An extended Special relativity (eSR) containing a set of universal equivalence principles and predicting a quantized spacetime

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Abstract

This paper proposes an extended Special relativity (**eSR**) containing a set of universal equivalence principles (**UEPs**), offering an alternative interpretation of the universal physical constants and predicting a "digital"/quantized spacetime, together with the possible existence of superluminal gravitons and a set of maximum speeds (in perfect vacuum) for each type of elementary particle.

Keywords: extended Special relativity (**eSR**), universal equivalence principles (**UEPs**); universal physical constants; "digital"/quantized spacetime; superluminal gravitons; set of maximum speeds (in perfect vacuum)

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I. An extended Special relativity (eSR) containing a set of universal equivalence principles (UEPS) and predicting a quantized spacetime

This paper proposes an extended Special relativity (**eSR**) based on Einstein's Special relativity (**SR**) and containing an additional set of universal equivalence principles (**UEPs**) based on the constancy of the values of some universal physical parameters like the speed of light in vacuum (**c**), the Planck constant (**h**), the universal gravitational constant (**G**) and Coulomb's constant (**k$_e$**).

eSR incorporates SR (on which is based), so that:

1. **1st statement of eSR**. The laws of physics are invariant/ identical in all inertial frames of reference.
2. **2nd statement of eSR**. The speed of light in vacuum (**c**) has the same value for all observers, regardless of the light source motion.

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3rd statement of eSR. The electromagnetic charge (**q**) is the same for all observers, regardless of the motion of the electromagnetic charge; its constancy is generically noted, such as:

$$\boxed{q \equiv 1} \quad \textbf{(Eq.1)}$$

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eSR also contains the following universal equivalence principles (which are additional eSR co-statements).

The time-distance equivalence principle (UEP[c]) (based on the 2nd statement of eSR). As c is a universal physical constant, its constancy (generically noted $\boxed{c \equiv 1}$) can be considered a UEP (and noted as **UEP[c])** between the distance (**d**) and time (**t**) so that:

$$\boxed{(c = d/t) \equiv 1} \overset{UEP[c]}{\Leftrightarrow} \boxed{d \equiv t} \quad \textbf{(Eq.2)}$$

Note. UEP[c] is essentially a time-distance equivalence principle, so that 3D space with an assigned (additional) time dimension can be modeled as a 4D spacetime defined as a 4D phase space in which time may be treated as an abstract 4th spatial dimension: that is how Einstein's General Relativity (EGR) also treats this 4D spacetime, defined as a 4D Minkowski space to be more specifically (also based on SR).

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4th statement of eSR. The Planck constant (**h**) is the same for all observers, regardless of the photons source motion.

The energy (E)-mass (M) equivalence principle (UEP[h]). The constancy of h (measured in energy*time units and generically noted $\boxed{h \equiv 1}$) is considered a UEP (and noted as **UEP[h]**) so that:

$$\boxed{(h = E \cdot t) \equiv 1} \overset{UEP[h]}{\Leftrightarrow} \boxed{M \frac{d^2}{t^2} t \equiv 1}$$

$$\underset{UEP[c]}{\overset{UEP[h]}{\Rightarrow}} \boxed{(E \equiv M) \equiv \frac{1}{d} \equiv \frac{1}{t}} \quad \textbf{(Eq.3)}$$

Note (1). The UEP[c]&UEP[h] combination offers a new insight on mass and energy which can both be regarded as generic "frequencies" (1/t) or "linear densities" (1/d) of non-stationary/stationary physical waves (including electromagnetic waves) oscillations.

Note (2). The UEP[c]&UEP[h] combination also offers a qualitative variant of Einstein's energy-mass equivalence principle (**EMEP**), "retrodicting" EMEP based on the quantum nature of light.

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5th statement of eSR. The (universal) gravitational constant (G) is the same for all observers (at least at macroscopic level), regardless of the gravitational field source motion.

UEP[G] predicting an "elementary" distance (d) and time(t). The constancy of G (measured in energy*distance/mass^2 units and generically noted $G \equiv 1$) is considered a UEP (and noted as **UEP[G]**) so that:

$$\left(G = \frac{E \cdot d}{M^2}\right) \equiv 1 \underset{UEP[h]\ UEP[c]}{\overset{UEP[G]}{\Rightarrow}} d \equiv t \equiv 1 \quad \textbf{(Eq.4)}$$

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PREDICTION SET NO. 1 OF eSR (c, h and G as indirect measures of both an elementary distance and time and not vice versa; a "digital"/quantized space; a new generic definition for quantum elementary particles [EPs]; a quantized time; a new definition for the speed of light in vacuum).

eSR interprets Eq.4 in the sense that there exists both:

(**1**) a predicted finite and non-infinitesimal constant elementary distance $d_e > 0m$ $(d_e \equiv 1)$ and

(**2**) a predicted finite and non-infinitesimal constant elementary time interval $t_e > 0s$ $(t_e \equiv 1)$,

SO THAT eSR interprets c, h and G as an indirect (derived) measures of both d_e and t_e (and not vice versa!).

The values of c, h and G are necessary and sufficient to inversely deduct/estimate (by using dimensional analysis, as Max Planck did in 1899, when he estimated the set of Planck "natural units") $d_e = \sqrt{hG/c^3}$ (approximately equal to Planck length $l_{Pl} = \sqrt{\hbar G/c^3}$, with $\hbar = h/(2\pi)$) and $t_e = \sqrt{hG/c^5}$ (approximately equal to Planck time $t_{Pl} = \sqrt{\hbar G/c^5}$), with the reserve that G may have much larger values at microscopic (including subatomic) scales, which implies larger values for d_e and t_e.

Furthermore, eSR proposes (and predicts!) a "digital"/quantized 3D space composed of spherical space voxels (**SVs**), each SV possessing an "intrinsic" energy and quantum (angular) momentum.

Each SV is also stated (and predicted) to have a generic (and finite) set of distinct (quantum angular) momentum (**H**) "excitation" levels (**L**): **L(0)** (corresponding to SV intrinsic momentum **H(0)**), **L(1)** (corresponding to SV intrinsic momentum **H(1)**), …**L(n)** (corresponding to SV intrinsic momentum **H(n)**, with n being a finite positive integer); all SVs are stated (and predicted) to share this set of allowed fixed momentum levels.

Notation. For simplicity, a SV found in its excitation level L(n) will be generically named a **SV(n)**; a transition of a SV from L(x) to L(y) (with x and y being positive integers) will be named an SV(x)-(y) transition. SV(0) is defined the "ground"/"zero" momentum level of a SV, with H(0)=0.

Definition. A local "perfect vacuum" is defined as a group of an arbitrary (finite and >0) number of adjacent SVs(0).

Prediction. Each type "x" of known/unknown EP is also predicted to be a specific distinct SV(x). For example, a photon is a SV(x), a gluon is a SV(y) with x and y being distinct integers (and H(x) distinct from H(y)).

If we note with $\mathbf{i_{ph}}$ the index of the SV excitation (momentum) level corresponding to the photon (**ph**), then:

$$H(i_{ph}) = h \quad \textbf{(Eq.5)}$$

Prediction. To "produce"/"generate" a photon at the first place in the perfect vacuum ("ex nihilo", "from nothing"), one should "inject" a chosen/arbitrary SV1(0) (a SV found its excitation level L(0)) with a specific energy E over a specific time interval t so that $E \cdot t = \left[H(i_{ph}) = h\right]$: that (initially) "injected" SV1(0) would then turn into a SV1(i_{ph}) with $H(i_{ph}) = h$; the time interval needed for this SV1(0)-(i_{ph}) transition is noted $t_{ph(1)}$; this newly produced SV1(i_{ph}) is stated to be unstable and reverse/dezexcite back again to its zero state, while integrally transferring its quantum (angular) momentum (**h**) to an adjacent SV2(0) and inducing it a SV2(0)-(i_{ph}) transition (and the process may continue indefinitely); the SV1(i_{ph})-(0) transition/dezexcitation time is noted $t_{ph(2)}$ and is stated to be exactly equal to $t_{ph(1)}$; the total SV1(0)-(i_{ph})-(0) transition (excitation/dezexcitation) time is noted and defined as:

$$t_{ph} = t_{ph(1)} + t_{ph(2)} = 2t_{ph(1)} = 2t_{ph(2)} \quad \textbf{(Eq.6)}$$

Definition. The motion of a photon is thus defined as a successive (angular) momentum quanta (**h**) transfer between an arbitrary number of adjacent distinct SVs(0).

Definition. The fixed diameter of a SV(0) is defined as $\boxed{d_0 = (d_e \cong l_{Pl})}$.

6th statement of eSR. d_0 is the same for all observers, regardless of the photons source motion.

7th statement of eSR. t_{ph} is the same for all observers, regardless of the photons source motion.

Definition. When moving in perfect vacuum, a photon actually moves from a generic SV1(0) to another adjacent SV2(0) crossing a d_0 distance (quanta) in a t_{ph} time (quanta) (a full SV1(0)-(i_{ph})-(0) transition cycle duration) at each step, so that the speed of light in (perfect) vacuum (**c**) is redefined, such as:

$$\boxed{c = d_0 / t_{ph}} \quad \textbf{(Eq.7)}$$

Important note. The 6th and 7th statements of eSR actually explain the 2nd statement of eSR, because invariant d_0 and t_{ph} imply an invariant $c\left(= d_0 / t_{ph}\right)$ for all observers.

A new interpretation for the Planck time. It is also important to note that, because $\boxed{d_0 \cong l_{Pl}}$ and $\boxed{c = l_{Pl} / t_{Pl}}$, it results that $\boxed{l_{Pl} \cong t_{ph}}$: in other words, l_{Pl} is predicted to measure the duration of a full SV(0)-(i_{ph})-(0) (excitation/dezexcitation) transition of each SV in the case of the photon propagation from one SV1(0) to another adjacent SV2(0).

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PREDICTION SET NO. 2 OF eSR (a new definition of quantum angular momentum; a set of maximum speeds in perfect vacuum associated with each EP in part). Furthermore, eSR defines (and predicts!) any specific intrinsic (quantum angular) momentum H(i) of a SV(i) to be the product between a specific rest energy of that SV(i) (E_i) and the mean lifetime of that SV(i) (t_i) (defined as the linear time interval between its "birth" and its transition moment to other SV(j), with $j \neq i$ and $i, j \in [0, n]$), such as:

$$\boxed{H(i) = E_i \cdot t_i} \quad \textbf{(Eq.8a)}$$

For example, let us consider the case of a theoretical (very small but) non-zero rest (**r**) energy $\left(E_{ph(r)} > 0\right)$ decaying (and almost "still") photon with a full oscillation duration equal to its mean lifetime (lt) $\left(t_{ph(lt)}\right)$, so that $\boxed{E_{ph(r)} \cdot t_{ph(lt)} = h}$: because this very low energy decaying photon is the lowest energetic state of a possible photon, $E_{ph(r)}$ can be considered the non–zero rest energy of this almost "still" photon.

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The photon. Based on the previous definition (Eq.8a), eSR predicts that the photon may actually have a very small but non-zero rest energy $E_{i(ph)} (> 0J)$ and a very long mean lifetime $t_{i(ph)} (>> 0s)$ so that:

$$\boxed{H(i_{ph}) = E_{i(ph)} \cdot t_{i(ph)} = h} \quad \textbf{(Eq.8b)}$$

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The W and Z bosons. Based on the same previous definition (Eq.8a), eSR predicts a quantum angular momentum for SV(i_W) identified with the W bosons (with rest energy $E_W \cong 80GeV$ and mean lifetime $t_W \cong 10^{-25} s$) estimated as $\boxed{H(i_W) = E_W \cdot t_W \cong 6h}$; eSR also predicts a quantum angular momentum for SV(i_Z) identified with the Z boson (with rest energy $E_Z \cong 91GeV$ and mean lifetime $t_Z \cong 10^{-25} s$), estimated as $\boxed{H(i_Z) = E_Z \cdot t_Z \cong 7h}$; W and Z bosons may thus be considered "heavy photons", as they are identified with SV(i_W) and SV(i_Z), which have $H(i_W)$ and $H(i_Z)$ values with approx. one order of magnitude higher than $H(i_{ph})$ of SV(i_{ph}).

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The gluon. Because the gluon mediates the strong nuclear field (**SNF**), which is ~100 times stronger than the electroweak field (**EWF**) (mediated by the photon and W&Z bosons), eSR predicts that the gluon is actually a SV(i_{gl}), with $i_{gl} > i_{ph}$, $i_{gl} \in [0, n]$ and

$$\boxed{\left[H(i_{gl}) \cong 10^2 h\right] > H(i_Z) > H(i_W) > H(i_{ph}) > 0Js};$$

$H(i_{gl})$ is thus estimated with approx. one order of magnitude higher than $h_Z \cong h_W \cong 10^1 h$; eSR also predicts a gluon with a very small (but non-zero!) rest energy $E_{i(gl)}(>0J)$ and a very long mean lifetime $t_{i(gl)}(>>0s)$, so that:

$$\boxed{E_{i(gl)} \cdot t_{i(gl)} = \left[H(i_{gl}) \cong 10^2 h\right]} \quad \textbf{(Eq.8c)}$$

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The Higgs boson. Based on the same previous definition (Eq.8a), eSR predicts a quantum angular momentum for SV(i_H) identified with the Higgs (H) bosons (with rest energy $E_H \cong 125 GeV$ and predicted mean lifetime $t_H \cong 10^{-22} s$) estimated as $\boxed{H(i_H) = E_H \cdot t_H \cong 5 \cdot 10^3 h}$; $H(i_H)$ is thus estimated with approx. one order of magnitude higher than $H(i_{gl}) \cong 10^2 h$.

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The hypothetical graviton. Because the hypothetical graviton may mediate the gravitational field (**GF**), which is much weaker (with ~40 orders of magnitude) than EWF, eSR predicts that the graviton is actually a SV(i_{gr}), with $i_{gr} < i_{ph}$, $i_{gr} \in [0,n]$ and even identifies SV(i_{gr}) with SV(1) (the closest to the ground state SV(0)), so that $\boxed{i_{gr} = 1}$ and:

$$\boxed{\left[H(i_{gr}) << h\right] = H(1) \cong 10^{-40} h > 0Js} \quad \textbf{(Eq.8d)}$$

eSR also predicts a graviton with a very small (but non-zero!) rest energy $E_{i(gr)}(>0J)$ and a very long mean lifetime $t_{i(gr)}(>>0s)$, so that:

$$\boxed{E_{i(gr)} \cdot t_{i(gr)} = \left[H(i_{gr}) \cong 10^{-40} h > 0Js\right]} \quad \textbf{(Eq.8e)}$$

The known bosons (plus the hypothetical graviton) can be indexed from 1 to 6, in the ascending order of their H(i) value as shown in the next table.

Table I-1. The set of known bosons (plus the hypothetical graviton) corresponding to distinct SV excitation levels L(i) (or SV(i)), in ascending order of their H(i) magnitude

SV index (i) (positive integer)	~H(i) (the quantum momentum of SV(i))	Correspondent elementary particle (EP) of that SV(i) with H(i) momentum
0	0	**perfect vacuum**
1	$10^{-40} h$	**hypothetical graviton**
H(i) magnitude gap		
2	h	**photon**
3	$6h$	$W^{+/-}$ **boson**
4(a)	$7h$	Z **boson**
5	$10^2 h$	**gluon**
6	$5 \cdot 10^3 h$	**Higgs boson**

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The fermionic SV(i). In opposition to bosons (which are identified with the low index SVs(i) and low H(i)), the fermions are identified by eSR with the higher index SVs(i), with H(i) estimated using the same formula: $\boxed{H(i) = E_i \cdot t_i}$ (with E_i being the rest energy of a specific fermion and t_i being its estimated/predicted mean lifetime); **see the next table**.

Table I-2. The set of known fermions corresponding to distinct SV excitation levels L(i) (or SV(i)), in ascending order of their H(i) magnitude (which magnitudes are generally much higher than H(i) values for bosonic SVs(i))

SV index (i) (positive integer)	~H(i) (the quantum momentum of SV(i))	Correspondent elementary particle (EP) of that SV(i) with H(i) momentum
4(b)	$21h$	**top quark**
7	$10^{11} h$	**tauon**
8	$3 \cdot 10^{11} h$	**charm quark**
9	$10^{12} h$	**bottom quark**
10	$3 \cdot 10^{14} h$	**strange quark**
11	$6 \cdot 10^{16} h$	**muon**
H(i) magnitude gap		
12(?)	$10^{51} h\,(\text{min})$	**neutrino**
13(?)	$10^{56} h\,(\text{min})$	**electron**

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Prediction. eSR predicts an exponential distribution of H(i) magnitudes. However, when graphed on the same (logarithmic) plot, the H(i) series of both bosonic and fermionic SVs(i) shows some "gaps" (appearing as "interruptions" in the linearity of the graph) which may indicate "missing" EPs to be discovered in the future. **Implication**. If bosons with H(i)<h (identified with SVs($i<i_{ph}$) will ever be proven to exist, then Heisenberg's uncertainty principle (**HUP**) can be generalized for any h_i=H(i).

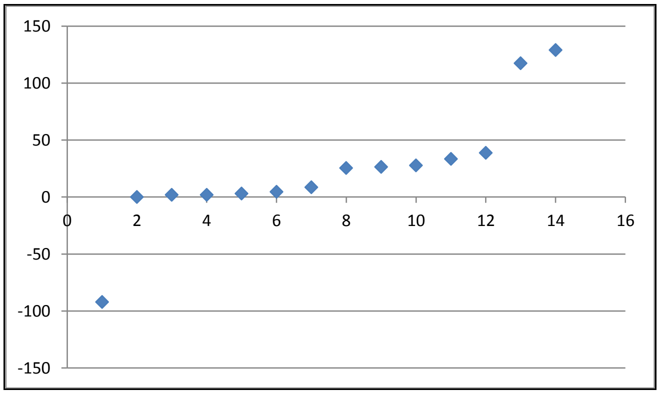

Figure I-1. The graph of the function $\boxed{f(i)=\ln\left(H(i)/h\right)}$ $\left(i\in[1,14]\right)$ for bosonic and fermionic L(i) (SV excitation levels), arranged in ascending order of H(i) magnitudes.

Note. In the past, the author has also considered a digital vacuum composed of space voxels with an exponential set of quantized energetic states. [**1**,**2**]

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Prediction. eSR also predicts than each full SV(0)-(i)-(0) (excitation/dezexcitation) transition has a specific/distinct time interval $\boxed{t(0,i)}$ for any distinct index i (invariant for all observers, in all inertial reference frames), so that $\boxed{\boxed{i<j}\Leftrightarrow\boxed{t(0,i)<t(0,j)}}$: for example, $\boxed{t(0,i_{ph})=t_{ph}\cong t_{Pl}}$ (as previously shown in the first set of eSR predictions), so that all EPs identified with SVs(j) (with $j>i_{ph}$) will have larger $t(0,j)$ (excitation/dezexcitation) intervals and thus specific maximum speeds of propagation in vacuum lower than the speed of light in vacuum (**c**):

$$\boxed{v_{\max}(j)\left[=d_0/t(0,j)\right]<c}\quad\textbf{(Eq.9a)}$$

However, the hypothetical graviton is identified with SV(i_{gr}) (with $\boxed{i_{gr}<i_{ph}}$) so that $\boxed{t(0,i_{gr})<t_{ph}}$, resulting a predicted maximum speed of the hypothetical graviton larger than the speed of light in vacuum (**c**)

$$\boxed{v_{\max}(i_{gr})\left[=d_0/t(0,i_{gr})\right]>c}\quad\textbf{(Eq.9b)}$$

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Prediction. eSR predicts that this superluminal ("tachyonic") hypothetical graviton may violate causality and may also explain quantum entanglement (**QE**), by possibly being implicated in the QE subtle mechanism. Furthermore, as eSR predicted that other (still unknown/"missing") EPs identified with SV indexes $i\in\left(i_{gr},i_{ph}\right)$ may also exist, these EPs are also predicted to be tachyonic and to be also possibly implicated in the QE mechanism. **Note**. Other authors have also considered superluminal gravitons and superluminal gravitational waves, but with other arguments [**3**,**4**,**5**].

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Prediction. eSR also predicts that, for any $i>0$, the SV(i) diameter $\left(d_i\right)$ will also be larger than $d_0\left(\cong l_{Pl}\right)$, such as:

$$\boxed{i>0}\Leftrightarrow\boxed{d_i>d_0}\quad\textbf{(Eq.10)}$$

Note (1). The previous Eq10 implies that, when very many EPs are confined in a relatively small volume (resulting high matter and radiation densities), these perpetual moving EPs will tend to increase the average index i_{av} of the SVs(i_{av}) from that spatial volume, thus increasing the average diameter of those SVs(i_{av}) (and also increasing their average excitation-dezexcitation time intervals of SVs(0)-(i_{av})-(0) transitions): in this way, that high (matter/radiation) density local 4D spacetime will appear as "dilated", also deforming the perfect vacuum around that local volume (composed of SVs(0)), which SVs(0) will tend to rearrange around that high density region of spacetime on the so-called "geodesics"; this predicted phenomenon may explain the principle of spacetime curving used by Einstein's General Relativity (**GR**).

Note (2). Eq10 also predicts and explains the apparition of quantum micro-curvatures of spacetime and may even explain wave function collapse by local critical quantum micro-curvatures, so that eSR can be regarded as an objective-collapse theory.

A redefinition of SI base units starting from the Planck constant. By analogy to the photon (for which any $E_{ph(x)}\cdot t_{ph(x)}$ combinational product equals Planck constant h), the generic quantum angular momentum of any SV(i) $H(i)\left(=E_i\cdot t_i\right)$ can be regarded as an indirect measure of some kind of "structural/intrinsic" physical information quantity (**PIq**) of that SV(i) (including the photon, which is identified to the SV(i_{ph})), which specific PIq(i)(=H(i)) gives distinctiveness to that SV(i).

Because the hypothetical graviton (**gr**) existence (with a hypothetical quantum angular momentum $h_{gr}<<h$) isn't a certainty, eSR proposes the Planck constant as an "**elementary PIq**" (usable to

characterize each SV in part) measured in "**physical bits**" ("**pbits**") so that:

$$[PIq] = 1 pbit = h \cong 10^{-33} Js \quad \textbf{(Eq.11a)}$$

All the redefined SI base units are listed in the next table, each with a short redefinition.

Table I-3. **A set of SI base units redefined by using the elementary physical information quantity (PIq or shortly "I") measured by the Planck constant (h).**

The redefined SI base unit	**SI base unit redefinition**	**Definition for each (redefined) SI base unit in part**
Quantum angular momentum (L)	$L = I$ $1J \cdot s \cong 10^{33}\ pbits$	Quantum angular momentum is identified with **PIq**
Energy (E)	$E = I / t$ $1\,Joule \cong 10^{33}\ pbits / s$	PIq transfer speed
Power (P)	$P = I / t^2$ $1 Watt \cong 10^{33}\ pbits / s^2$	PIq transfer acceleration
Force (F)	$F = I / (d \cdot t)$ $1N \cong 10^{33} (pbits / s) / m$	PIq transfer speed per unit of length
Mass (M)	$M = I \cdot t / d^2$ $1kg \cong 10^{33} (pbits \cdot s / m^2)$	PIq flow (in a time interval t) per unit of area

Note. The pbit(=h) is not an innovation per se. For example, the Bekenstein bound (**BB**) also uses the Planck constant (**h**) as an informational unit. BB is defined as the maximum entropy (**S**) or information (**I**) that can be contained within a given finite region of space which has a finite amount of energy (**E**) (which is the maximum amount of information required to perfectly describe that finite region of space down to the quantum level). For a spherical space with radius R and finite energy E, BB is estimated as:

$$BB = \left[(4\pi)^2 RE / (c \ln(2)) \right] / h \quad \textbf{(Eq.11b)}$$

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III. End references
(in the order of their apparition in this paper)

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