I address the question, "*What is the relationship between causality – the explanation of events in terms of causes – and teleology – the explanation of events in terms of purposes?*"

The relationship is that of time-like vs. space-like computation. Nowadays, it seems that everyone has accepted the absolute truth of Turing's proof of the universality of sequential computations. The latter is, I will show, the computational version of causality, and therefore fundamentally also time-like.

I will further argue that Turing's view of what computation is, is too narrow, and that what is missing is the the complementary view, which I call space-like computation. I will then show that space-like computation has an inherent hierarchical structure - a spin hierarchy, actually - whose exhibited behavior is naturally, though incompletely, describable as purposive.

The mathematical framework will be the discrete geometric (Clifford) algebras $G(n,0) = G_n$ over $\mathbb{Z}_3 = \{0,1,2\} = \{0,1,-1\}$. [Thus the opposition ± 1 will replace Boolean algebra's $0,1$.] The basic elements of these algebras are

$$\{0, \pm 1, a, b, c, ..., ab, ac, ..., abc, abd, ..., ...\}$$

where G_0 is the algebra of the scalar elements $\{0,1,-1\}$; zero is understood as *Void*, and -1 is the 'opposite' of $+1$. For $n > 0$, the elements are 1-vectors $a, b, c...$; 2-vectors (planes) $ab, ac, ...$; 3-vectors (volumes) $abc, abd, ...$; etc. All of these (except 0) are roots of unity, and 1-vectors anti-commute: $xy = -yx$, this being algebra's way to express geometry's 'perpendicular'. Computationally, 1-vectors are viewed as sensors, and the 1-vector $a + b + c + ...$ is the sensory boundary inside of which the aforementioned hierarchy is erected.

These elements are all mutually perpendicular, so G_n defines its *own* n-dimensional (multi-)vector space, an inordinately felicitous property called 'being coordinate-free'. Two powerful corollaries apply: (1) Parseval's Identity - that the projection of a function f onto an orthogonal space *is* the Fourier decomposition of f ; (2) Noether's theorem - $\exists$ a conservation law *iff* $\exists$ a group[1] - though I don't use it here.

Regarding the Fourier (ie. wave-like) decomposition, this means that every expression in the algebra, eg. $a+ac+bde$, is both a coordinate specification, the Fourier decomposition of some input, and a concurrent computation consisting of the independently acting - tho interdependent - processes a, b, c, d, e, ac, bde. Algebraically, they're all rotation operators: multiplication results in 90^o rotation(s).

Thus the whole mathematical and physical apparatus, *and implications*, of conservation laws, group theory, and wave-particle duality are built-in. I will show that the overall mathematical structure of time-like plus space-like computations is, uniquely, $U(1) \times SU(2) \times SU(3) \times SO(4)$, deriving from the geometric algebras G_2, G_3, G_5, G_4 respectively. $U(1)$ is the "circle group" - rotations, waves, roots of unity.

In plain words, with this algebra we have an alternative to Boole's True/False that needs no assumptions from the outside - it is conceptually complete in itself

[1] Via the exponential (ie. Fourier) loophole for discrete groups.

- and that brings with it virtually the entire arsenal of mathematics. There is no need for automata: *the semantics of a computation will be identical to the semantics of the algebra - they are one and the same.*

Turing's Box

A computational process is a sequence of operations ()()()...() whose actual order - ie. the particular positions of the operations in the sequence - is crucial. Thus, to short-circuit order-changing algebraic manipulations, require that the individual operations $\hat{X}$=() have no inverse, ie. are irreversible. Since having no inverse implies that there is an idempotent factor, take the $\hat{X}$ to be idempotent: $\hat{X}\hat{X}=\hat{X}$; reversible stuff can be factored out without loss of generality.

Idempotents in G have the form $\hat{X} = -1 \pm X$, where $X^2 = 1$, ie. X is unitary. It turns out that the form $-1 \pm X$ corresponds to the computational synchonization primitive *signal*$(+X)$, ie. make public the fact that the unitary thing X is in public state $+1$. Correspondingly, *signal*(-X) makes public the fact that X is in the public state -1. Physicists will recognize that $\hat{X}$ is a quantum measurement operator.

$\hat{X}$ understood as *signal*(X) has the counterpart *wait*(X), ie. stop until state X occurs. Multiplying on the left, we can derive *wait*'s form from the *signal* sequence "do Y, then do X":

$$(-1+X)(-1+Y) = (-1+X)(-1+X)(-Y)(-1+Y) = (-1+X)(Y-XY)(-1+Y)$$

whence we can conclude that $Y - XY$, which squares to zero ("nilpotent"), expresses the computational synchronization operation *wait*(Y) ... then do/*signal* X. It is more than tempting to identify *signals* with fermions and *waits* with bosons. We see that bosons are the carriers of the causal connection between two events = *signals*.

The operation $-1+X$ can be variously construed to yield memory read/write [1], and *if-a-then-X-else-Y* looks like this $[1 \cdot (\pm a) = 0]$:

$$X(-1-a) \cdot (\pm a) + Y(-1+a) \cdot (\pm a)$$

If a=+1 then the Y term drops out leaving $+X$; and if a=-1 then the X term drops out, leaving $+Y$. This makes good computational sense: two independent processes X and Y, each independently and concurrently testing for its own condition, only one of which will succeed. We see that doing ***if-then-else*** necessarily invokes observation, viz. the idempotents $-1 \pm a$, consistent with thermodynamic and quantum measurement theory.

Thus the entirety of Turing's computational universe, augmented with *wait* and *signal*, turns out to be products of idempotents and nilpotents, while sums denote concurrent (outwardly-) sequential processes. Physically, this is the world of 3+1d spacetime - causal, time-like, sequential - as will become apparent.

One can therefore reasonably ask, what else does this algebra have to offer?

Gimme Space

Geometric algebra was invented/discovered by W.K. Clifford, an English mathematician of the mid-1800's. Geometric algebra combines the insights of Hamilton, who discovered anti-commutativity; and Grassmann, who invented the so-called "outer" vector product, ie. that the product of two 1-vectors can be seen as a 2-d plane, etc.

Hamilton's great discovery was a new way to describe 3d space. Until then, one could only talk about rotations of a 2d object *in* a 3d space ... but what about rotations of a *3d* object in 3d space? His discovery was that the expression $1+xy+yz+zy$ could do this, and because there are four terms, he dubbed this form a *quaternion.* We are most interested in quaternion triples, $xy+yz+zx$, who obey the following table: [2]

$\times$	$Q_i = ab$	$Q_j = ac$	$Q_k = bc$
Q_i	-1	$-bc$	ac
Q_j	bc	-1	$-ab$
Q_k	$-ac$	ab	-1

=

$\times$	Q_i	Q_j	Q_k
Q_i	-1	$-Q_k$	Q_j
Q_j	Q_k	-1	$-Q_i$
Q_k	$-Q_j$	Q_i	-1

The defining property is that $Q_i^2 = Q_j^2 = Q_k^2 = Q_iQ_jQ_k = -1$, whence it follows that the quaternion elements xy are all $i$maginary 4^{th} roots of unity, $i \cong \sqrt{-1}$. It's worth mentioning that $(xy+yz+zx)^2 = (x+y+z)^2 = 0$, ditto their sum (ie. space's fundamental character is *Void*); and that the 1-vector $P = a+b+c$ has been identified as a photon [3].

Notice also how the top element in G_3, abc, captures the two 3d representations' relationship, $abc(a+b+c) = ab+bc+ca$, as a rotation. Notice in particular that because $(abc)^2 = -1$, whence $(abc)^4 = 1$, this rotation is *reversible,* which means that both representations of 3d space are always and simultaneously valid.

The quaternions, emerging first in G_3, give us the special unitary group $SU(2)$, where the "special" just means that its rotations won't "blow up". The natural question at this point is, What happens in G_4?

The quaternion group re-appears in G_4 as triples of the form $wx+yz$. Here is their multiplication table:

$\times$	$\mathcal{T}_i = ab-cd$	$\mathcal{T}_j = ac+bd$	$\mathcal{T}_k = ad-bc$
$\mathcal{T}_i$	$1+abcd$	$-ad+bc$	$ac+bd$
$\mathcal{T}_j$	$ad-bc$	$1+abcd$	$-ab+cd$
$\mathcal{T}_k$	$-ac-bd$	$ab-cd$	$1+abcd$

=

$\times$	$\mathcal{T}_i$	$\mathcal{T}_j$	$\mathcal{T}_k$
$\mathcal{T}_i$	"-1"	-$\mathcal{T}_k$	$\mathcal{T}_j$
$\mathcal{T}_j$	$\mathcal{T}_k$	"-1"	-$\mathcal{T}_i$
$\mathcal{T}_k$	-$\mathcal{T}_j$	$\mathcal{T}_i$	"-1"

Corresponding to the quaternions in the left-most table above are the triple $\mathcal{T}_i = ab-cd$, $\mathcal{T}_j = ac+bd$, $\mathcal{T}_k = ad-bc$. Above right is the same table, but with the mapping $1+abcd \mapsto$ "-1". I have therefore dubbed these $\mathcal{T}$-creatures, a novel representation of the quaternion group, *TauQuernions.*

[2]Here and later, I use a collapsed form of group table, where the redundancies of "times +1", "times -1", and anti-commutation are suppressed.

One can easily see that the two tables to the right, quaternion and tauquernion, are isomorphic. The tauquernions, elements of $\mathcal{G}_4$, recapitulate in four spatial dimensions what the quaternions, elements of $\mathcal{G}_3$, do in three.

The basic tauquernion element $wx + yz$ does indeed rotate things just like quaternions do. So there is space-like reversibility ... but nevertheless $wx + yz$ has no inverse! It is irreversible. This means that if the tauquernions are the means of creating 3+1d spacetime, then projecting through them defines the moment that entropy enters the picture.

So we now have *two* ways to describe 3d space: *quaternion* triples and *tauquernion* triples (plus irreversibility $\rightsquigarrow$ time $\Rightarrow$ +1d). Are there more? Yes! There is one more such set, made out of triples of the form vw+xyz, dubbed *tauquinions*:

$\times$	$\tau_i = ab + cde$	$\tau_j = ac - bde$	$\tau_k = bc + ade$
τ_i	$1 - abcde$	$bc + ade$	$-ac + bde$
τ_j	$-bc - ade$	$1 - abcde$	$ab + cde$
τ_k	$ac - bde$	$-ab - cde$	$1 - abcde$

=

$\times$	τ_i	τ_j	τ_k
τ_i	"-1"	-τ_k	τ_j
τ_j	τ_k	"-1"	-τ_i
τ_k	-τ_j	τ_i	"-1"

The respective tauquinions are $\mathcal{T}_i = ab + cde$, $\mathcal{T}_j = ac - bde$, $\mathcal{T}_k = bc + ade$. Their multiplication table is above left; on the right is the same table, but with the mapping $1 - abcde \mapsto$ "-1".

Like the Q's, the $\mathcal{T}$'s anti-commute, eg. $\mathcal{T}_i\mathcal{T}_j =$ -$\mathcal{T}_j\mathcal{T}_i$; close circularly, eg. $\mathcal{T}_i\mathcal{T}_k = \mathcal{T}_j$; and -$\mathcal{T}_i\mathcal{T}_j\mathcal{T}_k = \mathcal{T}_k\mathcal{T}_j\mathcal{T}_i$, etc. Clearly, the three tables to the right, quaternion, tauquernion, tauquinion, are isomorphic.

Like the tauquernions, the tauquinions are a strange combination of space-like and time-like rotations. Note also that the 2-vector vw in each tauquinion $vw + xyz$ turns out to be one of the components of the underlying tauquernion space. Constructively speaking, G_4's tauquernions emerge before G_5's tauquinions, which latter are anchored in the former.

It is easily shown that there are no more such quaternion representations in G. Furthermore, both the tauquernions and the tauquinions are entanglement operators (!) in addition to their other properties. But onward!

Upon examination, it is noticed that (1) each tauquernion / tauquinion element squares to $-1 = 1 \pm abcd$ / $1 \pm abcde$, the hallmark of spin 1/2; and (2) there are six distinct elements in each:

$$\{ab, ac, ad, bc, bd, cd\} \mapsto \{ab - cd, ac + bd, ad - bc\} \mapsto SO(4)$$
$$\{ab + cde, ac - bde, ad + bce, -bc - ade, bd - ace, -cd - abe\} \mapsto SU(3)$$

That is, both the tauquernions and the tauquinions are representations of the group *Spin*$\{6\}$. As shown above, *Spin*$\{6\}$ can map to either $SU(3)$ - the special unitary group in 3 dimensions - or $SO(4)$, the special othogonal group in 4 dimensions. $SO(4)$ is 3+1 spacetime - the tauquernions; and $SU(3)$ - the tauquinions - is exemplified by electro-magnetism. Recall that there are no more quaternion representations in G: quaternions + tauquernions + tauquinions are all there are ... and all there needs to be, as follows.

Building the Spin Hierarchy

Notice next that one can construct things like $abcd$ from ab and cd, or from a and bcd, etc. This observation induces the following successive constructions of G_{n+} from G_{n-}:

$$a + b \xmapsto{\delta} ab \qquad\qquad a + bc \xmapsto{\delta} abc$$
$$ab + cd \xmapsto{\delta} abcd \qquad\qquad a + bcd \xmapsto{\delta} abcd$$
$$ab + cde \xmapsto{\delta} abcde \qquad\qquad a + bcde \xmapsto{\delta} abcde$$

As it turns out, this construction is identical to that achieved by defining the boundary ∂ of X relative to Q as $\partial_X Q = XQ$. That is, define the boundary of a unitary Q as that part of Q's internal structure X that is unchanged by Q's actions. That is, define the boundary of Q relative to X as an *eigen-form* of Q: $\partial_X Q = XQ = X'$. Inversely, the *co-boundary* δ of X (and X') is Q.

With all praise to our Queen, $\mathscr{M}$*athematics*, these conditions exactly satisfy those of the differentiation / integration hierarchy (!) the present boundary / co-boundary operations ∂/δ being just a topological version of the calculus of Newton, Leibnitz, et alia. There is a very particular, computationally novel, hierarchy aborning here!

Looking at the skeleton below (next page), it's clear that the two 3+1d operators, $ab + cd$ and $ab + cde$, are the whole story re 3+1d. So the argument seems to be saying "space is all there is", as follows.

Geometric algebra contains yet another fertile structure, namely the recursive (and hence hierarchical) property that its semantics cycle exactly like the powers of $i : \{++--++--\ldots\}$ as the grade of its (pseudo-)vectors I increases - see the table below. What this pattern boils down to, is that the very *semantics* of G_n cycle mod 4, whence we can collapse elements of G accordingly.

The transitions from smaller to larger G's via δ are entropically favored [2], and we show below how to construct a hierarchy of spins, which, taken mod 4, yields successively more complex levels, yet levels whose inner structure is always $U(1) \times (SU(2) \times SU(3) \times SO(4)$.

The construction of this hierarchy, let us not forget, possesses a 1-for-1 computational interpretation. This interpretation is *entropic growth of structure*, with the mod 4 transitions corresponding to phase transitions. This growth can also be interpreted as learning in an AI context.

grade	$I \in \mathcal{G}_n$	*notation*	I^2
...	...	...	...
10	...	A_{10}	-1
9	$abcdefghj$	A_9	$+1$
8	$abcdefgh$	A_8	$+1$
7	$abcdefg$	A_7	-1
6	$abcdef$	A_6	-1
5	$abcde$	A_5	$+1$
4	$abcd$	A_4	$+1$
3	abc	A_3	-1
2	ab	A_2	-1
1	a	A_1	$+1$
0	1	A_0	$+1$

This is what the mod 4 folding does:

pairs	$\delta(pair)$	*new level*		
$3\,mod\,4 + 3\,mod\,4$	$\rightsquigarrow$	6	$= 2\,mod\,4$	$\searrow$
$2\,mod\,4 + 3\,mod\,4$	$\rightsquigarrow$	5	$= 1\,mod\,4$	$\searrow$
$2\,mod\,4 + 2\,mod\,4$	$\rightsquigarrow$	4	$= 0\,mod\,4$	$\searrow$
$1\,mod\,4 + 2\,mod\,4$	$\rightsquigarrow$	3	*charge*	. $\downarrow$
$1\,mod\,4 + 1\,mod\,4$	$\rightsquigarrow$	2	*spin*	$\overset{6}{\leftarrow}$ $\downarrow$
$0\,mod\,4 + 1\,mod\,4$	$\rightsquigarrow$	1	*existence*	$\overset{4,5}{\leftarrow}$ $\downarrow$.

Said growth is the product of interaction at the outermost boundary a+b+c+... . Let us now see how such environmental interactions are translated into stable oscillations, thus permitting further hierarchical growth of inner complexity. [The column *grade g* is the grade of the m-vector created by $\delta(pair)$.]

pair	*pair*	*pair*	*grade g*	*mod* 4	i	F_i	$F_i\,mod4$
		...	...	**0**	***12***	144	**0**
		$C_2 + C_3$	50+75=125	**1**	***11***	89	**1**
		$C_2 + C_2$	50+50=100				
		$C_1 + C_2$	25+50=75	**3**	***10***	55	**3**
		$C_1 + C_1$	25+25=50	**2**	***9***	34	**2**
	$B_1 + B_4$	$\mapsto C_1$	5+20=25				
	$B_2 + B_3$	$\mapsto C_1$	10+15=25	**1**	***8***	21	**1**
	$B_2 + B_2$		10+10=20				
	$B_1 + B_2$		5+10=15	**3**	***7***	13	**1**
	$B_1 + B_1$		5+5=10	**2**	***6***	8	**0**
$A_1 + A_4$	$\mapsto B_1$		1+4=5				
$A_2 + A_3$	$\mapsto B_1$		2+3=5	**1**	***5***	5	**1**
$A_2 + A_2$			2+2=4				
$A_1 + A_2$			2+1=3	**3**	***4***	3	**3**
$A_1 + A_1$			1+1=2	**2**	***3***	2	**2**
A_1			0+1=1	**1**	***2***	1	**1**
A_1			1	**1**	***1***	1	**1**
A_0			0	**0**	***0***	0	**0**

For example, the grade of the m-vector made by $\delta(A_2 + A_3) = A_5 \mapsto B_1$ is the sum of the grades of its two constituents, namely $2 + 3 = 5$, and $5\,mod\,4 = 1$; and similarly the next octave up, $B_2 + B_3 \mapsto 10 + 15 = 25$, we get C_1, and $25\,mod\,4 = 1$. So $B_2{+}B_3 \mapsto C_1$ is just like $A_2{+}A_3 \mapsto B_1$. The last three columns are, respectively, a counter i, the corresponding element F_i of the Fibonacci series, and finally $F_i\,mod\,4$. Note that the two *mod* 4 columns correspond. [3]

[3] The ratio of successive entries in the *grade g* column approximates the golden mean φ, eg. $g_{14}/g_{13} = 525/325 = 1.6153\ldots$ *vs.* $\varphi = (1+\sqrt{5})/2 = 1.6180\ldots$, as one would expect.

Bubble Sensings Up and Trickle Intents/Goals Down

It should be noticed that the actual hierarchical structure at run-time is - ignoring the “wrap-around” at the topmost nodes, described below - a rooted acyclic lattice. That is, most nodes will have several parents, and the sensory bubble-up is roots to leaves, and the trickle-down leaves to roots. Since all nodes are combinations of the grade 1 sensors at the system boundary (the roots), the latter are the ultimate parents of all later-created child nodes. So, unlike most tree-like structures in computer science, which are drawn downwards with the root at the top, the present co-exclusion based hierarchy [2] grows from the bottom up. We refer to this lattice structure as “the hierarchy”.

The algebraic prescription of execution behavior can be taken further using a form called an inner auto-morphism:

$$AXA^{-1} = X' = A^{-1}XA$$

The examples to follow use the form $A^{-1}XA$ for expository reasons, wherein the rightmost A is treated as the current state of the node in question, to be modified by the up-bubbling sensory X by multiplication on the left. An upgraded X is bubbled further up and eventually inverted, namely via some A^{-1}, again via multiplication the left, whence $X \mapsto X'$. The evolving state X' then trickles back down, meeting leftmost A^{-1}s, each of which reduces X's grade and trickles it further down. Eventually X' will meet an effector (ie. grade 1, at the sensory boundary), therewith completing the system’s reaction to the input.

An example of an inner auto-morphism is

$$ba(a+b)ab = -a-b$$

[which is the same as

$$ab(a+b)ba = -a-b$$

because for simple m-vectors like $ab, abc, ...$, their <u>in</u>verses equal their <u>re</u>verses:

$$AA^{-1} = AA^{\dagger} = aa = abba = baab = abccba = cbaabc = abcddcba\ldots = +1$$

]

The hierarchy is built out of inner auto-morphisms $A^{-1}XA = X'$ such that $A = \delta X$ for the bubble-up, and $X = \partial A$ on the trickle-down:

$$\begin{aligned}
ba(a+b)ab &= -a-b \\
cba(a+bc)abc &= a+bc \\
dcba(ab+cd)abcd &= ab+cd \\
dcba(a+bcd)abcd &= -a-bcd \\
edcba(ab+cde)abcde &= ab+cde \\
edcba(a+bcde)abcde &= a+bcde
\end{aligned}$$

These transformations hold for all variants of the X-form, eg. $cba(b-ac)abc = b-ac$.

The first and third lines in the table suggest trying input $(a + b) + (c + d)$ on the hierarchy $abcd = \delta(ab + cd) = \delta(\delta(a + b) + \delta(c + d))$.

The first thing that happens is that the state ab will be operated upon by *new* sensory information, namely the bubble $a + b$ (whence it follows that the immediately prior state was $-a-b$). For this bubble/node collision - multiplying, as prescribed, on the left - we write $(a + b)ab$, and similarly for $c + d$.

Suppose as a preliminary example that ab is the top of the hierarchy. It will then (by default) simply turn the bubbled-up change into a *goal* to change it back, ie. maintain equilibrium by completing the oscillation. So write therefore $ba(a+b)ab$ whose result $-a-b$ becomes the two goals, $+a \to -a$ and $+b \to -b$. Equilibrium has been maintained.[4]

Now expand the example so that $abcd = \delta(ab+cd)$ is the top of the hierarchy. Then the algebra tracks what happens as follows:

1. Two new state bubbles $(x + y)$ operate on their parents xy, making new internal xy states: $(+a + b)ab + (+c + d)cd = (-a + b) + (-c + d)$; and forming the grade 2 bubble $-ab - cd$.

2. The bubble from (1), $-ab - cd$, reaches $abcd$: $(-ab - cd)abcd$.

3. Reflect from top $\Rightarrow$ bubbles become droplets: $dcba(-ab - cd))abcd = ba + dc$. [Recall that $-xy = yx$.]

4. The two droplets from (3) hit their respective xy's: $ba(-a+b)+dc(-c+d)$ & then trickle further

5. down, having now become $-a - b - c - d$, which, being on the sensory boundary, are effector commands, ie. $+a \to -a$, $+b \to -b$, $+c \to -c$, $+d \to -d$.

Thus once again the change is complemented, the oscillation completed, and equilibrium maintained.

The hierarchical execution regime we have just described is a pure space-like computation. It reacts to its environment with utter immediacy - what *can* happen is what *does* happen ... and *only* that - in an uninterrupted, purely entropic and subjectively timeless *Now*.

The computation's only "purpose" is to maintain equilibrium with its surround, all the while growing new structure based on its sensory experience. *What* the computation does, *how* it actually attains its tectonic cthonic goals[5] is purely dependent on happenstance, on the surround just happening to be in a favorable configuration, *for it cannot pursue*. Genuine *purpose* - the *conscious* pursuit of a goal - demands further structure, as described in [1].

The behavior vis a vis the environment that is generated by this bubble-up / trickle-down process is predictable when only a single 'sub-tree' of the

[4] One can also, of course, simply ignore the bubble. But given the fundamental wave-like nature of the paradigm, inverting the change seems the obvious best *default* choice. Clearly, some top-most nodes will require human approval rather than defaulting.

[5] *Cthonic* [Wikipedia]: "In analytical psychology, the term chthonic was often used to describe the spirit of nature within".

hierarchical spin-lattice is activated. But usually there will be many, and the predictability of the behavior therewith becomes more probabilistic. From a probabilistic point of view, the *external* behavior generated by the hierarchy, which is governed by, driven by, *internal*, long-term stability-based goals, can easily and naturally be construed as goal-directed, which it indeed is. But the actual goals - inherently invisible from the outside, and devoted to maintaining overall resonant stability - and can only be inferred, and that imperfectly.

Conclusions

So finally we arrive at the actual questions at hand, eg. is there an objective test for *awareness* ["intelligence" is too vague].

Elsewhere [1] I define persistent awareness as a stable self-resonant state[6] of the spin hierarchy. *Consciousness* is then defined as awareness of awareness, that is, there exist two sets of resonances, the one more global (higher up in the hierarchy (= lower frequency) than the other. The persistence and extent of the second, higher-level resonance is then a measure of consciousness.

From outside, the behavior of a persistent unitary entity can be parsed as either wave-like or time-like ... that is, coherent but locally unpredictable behavior, sometimes acausal/structural in nature, *vs.* causal, sequential but non-deterministic, particulate, time-like behavior. In the latter case, the parse yields 3+1d relativistic spacetime, in the former, a quantum mechanical melding of observer and observed.

So the conclusion to the question "*What is the relationship between causality – the explanation of events in terms of causes – and teleology – the explanation of events in terms of purposes?*" is that both are true *and equivalent* accounts of reality, to the extent that the physical universe indeed has the structure $U(1) \times SU(2) \times SU(3) \times SO(4)$, which is the Standard Model of quantum mechanics augmented with an entangling projection into 3+1d via $SO(4)$.

So [self-maintaining] *goal-oriented behavior* - as stereotyped as a crystal's or biologically complex - is *a* [logically consistent way to categorize] *physical and cosmic ~~trend~~ behavior*, partly *an accident*, leading ultimately, however, to the goal-oriented pursuit of existential self-preserving resonance, ~~*or*~~ thus becoming *an imperative.*

So *what separates systems that are intelligent from those that are not? Can we measure this separation objectively and without requiring reference to humans?* I say this is tauquernion-based interaction, cf. the Topsy Test [1], which, like Newton and Leibniz, equates gravity with the concept of love.

[6] Relative to the environment in which it it necessarily immersed.

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