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Review Article

Mutual Interplay of Information and Entropy as Quantum Field

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Introduction

We study mutual interplay of information and entropy as quantum field using an information-theoretic (Shannon entropy) complex-vector analysis to calculate, respectively, the Gibbs free energy difference and virial mass. We define conjugate hyperbolic space and entropic momentum co-ordinates to describe these spiral structures in Minkowski space-time, enabling a consistent and holographic Hamiltonian-Lagrangian system that is completely isomorphic and complementary to that of conventional kinematics. Such double spirals therefore obey a maximum-entropy path-integral variational calculus ("the principle of least exertion". These simple analytical calculations are quantitative examples of the application of the Second Law of Thermodynamics as expressed in entropy terms. They are underpinned by a comprehensive entropic action ("exertion") principle based upon Boltzmann's constant as the quantum of exertion.

Its overriding significance to us as living beings is its functioning as an entropy engine. Landauer's seminal work (following Shannon and Brillouin teaches us that information has calculable entropy and obeys physical laws, while the introduction by Jaynes of maximum entropy (MaxEnt) as the basis of the rules of thermodynamics (for example, the determination of the partition function) is now recognised as far-reaching. The associated variational approach to entropy production first described by Onsager also provides critical insights into issues of thermodynamic reciprocity and symmetry in systems far from equilibrium [1-5].

The entropic treatment of information is standard in the analysis of the efficiency of communications networks in the presence of noise, and it has become clear that information and its transfer are associated with discontinuities, implying non-adiabatic: entropy changing conditions (see the equation p. 7). Indeed, Brillouin considered information (negative entropy, or negentropy) to be anti-correlated with entropy, and Bennett showed elegantly how information erasure has an entropy cost: note that perfect information copying is excluded by the "no-cloning theorem". Applying Landauer's Principle to a computation involves the transfer of information and therefore also results in a rise in entropy. Important is the mutual, reciprocity of information and entropy. In quantum mechanics information and entropy are in one, same Field, the are not anti-correlated, but correlated MaxEnt [5-8].

We choose to define the entropy s as the Hodge-dual *h of the information since this definition can be shown to have the correct properties; note that Penrose points out that Maxwell's equations are self-dual in the orthogonal complement sense of the Hodge-dual operation, with σm = *σn = Iσn:

s=kBln(xm)Iσmm∈{1,2,3};summationconventions=kBln(xm) Iσmm∈{1,2,3};summationconvention

Thus, we amplify Brillouin's assertion of the close relation of information with entropy by treating entropy mathematically as an orthogonal complement of information.

We choose entropic structures exhibiting a transverse helical geometry, that is, s3 = h3 = 0, with a "trajectory" axis (plane waves travelling) in the γ3direction. Then, given that s and h are conjugate (that is, the orthogonal complements of each other), the entropy eigenvector can be written as

s=kB(iln(x1)Iσ1−ln(x2)Iσ2)s=kB(iln(x1)Iσ1−ln(x2)Iσ2)

and it's (conjugate) information term similarly written as

h=kB(ln(x1)σ2−iln(x2)σ1)h=kB(ln(x1)σ2−iln(x2)σ1)

Courant & Hilbert point out that the Maxwell equations are a hyperbolic version of the Cauchy-Riemann equations, and Salingaros points out that the vacuum electromagnetic (EM) field is holomorphic [5,8,9]. To form a holo-morphic info-entropy function we combine together the expressions in Eqs. for information and entropy in the same way (and for the same reason) that is done in the Riemann-Silberstein complex-vector (holomorphic) description of the EM field:

F−−=(E−−+icB−−)γ0F_=(E_+icB_)γ0

where E and B are the 1-vector electric and magnetic fields; F is a bivector (see Penrose), hence the need for γ0. The equivalent complex-vector for the bivector info-entropy case is:

f=s+Ih, f=s+Ih,

so that we have, from Eq.:

f=kBln(x1/x2)I[iσ1+σ2]f=kBln(x1/x2)I[iσ1+σ2]

Note that the argument of the logarithm is now dimensionless, as is conventional. Note also that meromorphic functions are only piecewise holomorphic, so they can transmit information.

Just as Maxwell's equations have a complementary (dual, in a strong sense) helical structure of the electric and magnetic fields, we continue to choose a similar double-helical structure to the info-entropic geometry, such that the loci of the x1 and x2 co-ordinates of the info-entropic trajectory are related to each other by a pair of coupled differential equations:

x′1=−κ0x2x′1=−κ0x2

x′2=κ0x1x′2=κ0x1

(5b)

where the coupling parameter is given by κ0 ≡ 2π/λ0 with λ0 being the helical pitch along the γ3-axis (that is, the x3 direction) and the prime indicating the differential with respect to x3 (the trajectory axis) xn′ ≡ dx_n/dx_3 as usual [10,11].

In the entropic domain the x_3 co-ordinate plays a role analogous to that normally played by time t in conventional kinematics: to amplify this point, note that x0 ≡ ct and x_3 are also commensurate conjugates in the Pauli algebra. Considering only the functional part of the complex-vector, Eq. allows us to write the 'local' geometric entropy for a double-helical structure as (Eq.):

s=kBln(x′nκ0xn)≡kBlnWn∈{1,2}; summationconventions=kBln(x′nκ0xn)≡kBlnWn∈{1,2};summationconvention

which is functionally equivalent to Boltzmann's equation for entropy; where the quantity Wn ≡ xn′/κ0 xn therefore represents the number of states available for the nth plane wave.

We now consider the case of the double helix in more detail, and in particular as exhibited by the structure. Without loss of generality, we define the locus in space l1 of the first information-bearing with its axis aligned to the $\gamma_3$direction:

l1(x3)= γ1R0cosκ0x3+γ2R0sinκ0x3l1(x3)=γ1R0cosκ0x3+γ2R0sinκ0x3

Where R0, κ0 and x3 represent respectively the radius, pitch, and axial co-ordinate of the helix. The second helix l2, with its complementary base-pairing and anti-parallel (C2 space group) symmetry contains the same entropic information content as l1, but π/2 phase-shifted and propagating in the opposite (i.e. negative) γ_3 direction:

l2(x3)=γ1R0sinκ0x3−γ2R0cosκ0x3l2(x3)=γ1R0sinκ0x3−γ2R0cosκ0x3

These expressions are mathematically equivalent to those for the electric and magnetic fields of an EM wave, with l1 and l2 being complementary. Equivalent to Eqs., we now express the complex-vector ∑ = l1 + il2 to describe a single holomorphic trajectory in Euclidean coordinates with spatial basis vectors γn (n ∈ {1, 2}):

Σ=γ1R0eiκ0x3−γ2iR0eiκ0x3Σ=γ1R0eiκ0x3−γ2iR0eiκ0x3

We therefore see in Eq. the functionals represented by x1 = R0 exp(iκ0x3) and x2 = −iR0 exp(iκ0x3), from Eq., where the phase and sign difference between x1 and x2 are typical for a pair of coupled mode equations, and which together form a holomorphic function [12].

The conjugate quantity for position q is the momentum p, so that moving towards a Lagrangian formalism, we therefore also define the "entropic momentum" pn vectors in terms of an "entropic mass" mS and the velocity qn′, where as before qn′ ≡ dqn/dx3. Note that qn′ is dimensionless, so that either qn′ or its inverse 1/qn′ can be used as a "velocity" (this ambiguity is a feature of hyperbolic velocities). It turns out that the inverse definition is more fruitful:

entropicmomentum:pn≡mS/q′nn∈{1,2} entropicmomentum:pn≡mS/q′nn∈{1,2}

where the entropic mass mS is defined as:

entropicmass:mS≡iκ0kBentropicmass:mS≡iκ0kB.

We will use Eqs. as the basis for a set of Hamiltonian and Lagrangian equations. We consider first the entropic equivalent to kinetic energy, i.e. 'kinetic entropy' (KE) TS, based upon the conventional definition of kinetic energy:

TS(q′)=−∫pdq′=−mSlnq′TS(q′)=−∫pdq′=−mSlnq′

where the additional negative sign accounts for the inverse velocity. For the three spatial directions, we therefore have:

TS=∑n−mSlnq′n=−1/2mSln(q′nq′n) summationconvention,n∈{1,2,3}TS=∑n−mSlnq′n=−1/2mSln(q′nq′n)summationconvention,n∈{1,2,3}

We also define an entropic potential field VS(q) as a function of hyperbolic position q (the 'potential entropy'). However, for the present case of a double helix, Eq. clearly represents a pair of plane waves travelling in space; which is analogous to the kinematic "free-particle" situation, such that there is therefore no associated entropic potential field, VS = 0. The entropic Hamiltonian HS(q(x3), p(x3), x3) is defined as usual as HS = TS + VS, and is also a conserved quantity in hyperbolic space [13].

Using the canonical Legendre transformation, the entropic Lagrangian is given by Eq.:

LS==q′npn−HSsummationconvention,n∈{1,2,3}3mS−HSLS=q′npn−HSsummationconvention,n∈{1,2,3}=3mS−HS such that the required canonical equations of state are obeyed: ∂LS/∂x3 = −∂HS/∂x3, as well as p′n=∂LS/∂qnp′n=∂LS/∂qn and q′n=−∂LS/∂pnq′n=−∂LS/∂pn.

Entropy

Having defined the exertion integral, Eq. we can also now see that the equivalent space-trajectory integral of the entropic Hamiltonian HS (see Eq.) yields a quantity directly proportional to the entropy:

S=∫HSdl=χ∫HS(q,p,x3)dx3S=∫HSdl=χ∫HS(q,p,x3)dx3

Whereas Eq. describes a 'local' entropy s, the integrated quantity S can be considered as the 'global' or the overall system entropy. Eq. indicates that the overall entropy S depends not only on the centroidal trajectory of the double helix axis as described by x3, but principally upon the spiralling path described by l with its radial dependency such that the entropy is a function of the full spatial extent (in all spatial dimensions) of the double helix structure. For convenience, we offset the entropic Hamiltonian HS by the constant term mS ln(κ0 R0) which is an invariant for a double helical geometry – any Hamiltonian can be offset by a fixed (constant) amount to enable more convenient manipulation – such that the entropic Hamiltonian for a double helix can therefore be given as HS = πκ0kB; that is, each KE component (n = 1, 2) of the double helix contributes ½πκ0kB. We can also exploit the Fourier (periodic) nature of Salong the double helix as characterized by the parameter iκ0 to write the Fourier differential operator as:

ddx3≡iκ0ddx3≡iκ0

Since the Lagrangian and Hamiltonian are inversely related (through the Legendre transformation) and the exertion integral X Eq. is at an extremum (Eq.), δX = 0, then the closely connected Hamiltonian trajectory integral Eq. (that is, the entropy S) must also be at an extremum, δS = 0. Given that this represents a highly stable structure we infer from the Second Law that the entropy S is at a maximum; ergo the exertion X is at a minimum and topology represents a MaxEnt (most likely) trajectory in space. In summary, the overall entropy S is given by:

S=√(1+κ20R20)πκ0LkBS=√(1+κ02R02)πκ0LkB

It is clear that the entropy S is proportional to the length L. However, in the case of a photon its proper length is actually zero relativistically, since it travels at the speed of light: L = 0, therefore S = 0.

TBH=ℏc3/8πGMBHkB=1.5×10−14KTBH=ℏc3/8πGMBHkB=1.5×10−14K

MBH is given by Gillessen et al. as 4.3 ± 0.4 million solar masses $M_\odot$, where this 10% uncertainty is entirely due to the uncertainty in the galactic position of the Sun: the measurement actually has a precision better than 2% (the mass of the Sun is known very accurately, to about 10^{-4}: $M_\odot = 1.989 \times 10^{30}$ kg). Applying this temperature to SMW to obtain the energy (given by the product of entropy and temperature expressed as a mass through $E = mc^2$) we naturally recover MBH.

All quantities clearly revert to their respective double-helical quantities when the logarithmic spiral parameter Λ = 0. We find that a logarithmic spiral is associated with an entropic potential field VS ≠ 0 causing a hyperbolic acceleration; indeed, as the entropic analogy to Newton's second law of kinematics (F = mẍ), we solve the Euler-Lagrange equations (defined in hyperbolic space qn) dpn/dx3=−mSqn′′/qn′=−∂VS/∂qn2dpn/dx3=−mSqn′′/qn′=−∂VS/∂qn2, where the final term in the equation (the entropic potential gradient) is therefore equivalent to the entropic force FS. The associated entropic acceleration is given by Γn=−qn′′/qn′2Γn=−qn′′/qn′2, the minus sign being due to the inverse velocity nature of q′. The proof that the double-armed logarithmic spiral satisfies the Euler-Lagrange equations in hyperbolic space q (that is, obeys the principle of least exertion).

In Euclidean (x) space, we find that the entropic potential field VS for the logarithmic double spiral is expressed as:

VS(x)=imSK0eiκGx31−Λx3(x1+ix2x1x2)−mSK3eΛx3R3(1−Λx3)VS(x)=imSK0eiκGx31−Λx3(x1+ix2x1x2)−mSK3eΛx3R3(1−Λx3)

It is indeed interesting to note the existence of an inverse-square law (in Euclidean space) for the γ1 and γ2 directions at the heart of this entropic potential field; the entropic force varies as

F S , n = − ∂ V S ∂ x n = − m S K 0 e i κ G x 3 x 2 n (1 − Λ x 3) n=1,2FS,n=−∂VS∂xn=−mSK0eiκGx3xn2(1−Λx3)n=1,2

that is, FS,n ∝ xn−2, with FS also being proportional to the entropic mass mSassumed located at the centre of the system and to be the cause of the entropic potential field. We emphasise, however, that although Eqs and express the entropic field in a more intuitive Euclidean form, the entropic Hamiltonian and Lagrangian equations are only correctly applied in hyperbolic space [13-15].

Quantum Entanglement Entropy plays a key role

Gauge/gravity duality posits an exact equivalence between certain conformal field theories (CFT's) with many degrees of freedom and higher dimensional theories with gravity. We try to understand how bulk spacetime geometry and gravitational dynamics emerge from a non-gravitational theory [16,17]. In recent years, there have appeared hints that quantum entanglement entropy a key role. One important development in this direction was the proposal that the entanglement entropy between spatial domain D of CFT and its complement is equal to the area of the bulk extremal surface. Using this showed the emergence of linearized gravity from entanglement physics of the CFT, we continue this program. Moreover, we show that bulk stress-energy density in this region can be reconstructed point-by-point from entanglement on the boundary [18].

Relative entropy is a measure of distinguishability between two quantum state in the Hilbert space. The relative entropy of two density matrices and is defined as

S(/)=tr(log)-tr(log).

When and are reduced density matrices on a spatial domain D for two states of a quantum field theory (QFT), which is the case which implies that S(/) increases with the size of D.

Defining the modular Hamiltonial of implicitly through =

It is easy to see that above is equivalent to

S(/)= , where is the change in the expectation value of the operator and is the change in entanglement entropy across D as one goes between the states [19-21].

In general, the modular Hamiltonian associated to a given density matrix is nonlocal. There are a few simple cases where it is explicitly known. When is the reduced density matrix of the vacuum state of a CFT on a disk of radius R which (without loss of generality) we take to be centered at $X_0 = 0$,

where is the energy density of the CFT [22].

The Interface between quantum gravity and information science

1. Theory of quantum gravitation

- Lee Smolin showed an intriguing link between general ideas in quantum gravity

and the fundamental non-locality of quantum physics,

-We must replace the non-local behavior of quantum mechanics with the non-local behavior of quantum gravity [22].

2. Quantum entanglement entropy

- Ooguri and Marcolli's work shows that this quantum entanglement generates the extra dimensions of the gravitational theory,

- entangled particles have also complementary properties,

- entangled quantum particles cannot be seen individually, they form a single quantum object-field, even if they are located far apart,

- If two particles are entangled they have complementary wavefunction properties and measuring one places meaningful constraints on the properties of the other.

3. Quantum information

-- The interface between quantum gravity and information science is becoming increasingly important for both fields [21,22].

- Based on Lee Smolin's calling for continuing in Einstein's Unfinished Revolution, I propose the ultimate quest to supersede our two current (Mutually Corelated) descriptions of reality: General Relativity and Quantum Gravity.

- General Relativity and Quantum Gravity including Quantum Entanglement

- Entropy means that The Twofaced New Main Law of Nature may lead to a New

Scientific Revolution.

Conclusion: Quantum Field Contains Information and Entropy

It is a fundamental fact, that everything we do creates a corresponding energy that comes back to us in some form or another. From a scientific perspective it is not known enough that the energy you expend taking some action comes back to you or someone else. This means that every action become more or less entangled and produces further complications because of mutual interplay between information and entropy cooperation at quantum level. In other words, this quantum entanglement entropy (QEE) is the key to the human activities. Our above mathematical formula of changes in QEE is the essence how the Universe works. The QEE is a Karma of the Universe. Universe doesn't immediately respond to your actions with good Karma. It can take time before Universe repays your intentional actions with more actions that help you progress toward your goal. The Universe requires energy to be expended. You might find yourself generating days, if not weeks or months, of output before you can see the effects of your efforts. Sometimes, the efforts come in trickle, and other times, they can come in deluge. The trick is to keep your focus on generating actions that help also others in the direction you seek to go yourself. This is only the tip of the iceberg of the metaphysical dynamics of the Universe directed by the QEE. The more you put forth energies without expectation of personal gain, the more you'll be surprised at how the Universe will open the door to the goal you seek to attain. Make no mistake, nothing takes the place of commited All-in action every day. Never, Ever, Give Up on your dreams and soon you'll discover that Universe will not give up on you.

It has been shown that information and "entropy" – a measure of the disorder of a system – are linked together to "info-entropy" in a way exactly analogous to electric and magnetic fields ("electromagnetism"). Electric currents produce magnetic fields, while changing magnetic fields produce electric currents. Information and entropy influence each other in the same way.

Entropy is a fundamental concept in physics. For example, because entropy can never decrease (disorder always increases) you can turn an egg into scrambled eggs but not the other way around. If you move information around you must also increase entropy – a phone call has an entropy cost.

Light wave with electric (E) and magnetic (B) fields.

It has been showed that entropy and information can be treated as a field and that they are related to geometry. Think of the two strands of the DNA double helix winding around each other. Light waves have the same structure, where the two strands are the electric and magnetic fields. We showed mathematically that the relationship between information and entropy can be visualised using just the same geometry.

If we want to see if our theory could predict things in the real world, and decided to try and calculate how much energy you'd need to convert one form to another form of information and entropy as one quantum field. For example, the proton's structure can be modeled along with its attendant fields, showing how even though it's made out of point-like quarks and gluons, which has a finite, substantial size arising from the interplay of the quantum forces and fields inside it. In the quantum mechanics, the principle of locality is violated all the time. Locality may be nothing but a persistent illusion. Quantum gravity tries to combine Einstein's general theory of relativity with quantum mechanics. We typically view objects that are close to one another as capable of exerting forces on one another, but that might be an illusion. For example, Schrödinger's cat: the cat will be either alive or dead, depending on whether a radioactive particle decayded or not. If the cat were a true quantum system, the cat would be neither alive nor dead, but in a superposition of both states until observed. There are many properties that a particle can have – such as its spin or polarization – that are fundamentally indeterminate until you make a measurement. Prior to observing particle, or interacting with it in such a way that ti's forced to be in either one state or the other, it's actually in a superposition of all possibble outcomes. You can also take two quantum particles and entangle them, so that these very same quantum properties are linked between the two entangled particles. Whenever you interact with one member of the entangled pair you not only gain information about which particular state it's in, but also information about its entangled partner, including entropy.

By creating two entangled photons from pre-existing system and separating them by great distances, we can teleport information about the stateof one by measuring other, even from extraordinary different locations, including entropy. You'll find the member you measure in a particular state and instantly know some information also about the other entangled member, including entropy. Even though no information was transmitted faster than the speed of light, the measurement describes a troubling truth about quantum physics: it is fundamentally a non-local theory.

Measuring the state of your particle doesn't tell us the exact state of its entangled pair, just probabilistic information about its partner. You can only use this non-locality to predict a statistical average of entangled particle properties. If two particles are entangled, they have complementary wavefunction properties and measuring one places meaningful constraints on the properties of the other. There is an intriguing link between general ideas in quantum gravity and the fundamental non-locality of quantum physics. It means two current mutually compatible, two-faced descriptions of reality: General Relativity and Quantum Mechanics. Important is the mutual reciprocity of information and entropy. In quantum mechanics information and entropy are in one, same Field, the are not anti-correlated, but correlated MaxEnt [21,22]. Entropy can never decreases, disorder always increases. If you move information around you must also increase entropy. The energy is simply product of entropy and temperature. It's because info-entropy fields give rise to forces like other fields. Our World is choreographed by an entropic forces to maximise entropy.

Knowledge of recent neuorobiology is proving our thesis that Charles Darwin was wrong when formulated his theorem „Survival of the fittest". It was the biggest false myth of the modern Western Science. As we have demonstrated in our above study, the careerist is psychopat and not „the fittest". From this reason we must to correct Charles Darwin to „Survival of the careerist". Reality in 21 century is showing that Survival of the careerist based on the Quantum Entanglement Entropy (QEE) is more valid Law of Social Dynamics in our days because it is under the Universe's Law of Maximising Entropy. Careeristic Competition is the main cause of the QEE leading to icreased complications through Coincidenses of Social Dynamics.

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