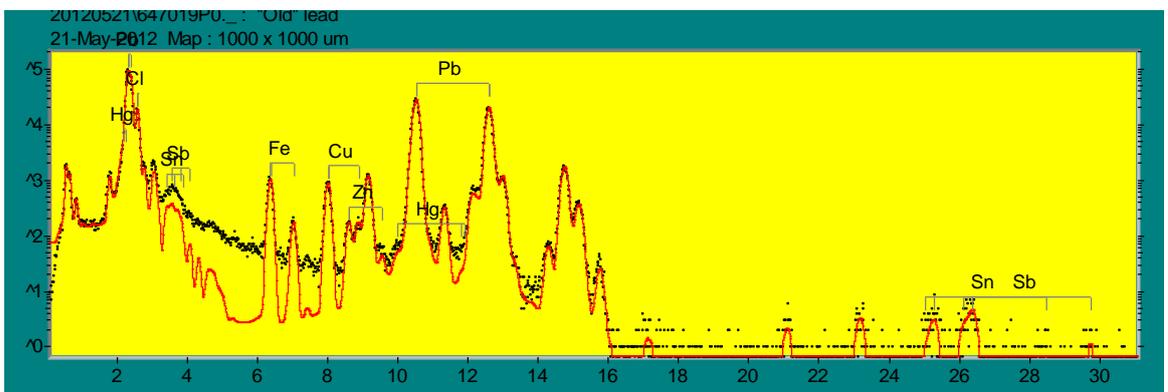
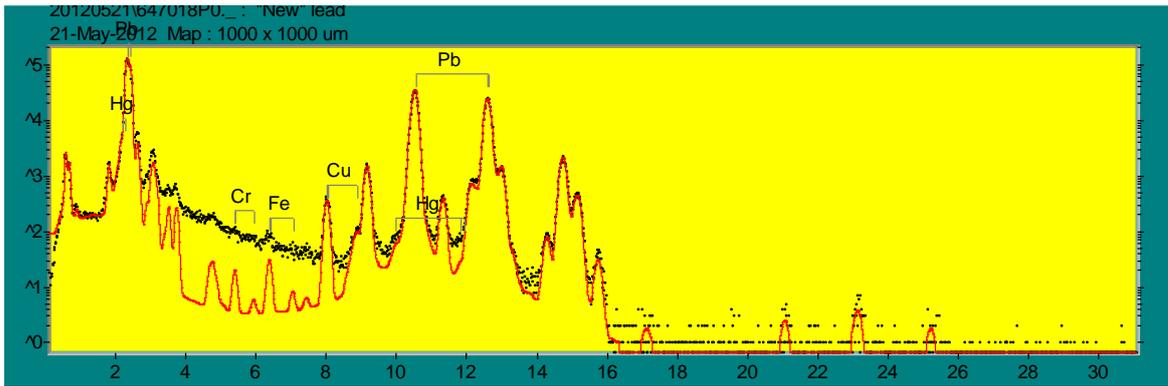
### ***Analytical Conditions***

2.530 MeV <sup>1</sup>H<sup>+</sup>, 21<sup>st</sup> May 2012. Beam current was ~500 pA, nominal beam size 2µm.

The PIXE detector was at 45° to the beam in the IBM geometry. It had a filter of 130 µm Be.

Beam incident in a near-normal direction.

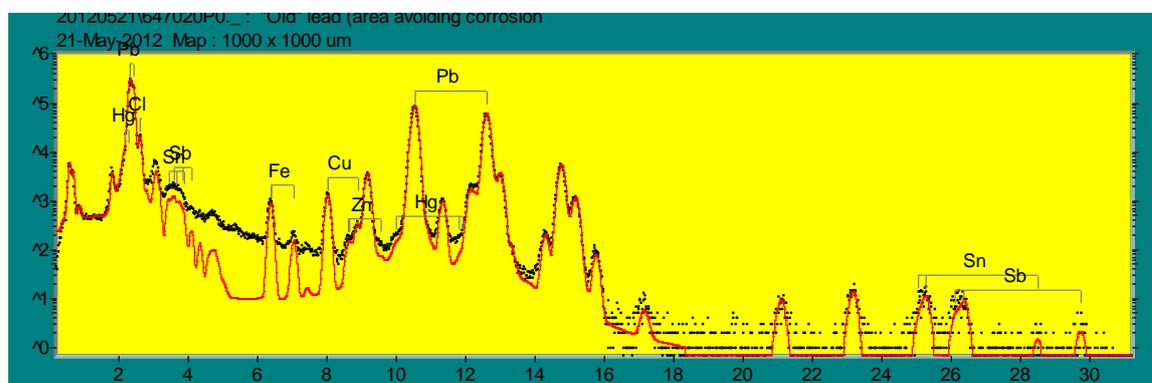
## Results

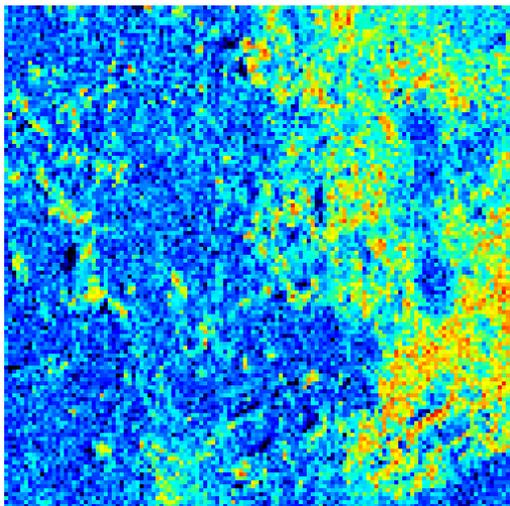


New lead

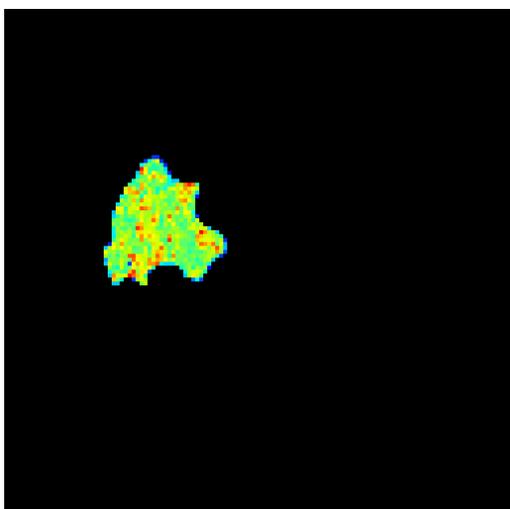
"Old" lead, full area

"Old" lead, selected area





Map of Cl signal: "Old" lead, full area



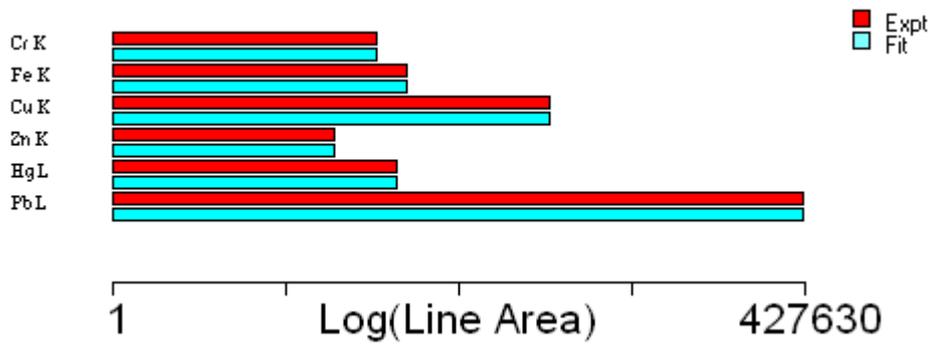
Map of Cl signal: "Old" lead, selected area

**Table 1: Quantitative composition of lead samples**

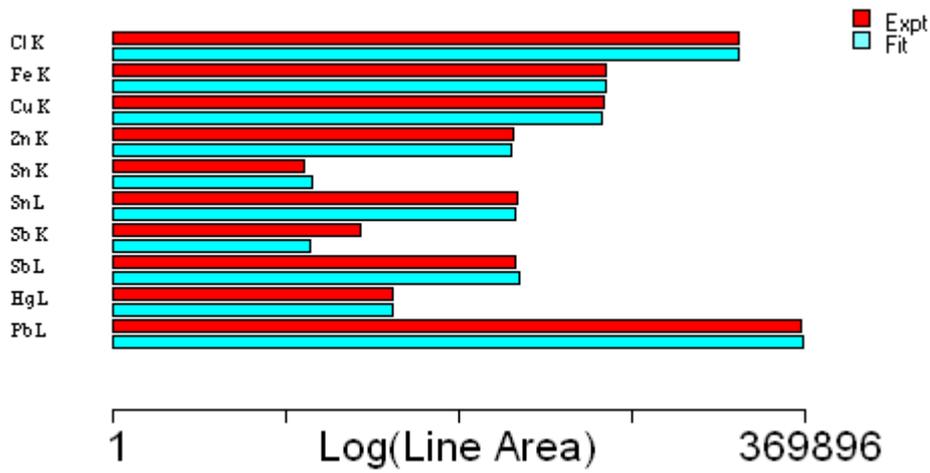
Sample	Parts per million (atomic)							
	Cr	Fe	Cu	Zn	Sn	Sb	Hg	Pb
"New" lead	212	377	6017	114	0	0	452	992830
"Old" lead	0	12695	14284	2921	3256	3760	433	962652
"Old" lead	0	5225	9726	887	4454	5899	438	973372

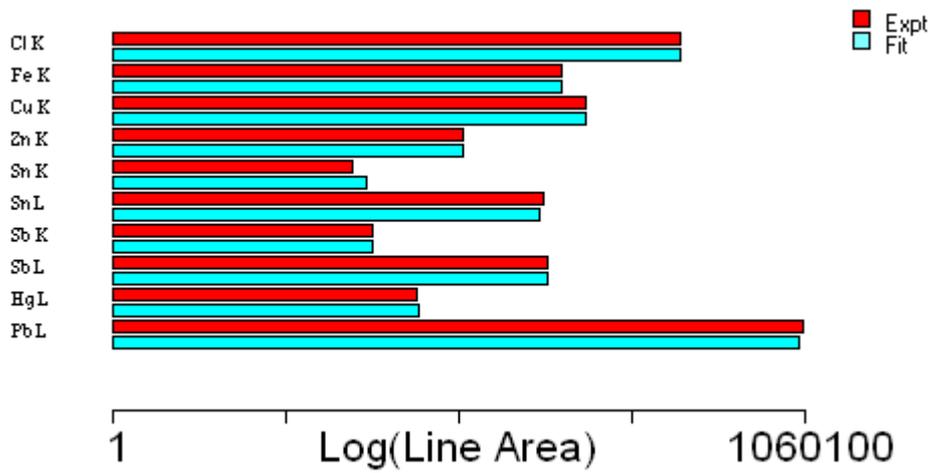
Sample	Uncertainties (ppm atomic)							
	Cr	Fe	Cu	Zn	Sn	Sb	Hg	Pb
"New" lead	87	79	144	78			131	1986
"Old" lead		178	200		326	376	121	2888
"Old" lead		89	117	63	223	295	96	1947



Sample#18: "New" lead



Sample#19: "Old" lead



Sample#20: "Old" lead

## Conclusions

The fits to the data are good, so the confidence is good.

There appears to be a fixed "Hg" signal associated with the Pb: perhaps this is an extra line excited by the proton beam?

The corrosion products on the surface of the "Old" lead sample are associated with chlorine, with enough Cl to give 42 nm equivalent thickness on average in the analysed area. Note that the quantity of Cl is very non-uniform and thus it will be much thicker in some areas.

The "Old" and "New" lead samples are quite different, with the "Old" sample having 0.1at% Zn and significant quantities of Sb and Sn. The corrosion products (chlorides) on the "Old" sample probably contain lots of transition metals (Fe, Cu, Zn) since these are reduced in the selected area. Note that the heavy metals (Sn, Sb) are *increased* in the selected area, as expected from extra absorption in the L lines (not much weight is given to the K lines which have a very high statistical uncertainty).

**Table 2: Quantitative composition of lead samples**

Sample	NaCl equiv. thickness	Parts per million (atomic)						
	nm	Fe	Cu	Zn	Sn	Sb	Hg	Pb
"New" lead	0	377	6017	114	0	0	452	992830
"Old" lead	42	12695	14284	2921	3256	3760	433	962652
"Old" lead (selected area)	25	5225	9726	887	4454	5899	438	973372

Sample	Uncertainties (ppm atomic)						
	Fe	Cu	Zn	Sn	Sb	Hg	Pb
"New" lead	79	144	78			131	1986
"Old" lead	178	200		326	376	121	2888
"Old" lead (selected area)	89	117	63	223	295	96	1947

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## **The Ion Beam Analysis Laboratory**

**Report on  $\alpha$  decay of two lead book pages**

**For Matthew Hood, Jordan Codices Group**

**G469, Job ##4405, 4475**

**23<sup>rd</sup> August 2016, C. Jeynes**

(minor revision to Figure on p.2 16<sup>th</sup> September)

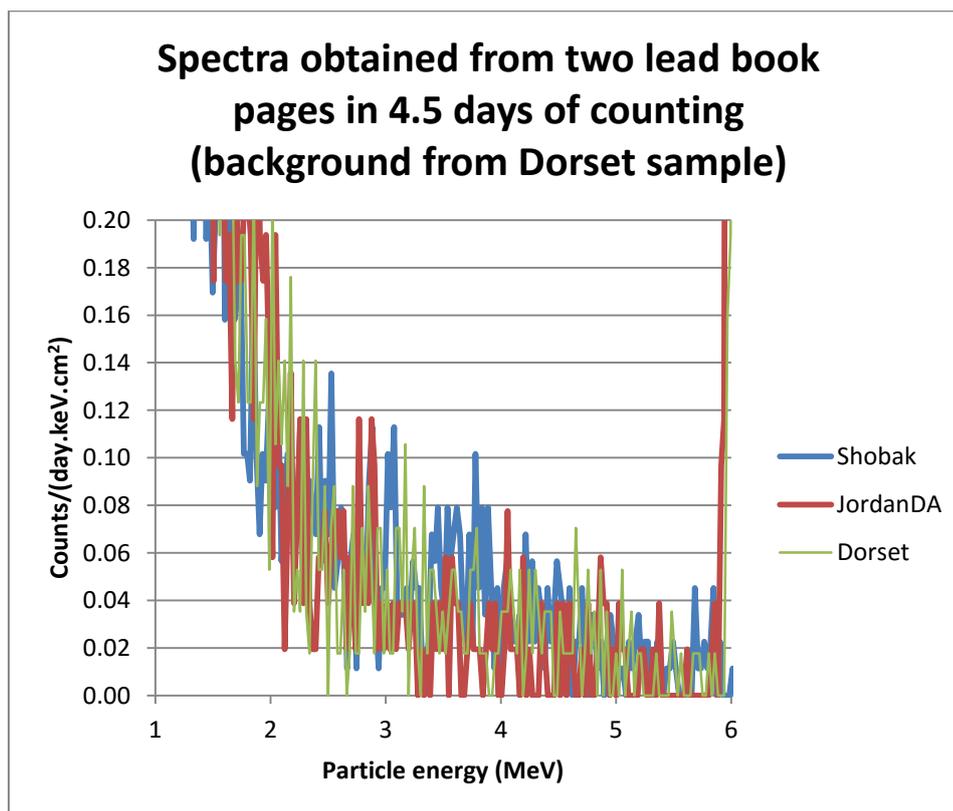
## ***Samples and Purpose of Analysis***

Weathered lead from a Roman site in Dorset obtained from Matthew Hood (see email 3<sup>rd</sup> June) which can be confidently dated (old!) is counted (#4405). Also RBS data is obtained to verify that the sample is lead to the surface. This is to verify that old lead does not count.

Two closed codices of six sheets each (#4475) were opened on 1<sup>st</sup> July with Jean-Claude Bragard, and David & Jennifer Elkington (also with Roger Webb and the photographer) present. One is known as the “Shovak” codex (see email from Matthew Hood, MH, 30<sup>th</sup> June) and the other is a codex from the Jordanian Department of Antiquities. We will call this the “JDA codex”.

The JDA codex was described by J-CB in an email to CJ of 15<sup>th</sup> June 2016, and MH subsequently (5<sup>th</sup> August) sent me a copy of an authorisation letter to “Mr & Mrs Elkington” from the Prof. Ziad al Saad of the Jordanian Department of Antiquities dated 21<sup>st</sup> April 2011.

## ***Results***

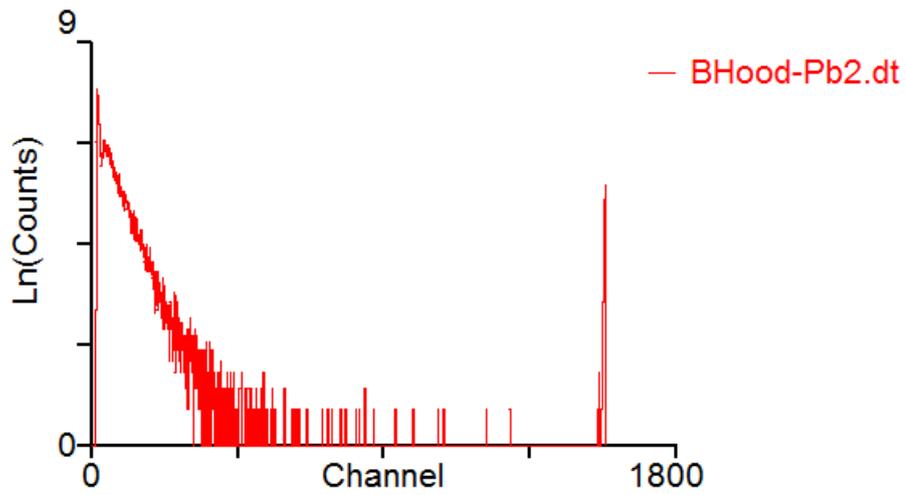


The Figure shows the normalised counts from both samples. We are looking for a signal with a high energy edge at 5.3 MeV. This appears not to be present.

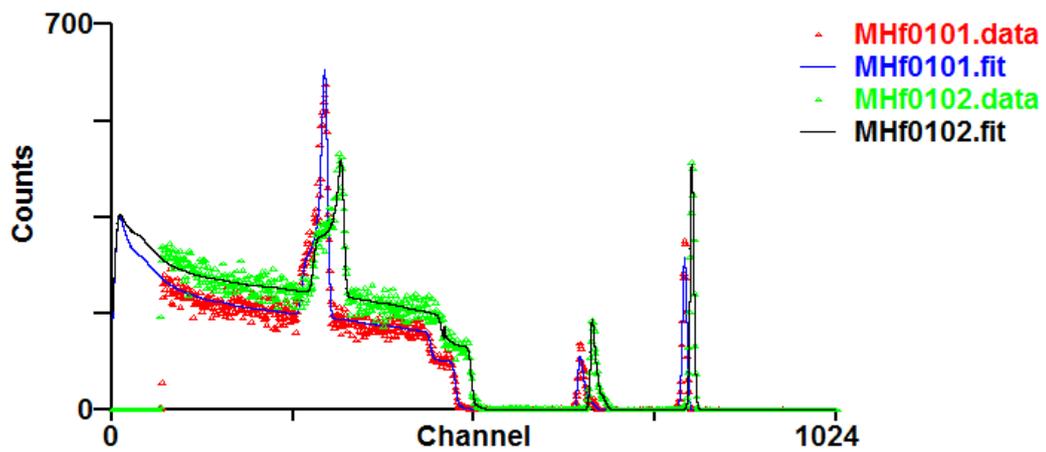
## ***Conclusions***

All samples appear to be equivalent (older than we can measure)

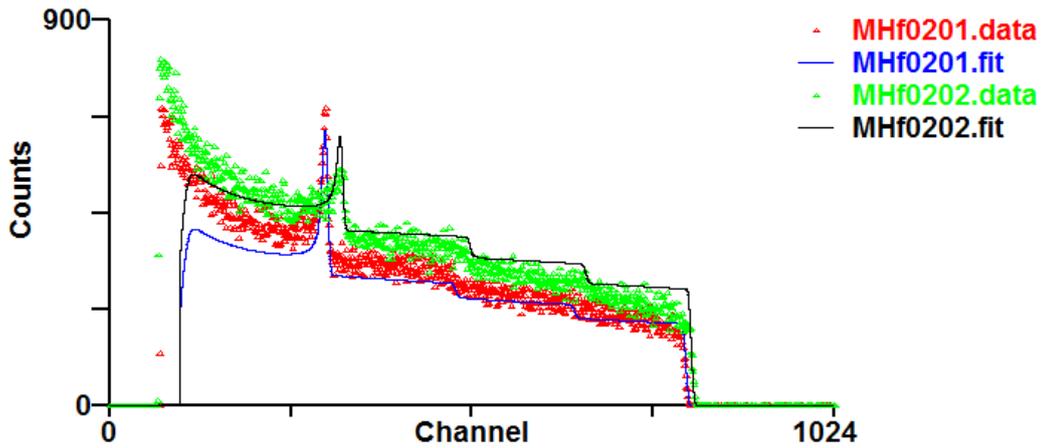
*Results (7<sup>th</sup> June)*



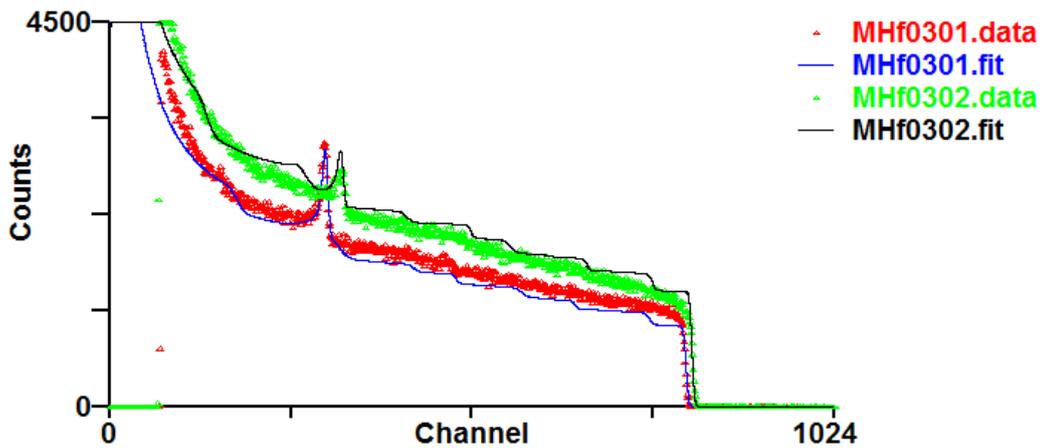
*Results (and analytical conditions) (15<sup>th</sup> June)*



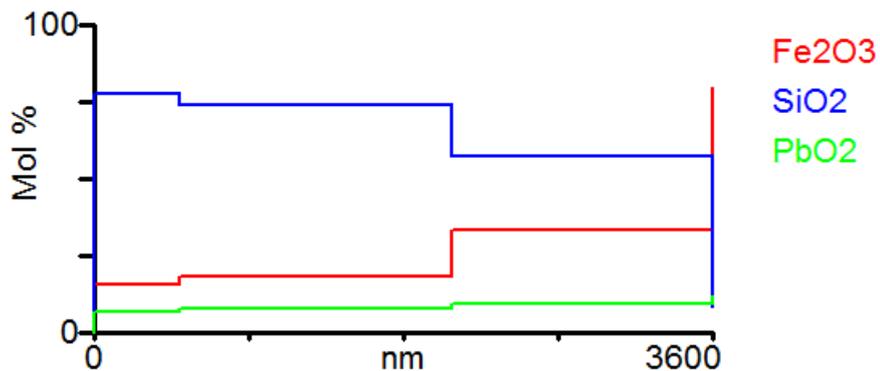
Calibration sample (Au/Ni/SiO<sub>2</sub>/Si). 3039 keV: detA, detB had gains of 3.40, 3.36 keV/channel



This is the Roman lead from Dorset with 3039 keV He. Fitted with (these numbers are only approximate!): 30at% Fe<sub>2</sub>O<sub>3</sub>, 66at% SiO<sub>2</sub>, 4% Pb. There is lead to the surface, but significantly attenuated.



As before, another area. This is similar but the thickness of the mineralised layer is different.



This is the structure used for fitting: it just gives an indication of the composition (mostly silicates, with other components).

### ***Results (1<sup>st</sup> July)***

Page 6 of the Shovak codex is placed in front of the A detector (aperture 70.9 mm<sup>2</sup>).

Page 6 of the JDA codex is placed in front of the B detector (aperture 41.8 mm<sup>2</sup>).

Detection channels A, B had gains of 3.40, 3.36 keV/channel.

We counted for 396688 secs (4.6 days). This time was obtained from the pulser signal.

The collected spectra for the Devon piece, and the Shovak and JordanDA codices were compressed to 256 channels (see spreadsheet) but not smoothed.

[Click here to view linked References](#)

### Ku wown biyuke

Ku wown biyuke  
 nikwe ukannuhwan amin madikte  
 ariknebdí inurikyene,  
 (warukma, kamuw, kayg)  
 hawata ukannuhwan umin wis amadgaya inin,  
 (uhiyakemni akak uwakemni)  
 in ka akkaka akisyavriknama akiw  
 ewka awen wownavrik.

Ku wown biyuke  
 nikwe madikte amadgaya inin,  
 (parahwokwa, warik, puwiknebdí akak ahavwi)  
 in ka kinetihwaka nimin akiw,  
 akak uhiyakemni payak akak uwegewni  
 mmanawa in kuwis menwe.

Ku wown biyuke  
 in ke wotbe pahayku lapot sabukwiyebe.  
 Nikwe hiyeg amedgenevwi inin  
 awetuvye pukuha  
 ku samah wowskawniy ay amadga inin.

Ku wown biyuke,  
 unetni adah kiyathaki akak amnihka  
 unetni adah kayahka akak batekka  
 wavan, westwa, unetni, uviryepkawni,  
 amekenegben gikehnikis  
 in ka kinetihwakati nimin akiw.

Ku wown biyuke  
 — aa, ka aynsima iwit kuwis biyuke,  
 ka aynsima iwit biyuknene akiw, kewa  
 pahak waruwbe bekbetepka aritnanyuvwi  
 nikwe wahawkrivwiy gikuvimnakis  
 tinwohawsepka adah avavyekwa  
 in ke igiskabe ku pariye wis biyukse  
 adah avavyekwa.

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### Se perdermos a nossa língua

Se perdermos a nossa língua,  
 então todo o nosso conhecimento  
 das coisas que estão acima no céu  
 (estrelas, sol e lua)  
 e das pessoas que vivem na terra (nossos  
 pensamentos e sentimentos mais profundos)  
 não será mais expressado da forma adequada  
 se perdermos a nossa língua.

Se perdermos a nossa língua,  
 então tudo no mundo  
 (mares e rios, animais e plantas)  
 nunca mais será articulado  
 com nossa sabedoria e nossas percepções  
 pois elas já teriam desaparecido.

Se perdermos a nossa língua,  
 Será como uma porta que se fechará para sempre  
 para os povos do mundo  
 que nunca entenderiam  
 como nós vivíamos aqui na terra.

Se perdermos a nossa língua,  
 nossas palavras de respeito e amor,  
 nossas expressões de dor ou felicidade,  
 nossas canções, nossas histórias, nossas preces,  
 as realizações dos nossos antepassados  
 nunca mais serão contadas.

Se perdermos a nossa língua  
 — e muitas línguas já foram perdidas  
 e muitas já estão desaparecendo,  
 como espelhos quebrados em pedacinhos —  
 as vozes dos nossos antepassados então  
 serão dessa vez silenciadas para sempre  
 e perderíamos uma grande riqueza  
 para todo o sempre.

Tradução de Simoni Valadares e Diana Green

### If our language is lost

If our language is lost  
 then all our knowledge  
 of things above  
 (stars, sun, and moon)  
 and our knowledge us humans on earth  
 (our thoughts and our deepest feelings)  
 will not be properly expressed again  
 when our language is gone.

If our language is lost  
 then everything in the world,  
 (seas and rivers, animals and plants)  
 may never again be spoken  
 with our understanding and insights  
 for these will have already vanished.

If our language is lost  
 it will be as though a door were closed  
 to the peoples of the world  
 and they will never understand  
 how we lived here on earth.

If our language is lost  
 our words of respect and love,  
 our expressions of pain or fondness  
 our songs, our stories, our prayers,  
 the accomplishments of our ancestors  
 will never be spoken of again.

If our language is lost  
 (Oh, many languages are already lost  
 and many more are almost lost,  
 like mirrors forever shattered)  
 then our ancestors' voices will be  
 silenced forever and ever  
 and a great treasure will be  
 forever lost to us.

Translated by Diana Green

## Ihcuac thalhtolli ye miqui

Ihcuac tlahtolli ye miqui  
mochi in teoyotl,  
cicitlaltin, tonatiuh ihuan metztli;  
mochi in tlacayotl,  
neyolnonotzaliztli ihuan huelicamatiliztli,  
ayocmo neci  
inon tezcapan.

Ihcuac tlahtolli ye miqui,  
mochi tlamantli in cemanahuac,  
teoatl, atoyatl,  
yolcame, cuauhtin ihuan xihuitl  
ayocmo nemililoh, ayocmo tenehualoh,  
tlachializtica ihuan caquiliztica  
ayocmo nemih.

Inhuac tlahtolli ye miqui,  
cemihcac motzacuah  
nohuan altepepan  
in tlanexillotl, in quixohuayan.  
In ye tlamahuizolo  
occetica  
in mochi mani ihuan yoli in tlalticpac.

Ihcuac tlahtolli ye miqui,  
itlazohticatlahtol,  
mehualizeltemiztli ihuan tetlazotlaliztli,  
ahzo huehneh cuicatl,  
ahnozo tlahtolli, tlatlauhtiliztli,  
amaca, in yuh ocatcah,  
hueliz occepa quintenquixtiz.

Ihcuac tlahtolli ye miqui,  
occequintin ye omiqueh  
ihuan miec huel miquizqueh.  
Tezcatl maniz puztecqui,  
netzatzililiztli icehuallo  
cemihcac necahualoh:  
totlacayo motolinia.

## Cuando muere una lengua

Cuando muere una lengua  
las cosas divinas,  
estrellas, sol y luna;  
las cosas humanas,  
pensar y sentir,  
no se reflejan ya  
en ese espejo.

Cuando muere una lengua  
todo lo que hay en el mundo,  
mares y ríos,  
animales y plantas,  
ni se piensan, ni pronuncian  
con atisbos y sonidos  
que no existen ya.

Cuando muere una lengua  
entonces se cierra  
a todos los pueblos del mundo  
una ventana, una puerta,  
un asomarse  
de modo distinto  
a cuanto es ser y vida en la tierra.

Cuando muere una lengua,  
sus palabras de amor,  
entonación de dolor y querencia,  
tal vez viejos cantos,  
relatos, discursos, plegarias,  
nadie, cual fueron,  
alcanzará a repetir.

Cuando muere una lengua,  
ya muchas han muerto  
y muchas pueden morir.  
Espejos para siempre quebrados,  
sombra de voces  
para siempre acalladas:  
la humanidad se empobrece.

## When a tongue dies

When a tongue dies  
things of heaven,  
sun moon and stars;  
the thoughts and fears  
of humanity  
are no more reflected  
in that mirror.

When a tongue dies  
all that is in the world,  
seas and rivers,  
animals and plants,  
can be neither thought nor said  
since both sight and sound  
are no more.

When a tongue dies  
then is shut  
to all the world  
a window, a door,  
a glimpse, a peek  
a different sight  
of what lives, has being on earth.

When a tongue dies,  
its words of love,  
songs of pain and longing,  
lays of old,  
old tales, speeches, prayers,  
no longer may anyone say,  
whomsoever they may be.

When a tongue dies,  
and many will have died  
and many will die.  
Mirrors forever cracked,  
the murmur of voices  
forever silenced:  
impoverishing all people

[Click here to view linked References](#)

נַעֲשֶׂה אָדָם בְּצַלְמֵנוּ כְּדְמוּתֵנוּ



[Click here to view linked References](#)*Poetics of Physics*: Hebrew poem of Table 1 (voiced)

תְּמִיד מְדַת דְּמוּתוֹ

יֵשֵׁב בְּצֶבֶא לְבוּשׁ בְּצִי

יוֹשֵׁעַ שְׁעֵי עֵצִי

יֵצֵן צְצִי צְצִי

יֵעֵן עֵצִי שְׁעֵעֵי

הַנֶּשֶׁב שְׁבַח בְּצַחִיח

הַנֶּשֶׁעַ שְׁעָה עֵצָה

הַנֶּעֵן עֵצָה שְׁעָה

הַעֵב עָבָה בְּעָה

אָעוּב עָבִי בְּעִי

תְּמִיד מְדַת הַדְּמוּת