A Unified Theory of Electrification in Natural Processes

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ABSTRACT

Electrification in natural processes is unified through the quantum electrodynamics (QED) confinement of electromagnetic (EM) thermal *kT* energy of atoms in nanoparticles (NPs). NPs have EM confinement frequencies beyond the vacuum ultraviolet (VUV) that by quantum mechanics (QM) restricts the specific heat of the atoms to vanishing small levels, and therefore transient *kT* energy remaining after solids and liquids fragment or steady *kT* energy absorbed from molecular collisions in the surroundings cannot be conserved by an increase in temperature. Instead, conservation proceeds by the emission of QED induced nonthermal EM radiation that at VUV levels electrifies the natural process by the photoelectric effect.

Index Terms — **Quantum dots, electromagnetic radiation, frequency conversion, thermal converters, light sources, optical resonators.**

1 INTRODUCTION

ELECTRIFICATION in natural processes is explained by photochemical reactions [1] initiated by EM radiation induced in NPs by QED – the process called QED induced EM radiation. NPs ubiquitous to natural processes emit EM radiation because the NP atoms are under EM confinement that by QM are restricted to vanishing specific heat. Therefore, transient *kT* energy present as NPs form during the fragmentation of liquids and solids or steady *kT* energy transferred to NPs in molecular collisions cannot be conserved by an increase in NP temperature. Here, *k* is Boltzmann's constant and *T* is absolute temperature. Instead, the *kT* energy now in excess of that allowed by QM is conserved by the emission of EM radiation at a frequency equal to that of the EM confinement of the NP, typically at VUV levels. The VUV from NPs then electrifies the natural process by the photoelectric effect.

How the NPs form depends on the specific natural process, but all electrifications are unified by the VUV emission from NPs induced by QED, e.g., static electricity comprising positive and negative charges is produced from VUV induced in NPs that form in the rubbing of dissimilar solids; atmospheric electricity from hydronium and hydroxyl ions from VUV in NPs that form in rubbing of ice particles; flow electricity from VUV induced in NP impurities in the fluid, and the Hubble redshift by the absorption of distant quasar light in NPs of cosmic dust instead of by the Doppler Effect in an expanding Universe.

Prior applications of QED induced EM radiation were based on the EM confinement of thermal *kT* energy in nanovoids (NVs) - bubbles in liquids and gaps in solids, e.g., see [1]. Indeed, NPs as the unifying basis in natural electrification evolved because of difficulties with EM confinement in bubbles and gaps. Bubbles offer full EM confinement, but do not nucleate in piping systems under pressure. Similarly, flow pressure precludes the formation of gaps in the electrical double layer (EDL) at pipe surfaces.

In contrast, NPs offer full EM confinement. NPs are similar [2] to solid state quantum dots (QDs) that by QED induce the emission of visible (VIS) light by frequency up-conversion of near infrared (NIR) laser radiation.

Unlike QDs, there are no NIR lasers in natural processes to irradiate the NPs. Ambient blackbody (BB) radiation in the far infrared (FIR) is available at about 10 microns, but may be neglected because the Mie absorption [3] efficiency for NPs at FIR levels is very low [4]. But this is of no consequence because the atoms in NPs upon fragmentation have transient *kT* energy and subsequently gain steady *kT* energy from molecular collisions, the *kT* energy in both cases induced by QED to undergo frequency up-conversion to VUV levels that by the photoelectric effect electrify the natural process. The NP conserving transient and steady *kT* energy is depicted in Fig. 1.

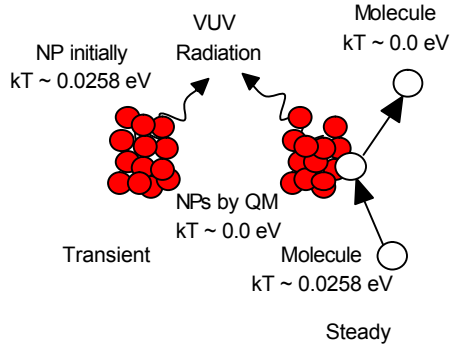

Figure. 1. Transient and Steady EM Emission from NPs

Manuscript received on 25 October 2008, in final form 15 November 2008.

2 PURPOSE

The purpose of this paper is to apply QED induced EM radiation to natural processes to show how a unified theory of electrification based on NPs might be formulated.

3 THEORY

3.1 QM RESTRICTIONS

The EM radiation in NPs is based on QM restrictions on kT energy during transient fragmentation and steady collisions by gas and liquid molecules in the natural surroundings. That the collisions are EM follows from the fact the kT energy depends on EM wavelength. Similar to QDs under NIR radiation, the collisions transfer wavelength dependent EM energy to the NPs. The QM restrictions on kT energy are given by the Einstein-Hopf relation for the harmonic oscillator [5] in terms of wavelength in Fig. 2.

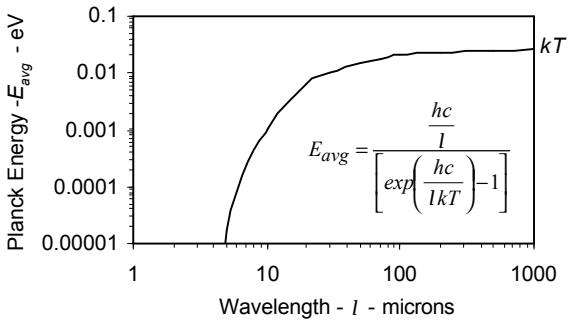

Figure 2. Harmonic Oscillator at 300 K
In the inset, h is Planck's constant, and c is the speed of light

3.2 TRANSIENT AND STEADY VUV RADIATION

Transient VUV radiation is produced [6] at the instant NPs form as solids or liquids fragment. Fig. 2 shows QM allows atoms absent EM confinement in the FIR beyond 100 microns to have full kT energy; whereas, under high EM confinement in the VUV at $\lambda < 0.2$ microns the kT energy vanishes. Upon NP formation, excess kT energy above that allowed by QM cannot be conserved by an increase in temperature because the NP specific heat vanishes [2] at typical EM confinement frequencies, and therefore the excess kT energy is conserved by a burst of VUV radiation.

Following NP formation, molecular collisions [6] allow the NPs to emit steady VUV radiation provided the NPs remain submicron, i.e., agglomeration lowers the QED induced EM emission to FIR levels that lacks the Planck energy necessary for electrification.

Molecular collisions transfer kT energy at FIR levels efficiently to NPs. Unlike NIR photons that scatter from QDs and reduce the Mie [4] absorption efficiency, collisions are inelastic because the molecules are far smaller than the NPs, and therefore transfer their full kT energy to the NPs.

3.3 EM CONFINEMENT

The NPs during transient or steady EM emission follow the theory [2] for QDs emitting VIS photons upon NIR laser radiation. Although NPs have $D << l$, it is instructive to first consider the case of $D > l$. The equatorial NP mode [7] shows the EM radiation trapped in the NP by total internal reflection (TIR). In TIR, the number n of reflections around the QD depends on the wavelength l of the incident radiation. As $l \rightarrow D$, the ratio $l/D \rightarrow p$. Since the speed of light c is reduced by the refractive index n_r, the frequency f_{TIR} of the TIR mode,

$$f_{TIR} = \frac{c / n_r}{pD} = \frac{c}{pn_r D} \tag{1}$$

NPs having $l >> D$ are assumed to have the macroscopic index n_r because the speed of light c in a medium is independent of size. Further, the TIR mode follows the QM analogy of creating photons of wavelength l by supplying EM energy to a QM box with walls separated by $l/2$. For the spherical NP as a QM box of diameter D, the Planck energy E_P induced by EM confinement at wavelength λ is,

$$E_P = \frac{hc}{l} \text{ and } l = 2n_r D \tag{2}$$

3.4 VANISHING SPECIFIC HEAT

In transient or steady NP absorption, the EM radiation is confined within the geometry of the NP. For the NP to conserve the absorbed EM radiation by an increase in temperature, the specific heat must be finite. The approach here differs from that usually assumed where the Einstein specific heat is given by the vibration of atoms as harmonic oscillators. Instead, the specific heat is given by the oscillation of BB photons in response to the absorbed EM radiation with atoms stationary.

Prior to any absorption of EM radiation, the BB thermal photons emitted from the atoms within the NP are in thermal equilibrium at temperature as shown in Fig. 2. But the absorbed EM radiation having $l >> D$ disturbs this equilibrium by photon oscillations while adjusting to the EM confinement frequency of the NP. Over this time, the specific heat of the NP may be determined from the Einstein-Hopf relation for BB photons evaluated at the oscillation frequency of the absorbed EM radiation as it adjusts to the EM confinement frequency imposed by the NP geometry.

Although Einstein assumed the atoms are harmonic oscillators vibrating independent of each other, the BB photons oscillate coherently at the EM confinement frequency imposed of the NP, the coherent oscillations taking Mie resonant modes. For each atom, one BB thermal photon is assumed for each degree of freedom (DOF). The total Planck energy U of a NP with N atoms, each atom having 3 DOF is,

$$U = 3N \frac{hc}{l}\left[exp\left(\frac{hc}{lkT}\right)-1\right]^{-1} \tag{3}$$

The NP specific heat C is,

$$C = \frac{\partial U}{\partial T} \tag{4}$$

In terms of the dimensionless specific heat C^*,

$$C^* = \frac{C}{3Nk} = \left(\frac{hc}{lkT}\right)^2 exp\left[\frac{hc}{lkT}\right]\left[exp\left(\frac{hc}{lkT}\right) - 1\right]^{-2} \tag{5}$$

where, l is the frequency of the quasi-bound leaking TIR mode, $l = 2n_rD$. At 300 K, the dimensionless specific heat C^* vanishes at $n_rD < 4$ microns as shown in Fig. 3.

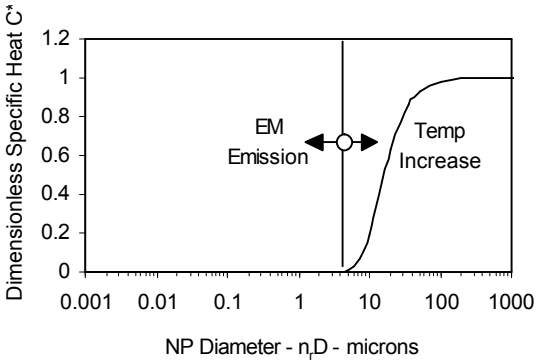

Figure 3. Dimensionless Specific Heat C^*at 300 K

4 ANALYSIS

4.1 FRAGMENTATION INDUCED CHARGE

The atoms in the NP have the same kT energy as those in the solid or liquid prior to fragmentation. The energy U is,

$$U = \frac{p}{2}\left(\frac{D}{D}\right)^3 kT \tag{6}$$

where, D is the cubic spacing between NP atoms at solid density, $D \sim 0.3$ nm. Lacking specific heat, the NP conserves the energy U by a burst of VUV radiation that electrifies the surroundings. The charge q is,

$$q = N_P Ye = \frac{U}{E_P} Ye = pkT\left(\frac{D}{D}\right)^3 \frac{n_r D}{hc} Ye \tag{7}$$

where N_P is the number of QED photons induced in the NP having Planck energy E_P, and e is the electron charge. For NPs having $n_r < 2$ and $D < 50$ nm, $E_P > 6$ eV where most materials have yields $Y \sim 0.1$ electrons/VUV photon, the QED induced charge q is of order $q \sim 0.5$ fC / NP.

4.2 COLLISION INDUCED CURRENT

Absent an increase in NP temperature, the collisional EM power Q_C is conserved by the emission of EM radiation

$$E_P \frac{dN_P}{dt} = Q_C \tag{8}$$

where, dN_P/dt is the rate of QED photons produced in the NP having Planck energy E_P.

The power Q_C transferred [8] to the NP is,

$$Q_C = \frac{p}{2\sqrt{3}} pPD^2 \sqrt{\frac{kT}{m}} \tag{9}$$

where, p is the probability of energy transfer, and P is the ambient pressure. The mass m of oil molecules is, $m = MW / N_{avag}$ where MW is molecular weight and N_{avag} is Avagadro's number. The QED induced current I is,

$$I = \frac{dN_P}{dt} Ye = \frac{p}{2\sqrt{3}} \frac{pPD^2}{E_P} \sqrt{\frac{kT}{m}} Ye \tag{10}$$

NPs with $n_rD < 100$ nm have $E_P > 6.21$ eV where the EM emission is in the VUV and $Y \sim 0.1$ electrons/VUV photon. For water and n-Hexane having $MW = 18$ and 86, the QED induced current I for transfer probability $p = 0.001$ and $n_rD <$ 100 nm is shown in Fig. 4.

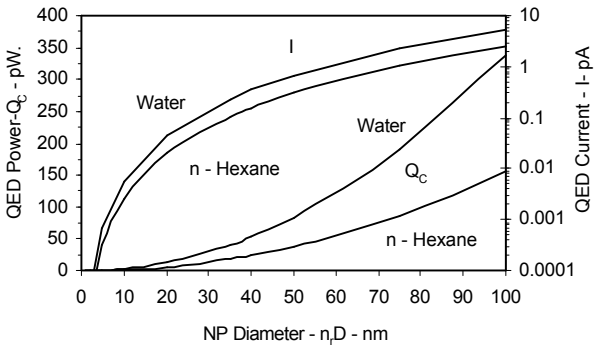

Figure 4. QED Induced Power Q_C and Current I / NP

The NP power Q_C generated by QED produces electrical current I depending on parameter n_rD. For $n_rD = 100$ nm in n-Hexane and water, Fig. 4 shows the power $Q_c = 150$ and 340 pW produces a current $I = 2.5$ and 5.5 pA. For $n_rD > 100$ nm, the current I tends to vanish because for $E_p < 5$ eV, the electron yield Y is very small. Otherwise; the current I is upper bound by that at $n_rD = 100$ nm.

4.3 SUMMARY

Generally, NP electrification depends on the specific natural process, but typically static charge and current may be considered to be about 0.5 fC and 1 pA / NP.

5 APPLICATIONS

In the following applications of QED induced EM radiation, various natural processes are described to support the argument that NPs are the source of electrification in natural processes by which electrification occurs.

Only a brief review of the natural process is presented from which the reader may form an opinion that NPs are most likely produced to justify QED induced EM radiation as an explanation for the electrification by NPs in natural processes.

5.1 STATIC ELECTRICITY

About 600 BC, the Greeks discovered static electricity. Amber rods rubbed with cloth were found to attract feathers, but why this is so has remained a mystery for over 2000 years. Currently, it is generally thought [9] that the mechanism underlying static electricity is mechanical, the electrons physically removed by the rubbing of material surfaces.

However, Einstein showed that EM and not mechanical energy is necessary to free an electron from a material. Electrons are more tightly bound to atoms than atoms are bound to each other. Hence, rubbing may only produce NPs of neutral clusters of atoms rather than free electrons, the electrons remaining bound to the atoms as the NPs separate from the materials. It is therefore very difficult to reconcile the fact that static electricity has been observed since the early Greeks unless neutral NPs formed by rubbing somehow produce EM radiation.

On this basis, static electricity was explained [10] by the photoelectric effect where electrons are produced by increasing the frequency of FIR radiation in gaps to VUV levels by QED induced EM radiation. In practice, however, VUV radiation is not produced because the necessary flatness of gap surfaces in the rubbing of materials cannot be held to nanoscale tolerances. Indeed, the lack of EM confinement of FIR radiation from atoms in the surfaces of gaps was experimentally confirmed [11] by the inability to produce VIS photons in the opening and closing of the gaps at ultrasonic frequencies.

The inability of NV gaps [11] between solid surfaces to produce VIS photons led to the study of NPs because the NP atoms are under their own EM confinement, i.e., NPs do not require gaps to produce static electricity.

5.2 CASIMIR FORCE

Similar to static electricity in gaps, the Casimir force [12] is negated by tolerances [11] between parallel plates. Tolerances aside, the Casimir [13] force does not exist on theoretical grounds. This is so, because as the gap closes, QED continuously conserves the EM radiation present in the gap with higher energy EM radiation. Alternatively, the EM energy in the gap is constant, and therefore there is no Casimir force because the gradient of EM energy with respect to gap closure vanishes. Nevertheless, VUV radiation is produced in the gap that charges the plates and produces an electrostatic attraction which has been erroneously interpreted as a verification of the Casimir force.

5.2.1 ATMOSPHERIC ELECTRICITY

Lightning based on thundercloud electrification is described by the dissociation of water molecules into hydronium and hydroxyl ions as solid NPs form from frosted graupel surfaces under freezing at high altitudes.

In contrast, prior QED induced EM radiation [14] assumed moisture carried to high altitudes supercools to form graupel, a liquid-ice mixture. Bubble NVs were posited to nucleate in the supercooled water because of the large volume expansion that accompanies freezing. Each bubble nucleation produced VUV radiation that dissociated water molecules on the bubble walls into hydronium and hydroxyl ions.

Charge separation occurs under gravity as the lighter hydronium ions rise above the heavier hydroxyl ions to form positive and negative charged clouds. Cloud-to-cloud lightning in the upper atmosphere then occurs between positive charged hydronium clouds and negative charged hydroxyl clouds, while cloud-to-ground lightning takes place as hydroxyl clouds that escaped discharge as cloud-to-cloud lightning fall to the lower atmosphere and discharge with the positive charged earth's surface.

QED induced VUV radiation induced in NPs [6] differs from that in NVs. Bubble formation in graupel is not necessary. Updrafts in thunderclouds carry graupel at velocities from 10 to 100 mph that freezes to form frosted graupel surfaces. Graupel that has moved to higher altitudes is frozen to produce solid ice that upon falling collides with upward moving frosted graupel to produce ice NPs. QED induces the NPs to produce VUV radiation that dissociates water-ice molecules to form the hydronium and hydroxyl ions that electrify the process.

5.3 FLOW ELECTRIFICATION

Over the past 50 years, the electrification of hydrocarbon liquids and oils flowing in metal pipes has been attributed to the EDL. Today, the mechanism by which the charges are produced in the EDL is thought caused by corrosion of the pipe surface, but the lack of corrosion products to confirm the electrochemical process suggests that other electrification mechanisms are at play.

Early applications [15] of QED induced EM radiation to flow electrification were based on the nucleation and collapse of bubbles in vortices and at the flow boundaries with channel walls. However, the formation of bubbles in flowing liquids is questionable because eddies lack the low pressure to nucleate bubbles, especially if the flow is pressurized.

Recent flow electrification analysis [16] of coolant oil in power transformers by QED induced EM radiation considered NPs comprising clusters of oil molecules that form in the EDL as the flow shears relative to the pipe wall. But molecular dynamics simulations showed clusters of oil molecules only form at shear rates far higher than those in flow electrification.

On this basis, QED induced EM radiation from submicron NP impurities present in the hydrocarbon are the likely source of flow electrification. What this means is the EDL has nothing to do with flow electrification.

5.4 STEAM ELECTRICITY

In the 1840's, steam boilers were commonplace in England. At Seghill, steam happened to leak through a cement seal around the safety valve on a boiler. When a workman placed one hand in the steam while the other was on the lever of the valve, a spark discharge occurred and the workman received an electrical shock.

Faraday [17] showed that steam alone produced no electricity, but liquid water distilled from the boiler and added as globules to the steam produced positive charged steam and a negative charged boiler. Faraday sought to eliminate steam altogether by testing both dry and common air. Common air having moisture condensation was found to produce positive charge similar to steam; whereas, dry air failed to be electrified. On this basis, Faraday thought the tribo-series for contact electrification by rubbing of water globules against the nozzle surfaces would explain steam electrification, but this was not confirmed by experiments.

QED induced EM radiation suggests the rubbing of water globules against the nozzle produced the NPs that emitted the VUV radiation that electrified the steam. Like the EDL having nothing to do with flow electrification, steam electrification has nothing to do with the tribo-series for water against nozzle materials. The VUV from NPs likely excites acid and alkali chemicals in the steam away from the contact nozzle surfaces which may have confounded Faraday. Photochemical reactions are complex and depend on the EM radiation produced by the NPs and not the tribo-effect of the water against nozzle materials.

5.5 LEIDENFROST PHENOMENON

In 1743, Johann Leidenfrost discovered what is now called the Leidenfrost phenomenon in which a drop of water is boiled while supported from a heated surface on a layer of its own vapor. The layer is formed from the flow of vapor from the underside of the drop. Leidenfrost used a “red hot” spoon to suspend the water drop, the drop evaporating slowly because the vapor layer acts as thermal insulation from the heated surface. Upon disappearing, the drop produces an audible "Crack!" leaving behind a powder residue.

Almost 200 years later, Pounder performed experiments [18] that showed particles emitted from the gap using water containing 3.5% NaCl representative of seawater, but similar results were found with distilled and tap water. The temperature of the hot surface above 400 C heats the underside of the drop to the boiling point of water. High-speed photography showed micron sized particle emission originated from the underside of the drop, the droplets rubbing along the heated spoon surface.

The Leidenfrost phenomenon that describes the electrification of a drop of boiling water supported from a hot surface is similar to that of static electricity by NPs. The difference is that the water drop is stationary relative to the hot surface, and therefore NPs are not produced by rubbing of the drop against the hot surface. Instead, micron sized particles are directly ejected from the drop that, in turn rub against the hot surface to produce NPs. Pounder found particles less than < 5 microns were emitted, and it is reasonable to assume NPs were formed as the particles rubbed against the hot surface.

5.6 SPRAY CHARGING

In 1969, large crude carriers were severely damaged by explosions caused from sparks in charged mist produced while their tanks were being washed with jets of hot and cold liquid water or steam. Since Faraday, steam has been known to be electrified, but because of the explosions during ship washing, wet steam was reaffirmed by Finke [19] as the source of the electrification.

Finke’s conclusion that wet steam is the source of spray charging follows the work of Faraday [17] who showed water globules added to steam produced steam electricity, but pure steam did not. Similar to steam electrification, the source of spray charging was found inconsistent with the tribo-series. By QED induced EM radiation, contact is necessary to form NPs that in spray charging produces the VUV necessary to dissociate the surrounding acidic and basic chemicals that electrify the steam.

5.7 WATERFALL ELECTRICITY

In 1892, Lenard [20] proposed the EDL theory as the explanation of waterfall electricity where positive charge is found in the splash. The EDL is only a rearrangement of water molecules which in mountain water carries a net negative charge common to limestone riverbeds having pH > 7, and therefore drop fragmentation in the splash produces negative charged vapor of NPs.

QED induced EM radiation from negative charged NPs produces VUV radiation that dissociates water molecules into positive hydronium and negative hydroxyl ion vapor. Consistent with Lenard’s observations, positive charge is attracted to and remains near the splash where fragmentation occurred while negative charged vapor is repulsed and found away from the splash.

5.8 HUBBLE REDSHIFT

In 1929, Edwin Hubble using the Doppler Effect estimated [21] the velocity at which the Universe is expanding based on the redshift of known spectral lines in galaxy light. However, competing theories have been proposed that Hubble redshift is not caused by galaxy recession but rather by the interaction of galaxy light with NPs of cosmic dust in the interstellar medium (ISM).

Hubble redshift by NPs may be explained [22] by the manner in which NPs conserve the absorbed galaxy light. Classically, the absorption of light in NPs is conserved [23] by an increase in temperature, but this is only valid for micron or larger particles. For NPs, QM restricts the specific heat of atoms to vanishing small levels, and therefore the

absorbed galaxy photon cannot be conserved by an increase in temperature. Rather, conservation proceeds by the QED induced frequency down-conversion of the absorbed galaxy photons to the EM confinement frequency of the NP.

In the ISM, the absorption of galaxy light in NPs cannot be denied, and therefore QED induced redshift unequivocally places in question the Hubble redshift as the basis for an expanding Universe. QED induced redshift depends on the EM confinement wavelength $l_o = 2Dn_r$. If galaxy light having wavelength $l = 0.7$ microns is absorbed in a NP having diameter $D = 0.2$ microns and $n_r = 2$, the wavelength $l_o = 0.8$ microns and the QED induced redshift $Z = (l_o - l)/l = 0.142$. Hubble theory based on the Doppler Effect states the Universe is expanding at velocity $V = c\ [(Z+1)^2 - 1] / [(Z+1)^2+1] = 0.132\ c$. But this is erroneous - QED induced redshift Z is caused solely by NP absorption of galaxy light!!!

Nevertheless, Hubble's finding negated Einstein's static or a non-expanding Universe. Confronted with Hubble's findings, Einstein admitted the static Universe was his biggest blunder. In retrospect, Einstein should have questioned Hubble's findings, but did not.

Laser experiments are planned to show NPs produce the Hubble redshift. If successful, Einstein's Universe may once again regain the prominence it had before Hubble's findings. Until then, QED induced redshift holds in question Hubble's finding that led to an expanding Universe following the Big Bang. It is important to note that QED induced redshift does not prove the Universe is not expanding, but rather an expanding Universe cannot be verified by Hubble redshift

6 CONCLUSIONS

A unified theory of electrification in natural processes based on NPs is presented. Although NP electrification depends on the specific natural process, typical static charge and current is shown to be about 0.5 fC and 1 pA / NP.

In formulating the unified theory, the photoelectric effect is chosen as the basis for electrification because natural processes always occur in the presence of low level EM radiation in the FIR. But the FIR lacks the Planck energy to remove electrons from solids and liquids, and therefore the unified theory relies on QED induced EM radiation in NPs for frequency up-conversion to the VUV necessary for electrification of the natural processes.

Usually NPs form by rubbing of solids against each other or by fragmentation. Provided the NPs remain submicron and do not agglomerate, electrification occurs by the photoelectric effect from VUV emission. Since Faraday, electrification has nothing to do with the EDL based on the tribo-series.

Finally, commonality in natural processes is required to allow a unified theory of electrification to be formulated. Only NPs may provide this commonality.

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