SunQM-6s5: Using {N,n} QM Field Theory to Describe A Propagating Photon as A 3D Spherical Wave Packet with the Oscillation Among Three QM States

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Abstract

The framework of the newly designed {N,n} QM field theory has been established in papers of SunQM-6, -6s1, -6s2, -6s3, and -6s4. It includes: re-classified the four fundamental forces to be three pair of forces (E/RFe-force, G/RFg-force, and S/RFs-force); all point-centered fields (including the mass field, the force field and the energy field) can be represented by the Schrodinger equation/solution (in form of non-Born probability as well as in the form of 3D spherical wave packet); the non-Born probability description that equals to the re-explanation of the Born probability density as the collection of all elliptical orbital tracks, the 3D wave packet description and the dis-entanglement of the outmost shell (i.e., the "general decaying" process), the "|nL0> elliptical/parabolic/hyperbolic orbital transition model", and the trick that using the high-frequency n' quantum number to pin-point any small region in the {N,n} QM field. In the current paper, using the E/RFe-force pair (but in an inversed mode), I re-described a propagating photon's 1D transverse wave by using a 3D spherical wave packet in the form of a non-Born probability (NBP) density ball that oscillates between |2,1,1> and |2,1,-1> QM states (through a middle state that is a mixture of equal amount of |2,1,1>, |2,1,-1> and |2,1,0> QM states). In this way, now we are able to describe a propagating photon as a single ball (which is more like its true shape than a 1D wave). The detailed structure of this multi-shell 3D wave packet has been analyzed. After emitted from a H-atom, an apparently linear polarized 656.1 nm photon actually is a circular polarized photon, with the (default) spin angular momentum in perpendicular to the propagation direction. The special relativity effect makes it appeared to be the linear polarized. Then, after passing through some different optic materials, this photon's spin vector can be reoriented in the 3D space (relative to its propagation direction) to produce either a right circular polarized, or a left circular polarized, or a 90° reoriented linear polarized, or an elliptical polarized photon. However, whatever the reorientation the spin vector has, its value is always $1\hbar$.

Key Words: Quantum mechanics, {N,n} QM field theory, photon, E/RFe-force, 3D spherical wave packet

Introduction

In September 2016, I discovered that the Solar system follows the {N,n//6} QM structure [1]. Based on that result, I further developed the {N,n} QM theory, and showed that not only the formation of Solar system [1] ~ [16], but also the formation of the whole universe [17] ~ [25], may can be explained by the {N,n} QM. As part of the {N,n} QM development, I designed a completely new {N,n} QM field theory [23] ~[24], [26] ~ [28]. The foundation of this theory includes: the four fundamental forces (Gravity, Electromagnetic, Strong, Weak, abbreviated as G-, E/M-, S-, W-forces) have been re-classified into three pairs of force (E/RFe-force, G/RFg-force; S/RFs-force, see SunQM-6); both E/RFe-force field and G/RFg-force field have been proved that they can be directly reconstituted by using either the Schrodinger equation/solution (in form of Born probability), or a 3D spherical wave packet (see SunQM-6s4); all point-centered field (including both the mass field and the force field) can be described in the same way (see SunQM-6s4); the non-Born probability description (see SunQM-4 series) has been established (that equals to the re-explanation of the Born probability density as the collection of all elliptical orbital tracks, see SunQM-6s2); the 3D wave packet description and the dis-entanglement of the outmost shell (or the "general decaying" process, see SunQM-6s1, -6s2, -6s3, etc.) has been established; the "|nL0> elliptical/parabolic/hyperbolic orbital transition model" (see SunQM-6s2, -6s3) has been established; and the trick that using the high-frequency n' to pin-point any small region in the {N,n} QM field (see SunQM-3s11, -6s1, etc.) has been established. In the current paper, I re-explained the 1D transverse electromagnetic wave [29] (in the classical physics) in a full {N,n} QM way, that is, by using the {N,n} QM field theory's 3D spherical wave packet, and the oscillation among three QM states.

Note: QM means Quantum Mechanics. For {N,n} QM nomenclature as well as the general notes, please see SunQM-1 sections VII & VIII. Note: Microsoft Excel's number format is often used in this paper, for example: x^2 = x^2, 3.4E+12 = 3.4*10^{12} = 3.4×10^{12}, 5.6E-9 = 5.6*10^{-9}. Note: The reading sequence for the (28 posted) SunQM series papers is: SunQM-1, 1s1, 1s2, 1s3, 2, 3, 3s1, 3s2, 3s6, 3s7, 3s8, 3s3, 3s9, 3s4, 3s10, 3s11, 4, 4s1, 4s2, 5, 5s1, 5s2, 7, 6, 6s1, 6s2, 6s3, and 6s4. Note: for all SunQM series papers, reader should check "SunQM-9s1: Updates and Q/A for SunQM series papers" for the most recent updates and corrections. Note: |n*l*m> means |n,*l*,m> QM state, "nLL" or |nLL> means |n,*l*,m> QM state with *l* = n-1 = L, and *m* = n-1 = L. "nL0" or |nL0> means |n,*l*,m> QM state with *l* = n-1 = L, and m = 0. Note: RF means "RotaFusion", or "rotation diffusion". Note: NBP means non-Born probability. Note: In this paper, I prefer to use the word "spin" (rather than "rotation") for the spinning $\vec{\mathbf{E}}$ vector (because it correlates to the photon's spin vector), and use the word "rotation" (rather than "spin") for the rotating $\vec{\mathbf{B}}$ vector (because it correlates to the RF, rotation diffusion, or RotaFusion).

I. In developing the {N,n} field theory, re-describe a photon's 1D transverse wave by using a 3D wave packet in the form of a non-Born probability density ball that oscillates in |2,1,m> QM states

In SunQM-6s4, I used {N,n} QM field theory to re-explain the (classical physics') static electric field. In the current paper, I tried to explain a photon's classical physical electromagnetic field under the {N,n} QM field theory with the detailed structure.

In all text books of physics, a propagating photon is always diagramed as a 1D transverse electromagnetic wave [29]. In {N,n} QM, I had explained it as a 3D (spherical) wave packet (see SunQM-6s1's section III-a, and SunQM-6s3's Table 3). This 3D wave packet description had also been unified with a photon's 1D transverse wave description, the 1D wave packet description, and the 3D wave description (see SunQM-6s2's Table 7). However, even in the 3D wave packet description, the electric field $\vec{\mathbf{E}}$ vector and magnetic field $\vec{\mathbf{B}}$ vector description (in this 3D spherical wave packet) is still in classical, not in QM (see SunQM-6s2's Fig-7). So, to fill in this gap, in the current paper, I designed a completely new description for a propagating photon by using the Schrodinger equation/solution, i.e., the three QM state of |2,1,1>, |2,1,-1>, and |2,1,0>, in the form of either the Born probability (abbreviated as **BP**) spherical 3D density map, or the **non-Born probability** (abbreviated as **NBP**) spherical 3D density map. (Note: In {N,n} QM, we always want to use NBP if possible. However, as we mentioned before, we have to use the BP density map to guide us to draw a NBP density map. Otherwise, we don't know how to draw a NBP density map directly).

In {N,n} QM, we should use NBP instead of BP (see SunQM-4 and SunQM-4s1). However, NBP (that directly equals to the wave function) contains the complex value that is difficult to plot, and even if we use only the real value (and ignore the imaginary value) to plot, the plotted diagram lacks of the enough information to show the real physical process. For example, for the θφ-2D wave function of |2,1,m> QM state,

$$\mathrm{Y}(1,1) = -\sqrt{\frac{3}{8\pi}}e^{i\varphi}\sin\theta = -\sqrt{\frac{3}{8\pi}}\frac{x+iy}{r} \qquad \text{eq-1}$$

$$\mathrm{Y}(1,-1) = \sqrt{\frac{3}{8\pi}}e^{-i\varphi}\sin\theta = \sqrt{\frac{3}{8\pi}}\frac{x-iy}{r} \qquad \text{eq-2}$$

$$Y(1,0) = \sqrt{\frac{3}{4\pi}}\cos\theta = \sqrt{\frac{3}{4\pi}}\frac{z}{r} \qquad \text{eq-3}$$

eq-1 clearly showed that the |2,1,1> wave function is spinning in xy-plane in direction of φ; eq-2 clearly showed that the |2,1,-1> wave function is spinning in xy-plane in direction of -φ; and eq-3 clearly showed that the |2,1,0> wave function is not spinning in xy-plane, but only pointing in +z axis. When plotting the real value only (for these wave functions, or for NBP), the spinning information in |2,1,±1> is completely lost. On the other side, the BP density map is able to show the spin process (although that is always in a steady state) more intuitively (in terms of its density shape). So, to compromise, when we present an NBP diagram for a physical process, we often need to also present a BP diagram side-by-side, and then to use the BP density to guide the explanation of the NBP diagram (e.g., see the similar situation in SunQM-6s2's Fig-2).

In paper SunQM-6, I had re-classified the four fundamental forces to be three pair of forces: E/RFe-force, G/RFg-force, S/RFs-force. In SunQM-6's Table 2 and eq-1, I had (conceptually) used the combination of multiple n(s) of |n,*l*,m> QM states to describe the QM mode of $\vec{\mathbf{E}}$ vector and $\vec{\mathbf{B}}$ vector. Although it is more accurate, it is too complicated to handle. So in the current paper, I no longer use the combination of n(s), but use only a single n QM state to describe the QM mode of $\vec{\mathbf{E}}$ vector and $\vec{\mathbf{B}}$ vector for the ground state and/or excited state. Even for a single n of |n,*l*,m>, it still contains many superpositioned QM states (because for each n, *l* = 0…n-1, m = -*l*, … +*l*). For the simplest and the most characteristic description, we would like to use the two extreme ends of the series QM states for the description, that is, the nLL mode (where *l* = n-1 =L. Note: here "L" means the maximum number of *l*, i.e., *l* = n-1. E.g., |2,1,1>, |4,3,3>, etc.), and the nL0 mode (where m = +*l* = n-1 =L. E.g., |2,1,0>, |4,3,0>, etc.).

In the {N,n} QM field theory, we can describe a static E/RFe-force field by using |n,*l*,m> QM state with n=2. Under this description, the original static E-force is in nL0 mode (i.e., |2,1,0>) and the original static RFe-force is in nLL mode (i.e., |2,1,1>). The spin of the E/RFe-force field inversed the QM Mode of this E/RFe-force, so that the spinning E-force is in nLL mode (e.g., |2,1,1>, or |2,1,-1>, depends on the direction of the spin), and the spinning RFe-force is in nL0 mode (e.g., |2,1,0>). (Note: In general, a spinning nL0 mode become a nLL mode, and a spinning nLL mode become a nL0 mode).

In the current paper, I re-explaining a photon with an E/RFe-force pair (but in an inversed nLL or nL0 mode), and only use a single n of |n,*l*,m> QM state with n =2 for the description. Figure 1 showed this completely new description for a propagating photon's 3D (spherical) wave packet by using the Schrodinger equation/solution, i.e., the QM state of |2,1,0>, |2,1,1>, and |2,1,-1>, in the form of either the Born probability 3D density map, or the non-Born probability (NBP) 3D density map.

I-a. Using an inversed E/RFe-force mode (i.e., the nLL mode) to describe a spinning E-force vector, and using |2,1,1> and |2,1,-1> QM states to describe the two opposite spinning

First, let's explain the Figure 1a through Figure 1f. Figure 1a showed the relationship of a static E/RFe-force pair, where a primary electric force's $\vec{\mathbf{E}}$ field vector (or, $\vec{\mathbf{E}}$ vector, in straight-line) is accompanied by an orthogonal magnetic $\vec{\mathbf{B}}$ field vector (or, $\vec{\mathbf{B}}$ vector, in circular-line), in a force-line description (copied from SunQM-6's Fig-1). In Figure 1b, the $\vec{\mathbf{E}}$ vector (that in Figure 1a) was described by the |2,1,0> QM state, and in BP density form. Because the $\vec{\mathbf{E}}$ vector is uni-directional (in +z), we need to use the +z BP density only, and thus we need to hide the -z BP density in Figure 1b. In Figure 1e, the same $\vec{\mathbf{E}}$ vector (that in Figure 1a) was described by the same |2,1,0> QM state, but in NBP form (in the real value only). We can see that the blue (= positive density) and yellow (= negative density) ball pair automatically showed that it is uni-directional (pointing to +z). So, for the $\vec{\mathbf{E}}$ vector, NBP description seems better (because it showed uni-direction naturally) than BP description. Also, the half covered Figure 1b (and Figure 1j and Figure 1q) is the BP density map that adapted to the NBP meaning. (Note: See Appendix A for more discussion).

In Figure 1c, the $\vec{\mathbf{B}}$ vector (that in Figure 1a) was described by the |2,1,1> QM state in BP density form. (Note: From previous studies, we know that if the $\vec{\mathbf{E}}$ vector is described by the |2,1,0> QM state, then its orthogonal companion $\vec{\mathbf{B}}$ vector has to be described by the |2,1,1> QM state). Because the $\vec{\mathbf{B}}$ vector is in circular rotation (in xy-plane), it can be naturally represented by the donut-shape of the BP density, and we only need to add the direction of the rotation for the meaning of NBP (that is, to show that its rotation is uni-directional, not a bi-directional steady state). In Figure 1f, the same $\vec{\mathbf{B}}$ vector (that in Figure 1a) was described by the same |2,1,1> QM state, but in NBP form (in the real value only). We can see that without the complex-value plot, it is difficult to show the circular rotational line character of the $\vec{\mathbf{B}}$ vector. So, for the $\vec{\mathbf{B}}$ vector, the BP description seems better than NBP description. Thus, neither the NBP diagram nor the BP diagram is perfect to show the physical character of the E/RFe-force. Therefore, when we want to use |n,*l*,m> QM state to represent the E/RFe-force in NBP form, we better to show both the NBP density map and BP density map side-by-side, to make the illustration more understandable.

Second, let's explain the Figure 1h through Figure 1n. In SunQM-6's Fig-5, we showed that a rotating positive charge will inverse the |n,*l*,m> description of $\vec{\mathbf{E}}$ vector from the initial nL0 mode to the nLL mode, and meanwhile inverse the $\vec{\mathbf{B}}$ vector description from the initial nLL mode to the nL0 mode. (Note: In SunQM-6s2's Appendix B, we further pointed out that this inversion is caused by the spinning (or rotation) of the $\vec{\mathbf{E}}$ vector, and not mainly by the spinning of the positive charge itself). In the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model" (that was proposed in papers of SunQM-6s3), the oscillation of a propagating photon's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors was explained under this model (see SunQM-6s2's Fig-5 and Fig-7).

Figure 1h (of the current paper) showed (in force-line description) that the spinning of $\vec{\mathbf{E}}$ vector caused its companion $\vec{\mathbf{B}}$ vector's inversion (from the nLL mode to nL0 mode, points to the reader). This description (i.e., spinning $\vec{\mathbf{E}}$ makes $\vec{\mathbf{B}}$ conversion) is valid for either the electron orbiting the proton (in the H-atom), or the oscillation of a propagating photon's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors (see SunQM-6s2's section II-f).

In Figure 1i, the spinning $\vec{\mathbf{E}}$ vector (shown in Figure 1h, spinning in xz-2D plane) was described by the |2,1,1> QM state in BP density form. Notice that before spinning, it is in nL0 mode of |2,1,0> (see Figure 1b), after spinning, the mode is inversed to nLL mode of |2,1,1> (see Figure 1i). The direction of the spinning of the $\vec{\mathbf{E}}$ vector was added in Figure 1i (because by default, the BP diagram is bi-directional spin). In Figure 1j, the companion $\vec{\mathbf{B}}$ vector (that in Figure 1h) was described by the |2,1,0> QM state, and we need to hide the half BP density (in +y) to show that the $\vec{\mathbf{B}}$ vector is uni-directional in -y direction. In Figure 1k, we combined Figure 1i and Figure 1j by manual drawing (not by mathematically adding), and it illustrated a combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors in BP density form.

In Figure 1*l*, the spinning $\vec{\mathbf{E}}$ vector (that in Figure 1h) was described by the |2,1,1> QM state in NBP density form (notice that equals to the wave function of $|Y(1,1)|^2$). The spin makes it inversed from nL0 mode of |2,1,0> (see Figure 1e) to nLL mode of |2,1,1> (see Figure 1*l*). The direction of the spin of the $\vec{\mathbf{E}}$ vector was added in Figure 1*l*. In Figure 1m, the orthogonal companion $\vec{\mathbf{B}}$ vector (that in Figure 1h) was described by the |2,1,0> QM state, and the spin makes it inversed from nLL mode of |2,1,1> (see Figure 1f) to nL0 mode of |2,1,0> (see Figure 1*m*). In Figure 1n, we combined Figure 1*l* and Figure 1m by manually drawing (not by mathematically adding), and it illustrated a combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors in NBP density form.

In Figure 2, the BP density of all three states at n=2 and *l*=1, |2,1,0>, |2,1,1>, and |2,1,-1>, was added mathematically (only the θφ-2D part, i.e., $|Y(1,0)|^2 + |Y(1,1)|^2 + |Y(1,-1)|^2$), and it ended as a perfect sphere. Remember that in the previous SunQM papers, the 3D wave packet of a photon (or any particle/planet) was described in sphere (see SunQM-6s1's Fig-4), thus we tried to illustrate the shape the combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ of both the BP density form (Figure 1k) and the NBP density form (Figure 1n) in a spherical shape (simply because from my "first principle thinking", they should be in a shape like a ball).

Third, let's explain the Figure 1o through Figure 1u. In the explanation of SunQM-6s2's section II-f-9, we showed that the spinning $\vec{\mathbf{E}}$ vector in the aphelion region of the electron's elliptical orbit (in a H-atom, spinning from +z to -x axis) made its companion $\vec{\mathbf{B}}$ vector points to -y axis (according to the right hand rule), while the strong deceleration of the same spinning $\vec{\mathbf{E}}$ vector in the perihelion region of the electron's elliptical orbit (spinning from -z to +x axis, that equivalent to an acceleration in opposite direction) made its companion $\vec{\mathbf{B}}$ vector temporarily points to +y axis (also according to the right hand rule). Figure 1o (of the current paper) showed (in force-line description) that a $\vec{\mathbf{E}}$ vector's strong decelerated spin (in the perihelion region of an elliptical orbit, that equivalent to the acceleration in the opposite direction) caused its companion $\vec{\mathbf{B}}$ vector to opposite its direction (from the -y direction to +y direction, or point away from the reader). Thus, Figure 1o through Figure 1u are similar as that of Figure 1h through Figure 1n, except opposite the directions of both $\vec{\mathbf{E}}$ vector's spin and $\vec{\mathbf{B}}$ vector.

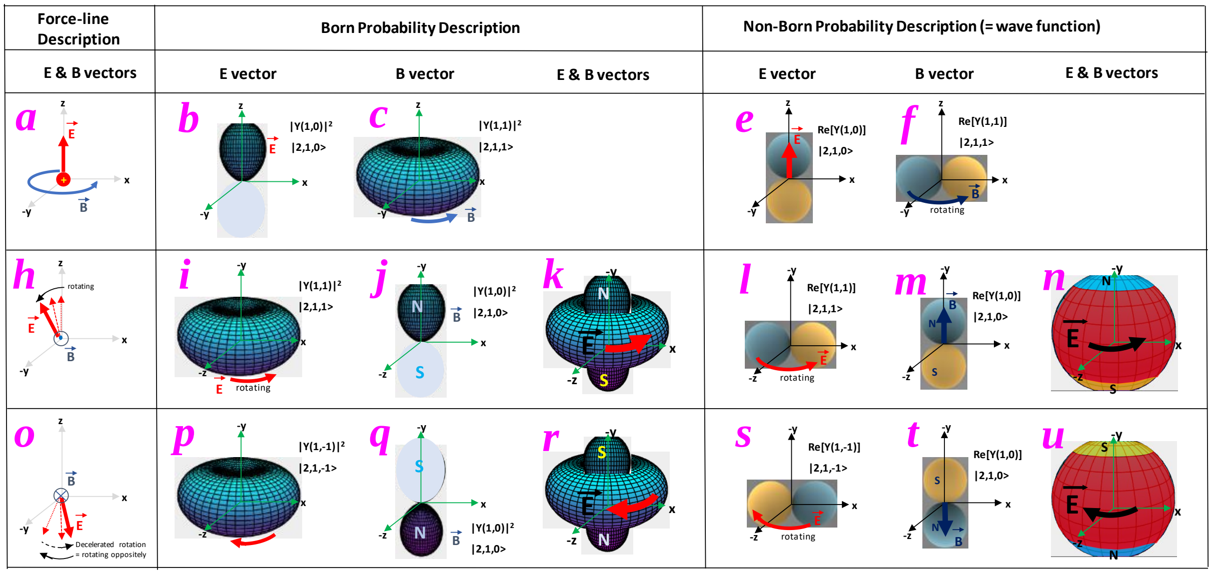

Figure 1. Using either the Born probability (BP) 3D density map, or the non-Born probability (NBP) 3D density map, to describe a propagating photon's 3D (spherical) wave packet. Spherical 3D plot of the Born probability |Y(1,0)|^2, |Y(1,1)|^2, and |Y(1,-1)|^2 were performed by using MathStudio (http://mathstud.io/) software. NBP (= wave function, the blue/yellow balls represent the function value that is positive/negative) diagram was copied and cut from wiki "Spherical harmonics". Author: Inigo.quilez. Copyright: CC BY-SA 3.0. Note: in Figure 1, all nL0 mode's BP density has its half part covered by using a grey patch, to show that the BP density illustrated here should be uni-directional.

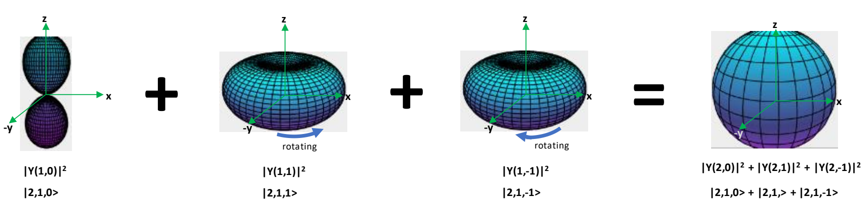

Figure 2. To illustrate that the BP density of all three states (at n=2 and *l*=1), |2,1,0>, |2,1,1>, and |2,1,-1>, when added mathematically (only the spherical harmonic part $|Y(1,0)|^2 + |Y(1,1)|^2 + |Y(1,-1)|^2$), it ended as a perfect sphere. Plotted by using MathStudio (http://mathstud.io/) software. (Note: Using traditional xyz-coordinate).

I-b. Using three QM states, |2,1,1>, |2,1,0>, and |2,1,-1>, and the oscillation among them, to describe a propagating photon's QM state and the dynamic change between QM states

The purpose of showing Figure 1 is to use |2,1,m> QM states (where m = -1, 0, +1) to describe the oscillation of the combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors in the 1D transverse electromagnetic wave. For this purpose, let's first define Figure 1n (and Figure 1k) as "**state A**", and define Figure 1u (and Figure 1r) as "**state C**". In the 1D transverse electromagnetic wave, there are some times that the combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors equals to zero, and we define it as in "**state B**". Here is the summery of states A, B, and C (using BP description):

State A: $\vec{\mathbf{E}}$ field vector is in 100% of |2,1,1> QM state (in uni-directional spinning from +z axis to -x axis), $\vec{\mathbf{B}}$ field vector is in 100% of |2,1,0> QM state with the probability intensity point only to -y axis (to fit to the right hand rule);

State C: $\vec{\mathbf{E}}$ field vector is in 100% |2,1,-1> QM state (in uni-directional spinning from +z axis to +x axis), $\vec{\mathbf{B}}$ field vector is in 100% |2,1,0> QM state with the probability intensity point only to +y axis (to fit to the right hand rule);

State B: $\vec{\mathbf{E}}$ field vector is 1/3 probability in |2,1,1> QM state, 1/3 probability in |2,1,0> QM state, and the last 1/3 probability in |2,1,-1> QM state, and because the same $\vec{\mathbf{E}}$ field vector points to all 4π direction uniformly (or isotropic, based on Figure 2. Also see Appendix B for more discussion), the add-up $\vec{\mathbf{E}}$ field vector shows zero; $\vec{\mathbf{B}}$ field vector is also one-third in |2,1,1> QM state, one-third in |2,1,0> QM state, and the last one-third in |2,1,-1> QM state, and because the same $\vec{\mathbf{B}}$ field vector is in a complete RF (RotaFusion, or rotation diffusion), the add-up $\vec{\mathbf{B}}$ field vector also shows zero; (Note: Figure 2 can be helpful for understanding this concept).

For the purpose of explaining the 1D transverse electromagnetic wave, we can further assume that state A and state C are always in oscillation (and using the state B as the middle state, see Figure 3). If so, then the dynamics of this oscillation can be described as: **From state A to state B**: ⅓ probability of |2,1,1> shifts to probability of |2,1,0> , and ⅓ probability of |2,1,1> shifts to probability of |2,1,0> then to |2,1,-1> , only the last ⅓ probability of |2,1,1> stays at |2,1,1> ; **From state B to state C**: ⅓ probability of |2,1,1> shifts to probability of |2,1,0> then to |2,1,-1> , and ⅓ probability of |2,1,0> shifts to probability of |2,1,-1> , and the last ⅓ probability of |2,1,-1> stays at |2,1,-1> ; From state C to state B to state A: reverse the above process.

Alternatively, we can define the **state B** as the "**base QM state"** |2,1,m>, where m = -1, 0, +1 is always in mixture and in equal probability, so that the above oscillation is between |2,1,1> QM state (i.e., state A) and |2,1,-1> QM state (i.e., state C) around the base QM state (i.e., state B). (Also see Appendix C for more discussion).

With all above preparative work ready, now we can re-explain the 1D transverse electromagnetic wave as a Born probability density ball and/or an NBP density ball (that is determined by the Schrodinger equation/solution). Figure 4a showed a typical drawing of a 1D transverse electromagnetic wave that can be seen in many text books of physics [29]. (Note: Figure 4a represents a matured photon (see SunQM-6s2's Fig-7 for explanation), and we want to use the matured photon (rather than the newborn photon) because it is easier to explain). Figure 4b is the same as that of Figure 4a, except both the -y axis and z axis are rotated 90° along x axis, to match the xyz coordinate in Figure 1n and Figure 1u. In Figure 4c, we showed that how the $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors of the 1D transverse wave correlate to the NBP description in state A, B and C at different time points (from t_1 to t_5). (Note: Here we used NBP rather than BP, because in {N,n} QM, we should use NBP whenever is possible. Note: See SunQM-6s1's Fig-5b and Fig-7 for the explanation of t_1 through t_5). We can see that at the time points of t_1, t_2, t_3, t_4 and t_5, the $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors of the 1D transverse wave correlate to the NBP description in state A, B, C, B, and A. It equivalent to a full cycle of oscillation that was shown in Figure 3.

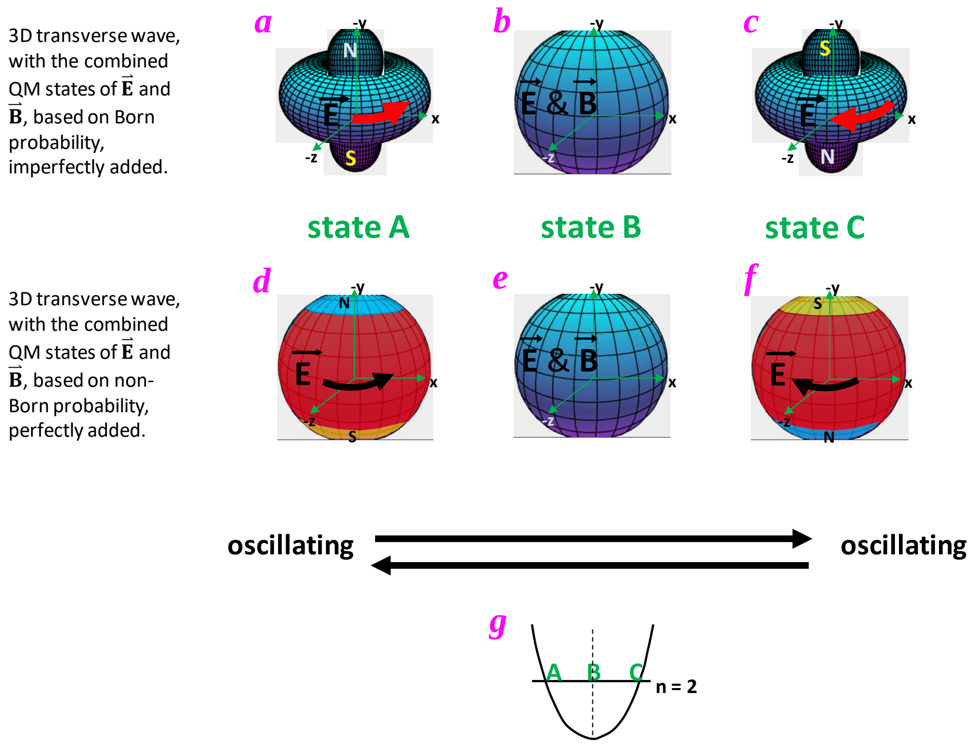

Figure 3. To illustrate that a propagating photon's state A and state C are in oscillation, with the state B as the middle state.
Figure 3 (a, b, c). State A, state B, and state C are presented in Born probability map.
Figure 3 (d, e, f). State A, state B, and state C are presented in non-Born probability map.
Figure 3g. Using a simple harmonic oscillator quantum potential well with n=2 [30] ~ [31] to illustrate the oscillation between state A and state C (through state B).

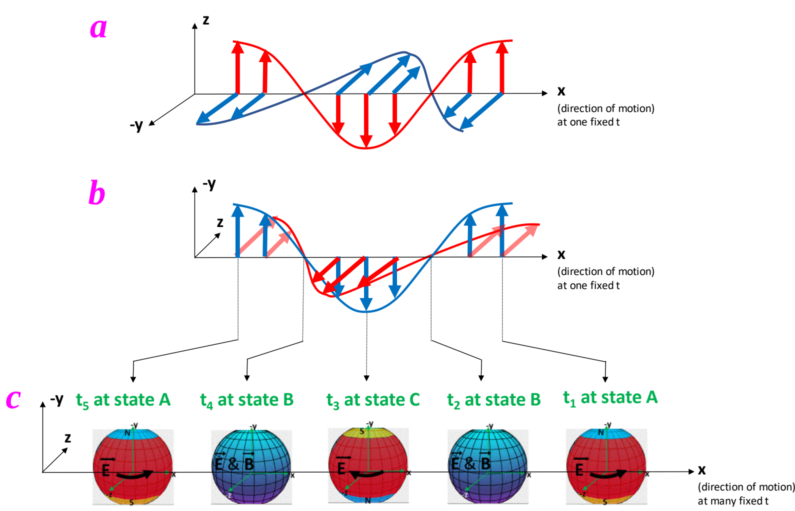

Figure 4 (a, b, c). Correlating the $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors of the 1D transverse wave to the NBP description in state A, B, and C.

However, showing all five states in one diagram (in Figure 4c) may cause confusion on understanding the photon propagation. (In fact, the 1D transverse electromagnetic wave diagram (in Figure 4a) also causes the same confusion on understanding the photon propagation). In a more intuitive presentation for a photon propagation, it should be that there is only one 3D spherical NBP density ball that is moving along x axis, and it oscillates between three QM states (A, B and C), as shown in Figure 5. In Figure 5a, we showed a propagating photon within one cycle of oscillation (between states A, B, C, B, and A, here we named it as **ABCBA cycle**). Form SunQM-6s2's Fig-7, we learned (by partly deduction, and partly hypothesis) that for a photon's 3D wave packet, any one shell (inside this 3D wave packet) has the size (in diameter) of about one wavelength (so that the core of a 3D wave packet has shortest wavelength, then from the inner shell, middle shell, outer shell, the wavelength increases). In Figure 5a, all five balls represented the same shell (at five different time-points t_1 through t_5) within a single 3D wave packet of a propagating photon (although each of five balls represents one of three states, A, B, and C). The diameter of the shell is one wavelength, which also equals to the propagating distance after one of ABCBA cycle. This means, when this ball moved along x axis for a distance of one diameter (= one wavelength = one wave period), it finished one ABCBA cycle. Then, from state A to state B, the ball must have moved ¼ wavelength, (Note: for outer shell's ¼ λ movement, the inner shell must have moved many of its λ because it has shorter λ), and then each of state B to C, or C to B, or B to A also moved ¼ wavelength. Alternatively, we can say that in one wave period (or propagates for one wavelength), a propagating photon's $\vec{\mathbf{E}}$ vector's QM state oscillates between |2,1,1> QM state (i.e., state A) and |2,1,-1> QM state (i.e., state C) around the base QM state |2,1,m=0,±1> QM state (i.e., state B). Figure 5b illustrated the same propagation but in many ABCBA cycles.

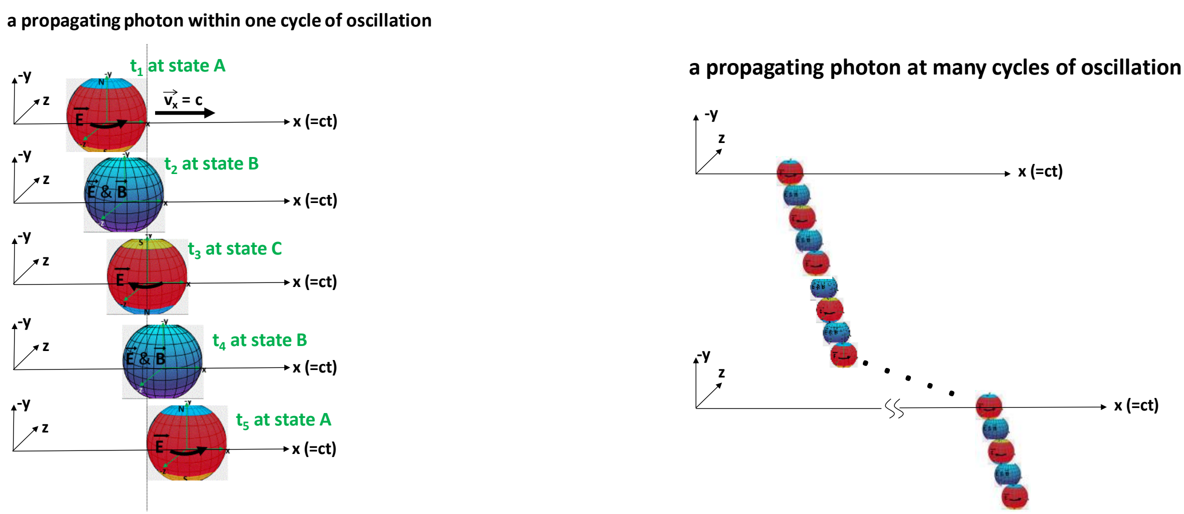

Figure 5. To illustrate that a single propagating photon should be described by a single propagating NBP density ball with |2,1,±1> QM state oscillation (or in ABCBA cycle). Figure 5a (left), for a single cycle of oscillation. Figure 5b (right), for many cycles of oscillation.

I-c. Adding the description of the forever size-growing to a propagating photon's 3D wave packet

In the previous SunQM papers, we have showed that a photon is always increasing its size (either by expanding the size of the existing shells or by adding new shell to the 3D wave packet) during propagation from low n state to high n state (see SunQM-6s1's Fig-4 and SunQM-6s3's Table 3). After adding this character (to Figure 5), Figure 6 illustrated a propagating photon, (while its $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors' QM state oscillating from state A to B and then to C), how its QM state increased from n state to n+b_1 state then to n+b_2 state (where both b_1 and b_2 are positive integers, like that n is integer), and how its size (or the outmost shell) also increased from n shell to n+b_1 shell then to n+b_2 shell respectively. Following are the more detailed explanation for Figure 6:

1) As mentioned before, we are using a matured photon as the example for the explanation. From SumQM-6s1's Table-2, we had showed that when a 656.1 nm photon emitted from a H-atom propagates to 3 mm away with n = 6^5 = 7776, it can be treated as matured (i.e., its shape become spherical and the all shells and core of the 3D spherical wave packet become concentric). So, for a matured photon, its n number (that based on the H-atom QM's n number) is always very large in comparison to the increment of Δn = 1 (i.e., from n state to n+1 state).

2) For the n state assignment, it follows Bohr formula $r_n = r_1 n^2$ (or $x_n = x_1 n^2$) along the photon's propagation axis x, so that usually ($x_{n+3} – x_{n+2}$) is larger than ($x_{n+2} – x_{n+1}$). However, due to the n is very large, the nonlinear relationship between r_n and n in the Bohr equation now become roughly linear relationship $\Delta r \approx 2nr_1 (\Delta n)$, where $2nr_1 \approx$ constant (under the condition of Δn =1, or Δn << n, see SunQM-7's eq-8). Therefore, for a matured photon, its small increment of Δn =1 has a (practically) linear relationship with increment of Δx as well as the increment of Δt. Thus, ($x_{n+3} – x_{n+2}$) = ($x_{n+2} – x_{n+1}$), and ($t_{n+3} – t_{n+2}$) = ($t_{n+2} – t_{n+1}$).

3) Now let's use a 656.1 nm photon (note: it has a base-size of 2r = λ = 656.1 nm) that is propagating along x axis as the example, and let's assume that one unit of the x axis is equals to 656.1 nm.

3a) According to SunQM-6s3's Table 3, if using the Sun{N,n//6} QM structural system with r_1 =1.38E+8 meters (i.e., the cold r-track), then a 656.1 nm photon has a base-size of around Sun{-10,3//6}, and a second-max-size at around Sun{0,3//6}. In Table 1, using the similar conception, we showed that if using the H-atom{N,n//6} QM structural system with r_1 = 5.29E-11 meters, then the same 656.1 nm photon can be presented as that it has a base-size at around H-atom{2,2//6}, and the second-max-size at around H-atom{12,2//6}. (Note: In Table 1, the reason to use H-atom{N,n//6} QM structure to describe a 656.1 nm photon is because this photon is produced from a H-atom. The reason to use Sun{N,n//6} QM structure to describe a 656.1 nm photon is because this photon is produced from a H-atom that inside our Sun and it propagated to our Earth. The reason to use phot{N,n//6} QM structure to describe a 656.1 nm photon is because this photon has a base-size of 656.1 nm).

3b) Now we choose to use the second-max-size of a 656.1 nm photon to be the example for Figure 6. According to Table 1, it has total n = 2*6^12 (= 4.36E+8), and we write it as in "n state" with "n = 2*6^12". So, in Figure 6a we assign that at the time t_n (=0), this 656.1 nm photon is in n state (with n = 2*6^12), and at the x_n position. This 3D spherical wave packet has the size of the outmost shell (or the n shell) in diameter = $2r_n = \lambda_n$ = 2.01E+9 meters (calculated as $2r_n = 2r_1 n^2$ = 2* (5.29E-11) * (2*6^12)^2, also see Table 2 column 13 row 5). (Note: More accurately, for the 100% field occupancy, we should use n+1 = 2*6^12 + 1 to calculate the size. Obviously, here it can be treated as n + 1 ≈ n = 2*6^12).

3c) In Figure 6b, at the time t_{n+b1} (that is (¼ λ_n) /c = 1.67 second), the n (= 2*6^12) shell of this 656.1 nm photon is propagated for a distance of ¼ λ_n, (or, (2.01E+9) /4 = 5.01E+8 meters), and according to Figure 5a, this n shell must have oscillated from state A to the state B (because of the ¼ λ_n distance). During this propagation, besides its n shell is retained, its forever-growing outmost shell is (newly) increased from n shell to n+b_1 shell, with the diameter increased by 1.5×, or, $2r_{n+b1} = \lambda_{n+b1}$ = (2.01E+9)×(1 + 0.5) = 3.01E+9 meters. Using Bohr formula $r_n = r_1 n^2$, we calculated out that n+b_1 = 2.45*6^12. Therefore, when this 656.1 nm photon's outmost shell increased from n (=2.00*6^12) shell (or n state) to n+b_1 (= 2.45*6^12) shell (or n+b_1 state, see Table 2 column 14), its n shell's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors oscillated from state A to state B.

3d) Similarly, in Figure 6c, at the time t_{n+b2} (that is (½ λ_n) /c = 3.34 second), the n (= 2*6^12) shell of this 656.1 nm photon is propagated for the distance of ½ λ_n, (or, 2.01E+9 /2 = 1.00E+9 meters), and according to Figure 5a, this n shell must have oscillated from state A to the state C (because of the ½ λ_n distance). During this propagation, besides its both n shell and n+b_1 shell are retained, its forever-growing outmost shell is (newly) increased from n+b_1 shell to n+b_2 shell, with the diameter increased (totally) by 2.0×, or, $2r_{n+b2} = \lambda_{n+b2}$ = (2.01E+9)×(1 + 1) = 4.01E+9 meters. Using Bohr formula $r_n = r_1 n^2$, we calculated out that n+b_2 = 2.83*6^12. Therefore, when this 656.1 nm photon's outmost shell increased from n (=2.00*6^12) shell (or n state) to n+b_2 (= 2.83*6^12) shell (or n+b_2 state, see Table 2 column 15), its n shell's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors oscillated from state A to state C.

3e) This process repeated again and again, until the newly formed outmost shell is too big, and then it will be trimmed off (according to the Hubble's constant, see SunQM-6s2).

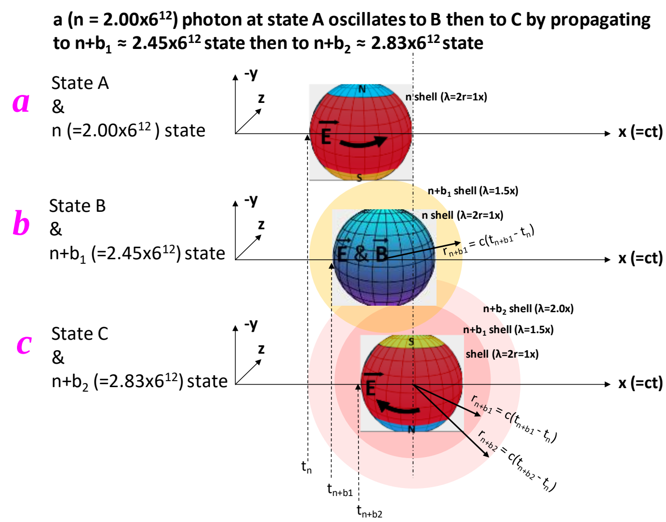

Figure 6. To illustrate the size-growing of a propagating photon that propagates from n state to n+b_1 state, then to n+b_2 state (note: the shown sizes are not on scale), with its QM state oscillation between state A, B, and C. Both the dark-red color ball (in Figure 6a and Figure 6c) and blue ball (in Figure 6b) represent the n shell of a n state photon, the yellow color ball (in Figure 6b) represents the n+b_1 shell of a n+b_1 QM state photon; the middle-light-red color ball (in Figure 6c) represents the n+b_1 shell of a n+b_2 QM state photon, the light-red color ball (in Figure 6c) represents the n+b_2 shell of a n+b_2 QM state photon.

Table 1. Using the Bohr radius r_1 = 5.29E-11 meters as {0,1//6} to setup a new {N,n//6} system, named as **H-atom{N,n//6}**, and then the base-size of a 656.1 nm photon can be described as it has a size of H-atom{2,2//6}.

Sun{N,n//6} QM structure						Using Sun{N,n//6} to describe a 656 nm photon's 3D wave packet							Using H-atom{N,n//6} to describe a 656 nm photon's 3D wave packet					
N=	n=	total n=	Cold-G r track r_n=r_1*n^2			photon's n=	r of each shell	λ =2r of each shell	f =c/λ of each shell	656 nm photon's	Sun{N,n//6}	phot{N,n//6}	N=	n=	total n=	r_n=r_1*n^2 r_1=5.29E-11 m	λ =2r of each shell	H-atom{N,n//6}
			m	AU	ly		m	m	Hz							m	m	
-22	1	7.60E-18	7.94E-27															
-21	1	4.56E-17	2.86E-25			3	2.57E-24	5.15E-24	5.83E+31	core-size	{-21,3//6}	phot{-11,1//6}						
-20	1	2.74E-16	1.03E-23			3	9.27E-23	1.85E-22	1.62E+30		{-20,3//6}	phot{-10,1//6}						
-19	1	1.64E-15	3.71E-22			3	3.34E-21	6.67E-21	4.50E+28		{-19,3//6}	phot{-9,1//6}						
-18	1	9.85E-15	1.33E-20			3	1.20E-19	2.40E-19	1.25E+27		{-18,3//6}	phot{-8,1//6}						
-17	1	5.91E-14	4.80E-19			3	4.32E-18	8.65E-18	3.47E+25		{-17,3//6}	phot{-7,1//6}						
-16	1	3.54E-13	1.73E-17			3	1.56E-16	3.11E-16	9.64E+23		{-16,3//6}	phot{-6,1//6}						
-15	1	2.13E-12	6.23E-16			3	5.60E-15	1.12E-14	2.68E+22		{-15,3//6}	phot{-5,1//6}						
-14	1	1.28E-11	2.24E-14			3	2.02E-13	4.03E-13	7.44E+20		{-14,3//6}	phot{-4,1//6}						
-13	1	7.66E-11	8.07E-13			3	7.26E-12	1.45E-11	2.07E+19		{-13,3//6}	phot{-3,1//6}						
													0	1	1	***5.29E-11***	1.06E-10	H-atom{0,1//6}
-12	1	4.59E-10	2.90E-11			3	2.61E-10	5.23E-10	5.74E+17		{-12,3//6}	phot{-2,1//6}	0	2	2	2.12E-10	4.23E-10	H-atom{0,2//6}
-11	1	2.76E-09	1.05E-09			3	9.41E-09	1.88E-08	1.59E+16		{-11,3//6}	phot{-1,1//6}	1	2	12	7.62E-09	1.52E-08	H-atom{1,2//6}
-10	1	1.65E-08	3.76E-08			3	3.39E-07	***6.78E-07***	4.43E+14	base-size	{-10,3//6}	phot{0,1//6}	2	2	72	2.74E-07	5.48E-07	H-atom{2,2//6}
-9	1	9.92E-08	1.36E-06			3	1.22E-05	2.44E-05	1.23E+13		{-9,3//6}	phot{1,1//6}	3	2	432	9.87E-06	1.97E-05	H-atom{3,2//6}
-8	1	5.95E-07	4.88E-05			3	4.39E-04	8.78E-04	3.42E+11		{-8,3//6}	phot{2,1//6}	4	2	2592	3.55E-04	7.11E-04	H-atom{4,2//6}
-7	1	3.57E-06	1.76E-03			3	1.58E-02	3.16E-02	9.49E+09		{-7,3//6}	phot{3,1//6}	5	2	1.56E+04	1.28E-02	2.56E-02	H-atom{5,2//6}
-6	1	2.14E-05	6.32E-02			3	5.69E-01	1.14E+00	2.64E+08		{-6,3//6}	phot{4,1//6}	6	2	9.33E+04	4.61E-01	9.21E-01	H-atom{6,2//6}
-5	1	1.29E-04	2.28E+00			3	2.05E+01	4.10E+01	7.32E+06		{-5,3//6}	phot{5,1//6}	7	2	5.60E+05	1.66E+01	3.32E+01	H-atom{7,2//6}
-4	1	7.72E-04	8.19E+01			3	7.38E+02	1.48E+03	2.03E+05		{-4,3//6}	phot{6,1//6}	8	2	3.36E+06	5.97E+02	1.19E+03	H-atom{8,2//6}
-3	1	4.63E-03	2.95E+03			3	2.66E+04	5.31E+04	5.65E+03		{-3,3//6}	phot{7,1//6}	9	2	2.02E+07	2.15E+04	4.30E+04	H-atom{9,2//6}
-2	1	2.78E-02	1.06E+05			3	9.56E+05	1.91E+06	1.57E+02		{-2,3//6}	phot{8,1//6}	10	2	1.21E+08	7.74E+05	1.55E+06	H-atom{10,2//6}
-1	1	1.67E-01	3.82E+06			3	3.44E+07	6.88E+07	4.36E+00		{-1,3//6}	phot{9,1//6}	11	2	7.26E+08	2.79E+07	5.57E+07	H-atom{11,2//6}
0	1	1	***1.38E+08***			3	1.24E+09	2.48E+09	1.21E-01	2nd-max-size	{0,3//6}	phot{10,1//6}	12	2	4.35E+09	1.00E+09	2.01E+09	H-atom{12,2//6}
1	1	6	4.95E+09			2	1.98E+10	3.96E+10	7.57E-03	max-size	{1,2//6}	~ phot{11,1//6}	13	2	2.61E+10	3.61E+10	7.22E+10	H-atom{13,2//6}
2	1	36	1.78E+11	1.19E+00														
3	1	216	6.42E+12	4.29E+01														

Note: Columns 1 ~ 13 were copied from SunQM-6s3's Table 3. Columns 14 ~ 19 were calculated by using the same method as that for columns 7 ~ 13. That is, based on H-atom's r_1 = 5.29E-11 meters, to manually adjust the N and n value to make $\lambda = 2r_n = 2(r_1 n_{total}^2)$ close to 656.1 nm. The result: for a base-size of 656.1 nm photon, its size can be described by either the Sun{-10,3//6} with r_1=1.38E+8 meters, or by the H-atom{2,2//6} with r_1=5.29E-11 meters, or simply by phot{0,1//6} with r_1=6.561E-7 meters.

Table 2. Calculation on a n=2*6^12 photon, for the inner shells' ABCBA cycle periods, and for the n+b_1 or n+b_2 values after the further propagation.

	unit	n=2*6^2	n=2*6^3	n=2*6^4	n=2*6^5	n=2*6^6	n=2*6^7	n=2*6^8	n=2*6^9	n=2*6^10	n=2*6^11	n=2*6^12	n+b_1=2.45*6^12	n+b_2=2.83*6^12
n=		72	432	2592	15552	93312	559872	3.36E+06	2.02E+07	1.21E+08	7.26E+08	4.35E+09	5.33E+09	6.16E+09
r1=	m	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11	5.29E-11
rn=r1*n^2	m	2.74E-07	9.87E-06	3.55E-04	1.28E-02	4.61E-01	1.66E+01	5.97E+02	2.15E+04	7.74E+05	2.79E+07	1.00E+09	1.50E+09	2.01E+09
λ = 2*rn=	m	5.48E-07	1.97E-05	7.11E-04	2.56E-02	9.21E-01	3.32E+01	1.19E+03	4.30E+04	1.55E+06	5.57E+07	2.01E+09		
f = c/λ	1/s	5.47E+14	1.52E+13	4.22E+11	1.17E+10	3.26E+08	9.05E+06	2.51E+05	6.98E+03	1.94E+02	5.39E+00	1.50E-01		
$\Delta x_{(@from\ 6^\wedge 12\ to\ 6^\wedge 12+1)} = \Delta r \approx 2n_{(=6^\wedge 12)} r_1\ (\Delta n)$	m	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01	4.61E-01		
$\Delta t_{(from\ 6^\wedge 12\ to\ 6^\wedge 12+1)} = \Delta x_{(from\ 6^\wedge 12\ to\ 6^\wedge 12+1)} / c$	s	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09	1.54E-09		
$(2^* \Delta x_{(from\ 6^\wedge 12\ to\ 6^\wedge 12+1)}) / \lambda =$	m/m	1.68E+06	4.67E+04	1296.0	36.0	1.0	2.78E-02	7.72E-04	2.14E-05	5.95E-07	1.65E-08	4.59E-10		
													n→Δx=0λ, n+b_1→Δx=0.25λ,	
													n+b_2→Δx=0.5λ	

Note: In Table 2, the green cell with 5.48E-7 meters represents the wavelength closest to λ = 656.1 nm, the base-size of a photon in our example. The orange cells represent a matured photon.

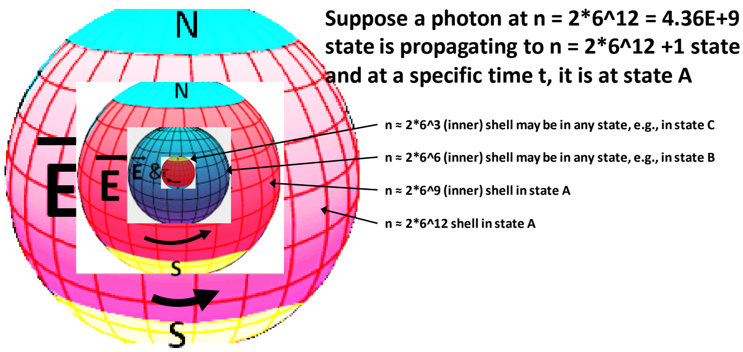

Figure 7. To illustrate that during the propagation, at a certain fixed time (t), an n=2*6^12 = 4.36E+9 state photon if its outmost shell (the n=2*6^12 shell) is at state A, what the state (A, B, or C) will possibly be for the inner shells of this 3D wave packet.

Figure 6 only showed the n shell's $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors oscillation state during the propagation. For the newly expanded (or the newly increased) outmost shell, we still don't know how to determine at what state (of A, B, C) of oscillation it is (for its $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors). However, for those inner shells (of the n = 2*6^12 shell), we do know how to determine in what oscillation state that their $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vectors are (see Table 2). In Table 2, I calculated that the n shell from n = 2*6^12 state to n+1(= 2*6^12 + 1) state propagated $\Delta x = \Delta r \approx 2nr_1(\Delta n)$ = 2*(2*6^12)*(5.29E-11)*1 = 4.61E-1 meters, and within time $\Delta t = \Delta x / c$ = 4.61E-1 / 3E+8 = 1.54E-9 seconds. The row 9 of columns 3~12 of Table 2 showed that during this time (Δt), each of these inner shells (notice that they have different λ, see the row 5) has how many cycles of oscillation. The result showed that for the inner shells that have the comparable sizes (from n = 2*6^11 down to n = 2*6^7), they all have much less than one ABCBA cycle, so that they should all have the similar oscillation state at that of n = 2*6^12 shell. For those really small sized inner shells (from n = 2*6^6 and below), they all have more than one ABCBA cycle per Δt = 1.54E-9 seconds, so they can be in any state (of A, B, and C). Furthermore, from the trend that shown in Table 2, I guessed that the newly formed outmost shell (i.e., the n+b_1 and n+b_2 shells) should have the similar oscillation state that of the n shell.

According to the result in Table 2, Figure 7 illustrated that during a 656.1 nm photon's propagation, at a certain fixed time (t), for a n=2*6^12 = 4.36E+9 state photon, if its outmost shell (the n=2*6^12 shell) is at state A (for the combined $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ field ball), then all the inner shells from n=2*6^12 down to n=2*6^7 must also at state A, and the even-inner shells with n less than 2*6^6 may be at any one of states of A, B, or C. This analysis also revealed that the text book's 1D transverse wave [29] correlates to the {N,n} QM field theory's 3D wave packet only at a photon's base-sized shell (because both of them have λ = 656.1 nm).

Now let me summarize the above work (under the large framework and with the historic development). In SunQM-6, I had re-classified the four fundamental forces (G-, E/M-, S-, W-force) to be three pair of forces: E/RFe-force, G/RFg-force, S/RFs-force. Based on these three new pair of forces, I started to build up the new {N,n} QM field theory. From the classical physics, we know that a photon can be described by the electromagnetic 1D transverse wave, so in the {N,n} QM field theory, the same photon has to be described by the E/RFe-force pair. However, we are not able to directly use the regular (or the static) E/RFe-force field to describe a photon's electromagnetic 1D transverse wave (because in the static E/RFe-force field, the RFe-force field vector has to be in circular, which means it has to be in nLL mode, see Figure 1(a~c)). Then, under the newly proposed "|nL0> elliptical/parabolic/hyperbolic orbital transition model" (see SunQM-6s2 and SunQM-6s3), when I tried to explain the emission process of a photon from an H-atom (also by using the E/RFe-force pair and the {N,n} QM field theory), I could do it by inversing the $\vec{\mathbf{E}}$ vector from nL0 mode to nLL mode, and inversing the $\vec{\mathbf{B}}$ vector from nLL mode to nL0 mode. Then, it is natural to use the same explanation for the propagating photon. So, in the {N,n} field theory (that shown in this section), a propagating photon (in +x direction) has its $\vec{\mathbf{E}}$ vector spinning in xz-plane, while its companion $\vec{\mathbf{B}}$ vector is oscillating in ∓y directions (following the right hand rule, when $\vec{\mathbf{E}}$ vector is doing the normal spin in the aphelion region, or doing the deceleration spin in the perihelion region (that correlate to an elliptical orbit of electron in H-atom)). If this description (in the {N,n} field theory) is correct, then a photon's 1D transverse electromagnetic wave become an overly simplified description: while its $\vec{\mathbf{B}}$ vector description is correct, its $\vec{\mathbf{E}}$ vector description is overly simplified because it projected a xz-plane spinning $\vec{\mathbf{E}}$ vector to the z-axis, so that $\vec{\mathbf{E}}$ vector become oscillating between ±z directions. (Note: See more explanation in the next section).

II. Illustration of a photon's 3D spherical wave packet structure observed under the special relativity

In SunQM-6s1's Fig-3, when using the 3D wave packet to describe a photon's propagation, its core propagates with the light speed c, its outmost shell's wave-front propagates with 2c (in the Euclidean space), and its outmost shell's wave-tail propagates with 0c. This means, when we set the coordinate on the photon's core, this photon's electromagnetic field radiates from the point center of the photon to all 4π directions in the light speed c, and it is just like a single point charge's static electric field radiates to all 4π directions in the light speed c (see Figure 8a). Thus, in this aspect they are the same (in the Euclidean space), and it makes sense. Therefore, under the {N,n} QM, a propagating photon does have a wave-front propagates faster than c. Then its wave-front can interfere with the double-slit, and thus guide the particle core's trajectory to pass through the double-slit (see SunQM-6s1's section III-d). On the other hand, practically, we only can see a photon at its base-size (e.g., a "ball" with a diameter of 656.1 nm), and (practically) we don't see the outer shells of a photon's 3D wave packet (because those (auxiliary) outer shells are designed to help explaining some special characters of a propagating photon). An inside observer see this 656.1 nm photon has the size of Δx = Δy = Δz = 656.1 nm. However, due to the special relativity that caused x-dimensional compressing by a factor of $\sqrt{1 - v^2/c^2}$, as the $\overrightarrow{\mathbf{v}_x}$ increased to the light speed c, (see Figure 8b, also see SunQM-6s7's Fig-3b and Fig-3c), an outside observer see this (x directional propagating) 656.1 nm photon has the size of Δy = Δz = 656.1 nm, but Δx ≈ 0, so that the **dynamic space** of Δx for this 656.1 nm photon is compressed to zero. Then, based on the result of Figure 8b, a photon's 3D spherical wave packet structure will be seen as something like Figure 8c if viewed by an outside observer. Figure 8c showed that although the dynamic space of Δx for the wave-front (from c×t to 2c×t) is compressed to zero, the dynamic space of Δx for the wave-tail is still almost the same as the Euclidean space. (Note: From this point of view, all previous figures about the newborn, matured, old and decaying photon's 3D wave packet (see SunQM-6s2's Fig-7j, Fig-7k, Fig-9) were drawn from an inside observer's view).

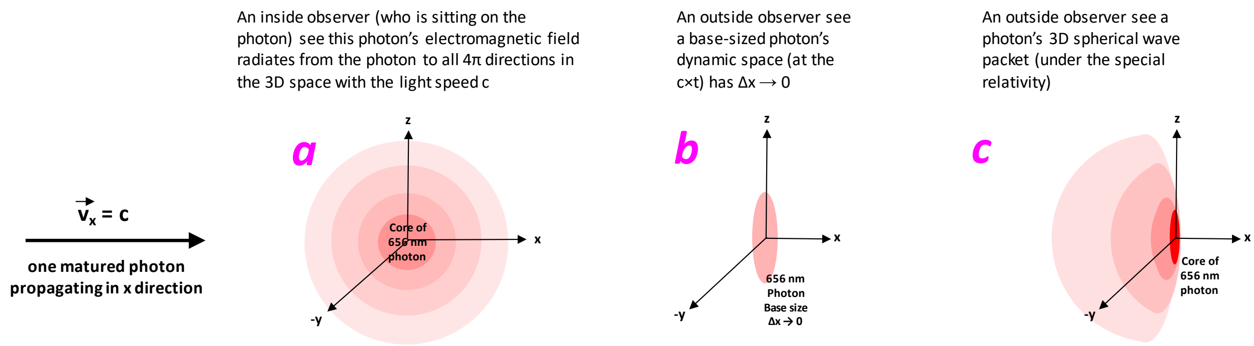

Figure 8a. Illustration of a (matured) photon's 3D spherical wave packet structure viewed by an inside observer.
Figure 8b. Illustration of a (matured) photon's base-sized spherical structure viewed by an outside observer.
Figure 8c. Illustration of a (matured) photon's 3D spherical wave packet structure viewed by an outside observer.

III. Besides n=2 QM states, other n > 2 QM states can also be used to describe a propagating photon's QM state dynamic change

In the above work, we only used the n=2 QM state (i.e., $|2,1,m_{=0,\pm1}>$) to describe a photon's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors oscillation in the 3D spherical wave packet. In fact, we may can use a |n,*l*,m> QM state at any n number to do the same description.

Example-1, we can use n=4 (with *l* =3) QM state to describe a photon's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors oscillation in the 3D spherical wave packet: the state A correlates to $\vec{\mathbf{E}}$ at 100% of |4,3,3> and $\vec{\mathbf{B}}$ at 100% of |4,3,0>, the state C correlates to $\vec{\mathbf{E}}$ at 100% of |4,3,-3> and $\vec{\mathbf{B}}$ at 100% of |4,3,0>, and the state B correlates to both $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ at equal percentage of |4,3,m> where m = -3, -2, -1, 0, +1, +2, +3;

Example-2, alternatively, we also can use n=4 (with *l* =2) QM state to describe a photon's $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ vectors oscillation in the 3D spherical wave packet: the state A correlates to $\vec{\mathbf{E}}$ at 100% of |4,2,2> and $\vec{\mathbf{B}}$ at 100% of |4,2,0>, the state C correlates to $\vec{\mathbf{E}}$ at 100% of |4,2,-2> and $\vec{\mathbf{B}}$ at 100% of |4,2,0>, and the state B correlates to both $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ at equal percentage of |4,2,m> where m = -2, -1, 0, +1, +2;

Example-3, in SunQM-6's Table 2 and eq-1, I had (conceptually) used the combination of multiple n(s) of |n,*l*,m> QM states to describe the QM mode of $\vec{\mathbf{E}}$ vector and $\vec{\mathbf{B}}$ vector. Although it is more accurate, it is too complicated to handle. So in the rest papers (of SunQM-6 series), I (mostly) no longer use the combination of n(s), but use only a single n QM state to describe the QM mode of $\vec{\mathbf{E}}$ vector and $\vec{\mathbf{B}}$ vector for the ground state and/or excited state. To make the description even more simple, for each n, we limited the *l* = n-1 (= L), so that now we can use only nLL mode or nL0 mode for the description (for the $\vec{\mathbf{E}}$ vector field's and the $\vec{\mathbf{B}}$ vector field's QM state). In the section-I of the current paper, to make the description the simplest, I further limited the n to be n=2 only, so that now we only use nLL (i.e., |2,1,1> or |2,1,-1>) or nL0 (i.e., |2,1,0>) to describe the QM state of $\vec{\mathbf{E}}$ vector and the $\vec{\mathbf{B}}$ vector in a photon.

IV. Describing an ABCBA cycle for a newborn photon, or an old and decaying photon

All above description is for a matured photon (i.e., all of its 3D wave packet spherical shells and core were drawn as concentric circles, see SunQM-6s2's Fig-7k, also see Figure 9b). Then, for a newborn photon (see SunQM-6s2's Fig-7j, where the core's center is drawn behind all other shells' centers), or for an old and decaying photon (see SunQM-6s2's Fig-9, where the core's center is drawn ahead of all other shells' centers), the above explanation become much more complicated. For example, for a newborn photon (from H-atom's n=3 to n=2 transition), we may can use the following simplified description for its ABCBA cycle (see Figure 9a):

t_1 at state A contains |3,2,2> for the $\vec{\mathbf{E}}$ field, and |3,2,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along -y axis);

t_2 at state B contains $|3,2,m_{=-2..+2}>$ for both $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ field (both showed zero net vectors);

t_3 first at a state C contains |3,2,-2> for the $\vec{\mathbf{E}}$ field, and |3,2,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along +y axis), then shifts to a state C contains |2,1,-1> for the $\vec{\mathbf{E}}$ field, and |2,1,0> for the $\vec{\mathbf{B}}$ field (also with the portability density vector along +y axis);

t_4 at state B contains $|2,1,m_{=-1..+1}>$ for both $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ field (both showed zero net vectors);

t_5 at state A contains |2,1,1> for the $\vec{\mathbf{E}}$ field, and |2,1,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along -y axis).

Similarly, we may can approximately describe an old and decaying photon's ABCBA cycle as (see Figure 9c, note: L = n-1),

t_1 at state A contains |n,L,L> for the $\vec{\mathbf{E}}$ field, and |n,L,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along -y axis);

t_2 at state B contains $|n,L,m_{=-L..+L}>$ for both $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ field (both showed zero net vectors);

t_3 first at a state C contains |n,L,-L> for the $\vec{\mathbf{E}}$ field, and |n,L,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along +y axis), then shifts to a state C contains |n+1,n,-n> for the $\vec{\mathbf{E}}$ field, and |n+1,n,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along +y axis);

t_4 at state B contains $|n+1,n,m_{=-n..+n}>$ for both $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ field (both showed zero net vectors);

t_5 at state A contains | n+1,n,n > for the $\vec{\mathbf{E}}$ field, and | n+1,n,0> for the $\vec{\mathbf{B}}$ field (with the portability density vector along -y axis). (Note: see Appendix D for an alternative description).

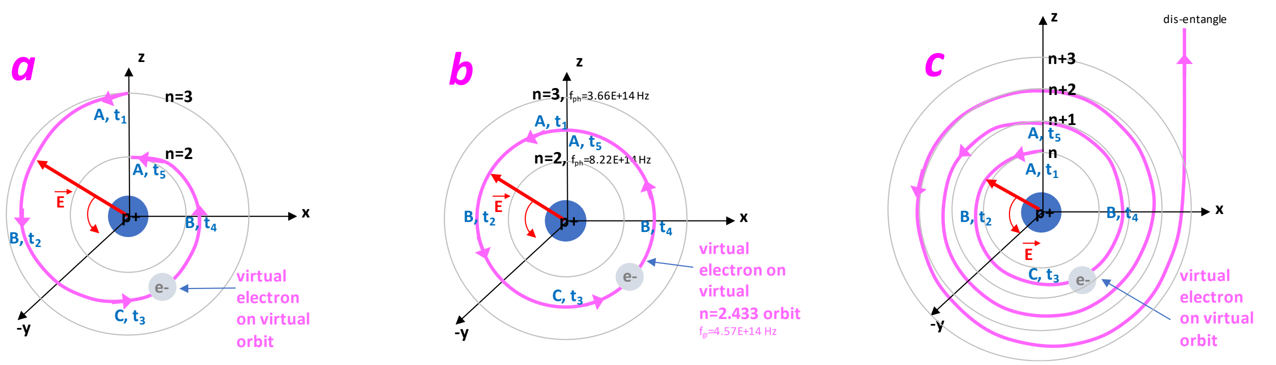

Figure 9a. To illustrate an ABCBA cycle for a newborn photon (from H-atom's n=3 to n=2 transition);
Figure 9b. To illustrate an ABCBA cycle for a matured photon (originated from H-atom's n=3 to n=2 transition);
Figure 9a. To illustrate an ABCBA cycle for an old and decaying photon.

V. The new explanation of a propagating photon's spin vector: (by default) it is perpendicular to the photon's propagation direction, and it can be reoriented to appear as the circular/elliptical/linear polarization

In SunQM-6s2, we happened to choose H-atom's n=3 to n=2 transition as |3,2,0> to |2,1,0> QM state transition. (Note: In this case, the contour line of the Born probability density map of the |3,2,0> QM state represents the electron's orbital trajectory that equivalents to the photon's $\vec{\mathbf{E}}$ vector's spinning trajectory. It does not directly represent the photon's spinning $\vec{\mathbf{E}}$ vector itself (because the spinning $\vec{\mathbf{E}}$ vector is described in nLL mode (see in SunQM-6s5's Fig-1i), only a static $\vec{\mathbf{E}}$

vector is described as in nL0 mode (see in SunQM-6s5's Fig-1b))). According to the selection rule "*No transition occur unless $\Delta l = \pm 1$*" [32], the transition between |3,2,0> to |2,1,0> is allowed. According to the text book [33], "*the orbital angular momentum of an H atom must change by one unit when it emits a photon, conservation of angular momentum tells us that the photon must carry off angular momentum. Indeed, experimental evidence of many sorts shows that the photon can be assigned a spin angular momentum of 1ℏ*".

Wiki "Spin angular momentum of light" said "*Spin is the fundamental property that distinguishes the two types of elementary particles: fermions with half-integer spins and bosons with integer spins. Photons, which are the quanta of light, have been long recognized as spin-1 gauge bosons. The polarization of the light is commonly accepted as its "intrinsic" spin degree of freedom. However, in free space, only two transverse polarizations are allowed. Thus, the photon spin is always only connected to the two circular polarizations. … For s single plane-wave photon, the spin can only have two values* $\pm\hbar$". Wiki "Polarization (physics)" said: "*Circularly polarized electromagnetic waves are composed of photons with only one type of spin, either right- or left-hand. Linearly polarized waves consist of photons that are in a superposition of right and left circularly polarized states, with equal amplitude and phases synchronized to give oscillation in a plane*". This description may hint that the left and the right circular polarized electromagnetic waves are the two fundamental wave structures (that even more fundamental than the linear polarized electromagnetic wave). However, for a linear polarized photon, because it has (or it can be decomposed into) the left and the right circular polarization simultaneously, this simultaneous $\pm\hbar$ may leads to the total spin = 0 for a linear polarized photon. This result seems contradictory to the statement of "*the photon can be assigned a spin angular momentum of 1ℏ*" (at least for a linear polarized photon).

In the {N,n} QM field theory, I have to describe a photon's spin angular momentum of $1\hbar$ in a very different way. Figure 10a copied from SunQM-6s1's Fig-1a (but with the xyz-coordinate changed). It showed that a 656.1 nm photon (that emitted from the de-excitation of an electron from the n=3 orbit to n=2 orbit of the H-atom) has its electromagnetic wave (group) frequency (f_{gr} = 4.57E+14 Hz) equals to the difference of the same electron's orbital (phase) frequency at n=3 (f_{ph} = 3.66E+14 Hz) and n=2 (f_{ph} = 8.22E+14 Hz), and the $\vec{\mathbf{E}}$ vector spinning of this 656.1 nm photon can be directly represented by the (spinning of) $\vec{\mathbf{E}}$ vector that points from the H-atom's central proton to a virtual electron that is moving on a virtual circular orbital with n=2.433. (Note: The perfect circular orbit of n=2.433 means that it must correlate to a matured photon (that is simplest to explain)).

Case-0: By default (here named as **Case-0**), a x-directional propagating photon has its electric field force $\vec{\mathbf{E}}$ vector's spin vector $\vec{\mathbf{s}}$ overlap with -y axis (or $\overrightarrow{\mathbf{s}_{-y}}$ = 1, so that it has spin angular momentum of $1\hbar$). However, the direction of this spin vector $\vec{\mathbf{s}}$ can be re-oriented (or modulated) by passing some optical material, (as shown in the following several cases):

Case-1: From Case-0, after passing through one special optical material, if the $\vec{\mathbf{s}}$ vector is re-orientated to overlap with +x axis (or $\overrightarrow{\mathbf{s}_{+x}}$ = 1), then this photon is said to be the right-circular-polarized (see Figure 10b and Figure 10c);

Case-2: From Case-0, after passing through one different optical material, if the $\vec{\mathbf{s}}$ vector is re-orientated to overlap with -x axis (or $\overrightarrow{\mathbf{s}_{-x}}$ = 1), then this photon is said to be the left-circular-polarized;

Case-3: From Case-0, after passing through one different optical material, if the $\vec{\mathbf{s}}$ vector is re-orientated to overlap with +z (or -z) axis (either $\overrightarrow{\mathbf{s}_{+z}}$ = 1 or $\overrightarrow{\mathbf{s}_{-z}}$ = 1), then it is showed up as the linear-polarized with the polarization direction +90° (or -90°) changed in comparison with the Case-0;

Case-4: From Case-0, after passing through one different optical material, if the $\vec{\mathbf{s}}$ vector is re-orientated to overlap with +y axis (or $\overrightarrow{\mathbf{s}_{+y}}$ = 1), then it is showed up as the same linear-polarization direction in comparison with the Case-0, but with the polarization (time) phase delayed by 180°;

Case-5: From Case-0, after passing through one different optical material, if the $\vec{\mathbf{s}}$ vector is re-orientated to a random direction (other than ±x, ±y, or ±z axis), then (generally) it is showed up as an elliptical polarized light. (Note: you can imagine a randomly oriented 2D circular plane in the xyz-3D space is projected onto the fixed yz-2D plane).

Notice that in all these six cases, a propagating photon (including both the original photon and/or the $\vec{\mathbf{s}}$ vector re-oriented photon) always has a spin angular momentum of $1\hbar$, the only difference is that its $\vec{\mathbf{s}}$ vector is re-oriented differently in the 3D space (relative to the propagation direction). Also, under this explanation, or under the {N,n} QM, for a +x directional propagating light, there is no real ±z linear polarized photon, there is only ±y circular polarized photon (that appeared to be ±z linear polarized under the special relativity, see section II).

According to this explanation, a linear-polarized (i.e., $\overrightarrow{s_{-y}}$ = 1 photon) photon can become either a left or a right (but not both) circular-polarized photon by passing through an optical material. Similarly, either a left, or a right circular-polarized photon can become a linear-polarized (i.e., $\overrightarrow{s_{-y}}$ = 1 photon) photon by passing through an optical material. However, I don't believe that we can directly combine one left circular-polarized ($\overrightarrow{s_{-x}}$ = 1) photon and one right circular-polarized ($\overrightarrow{s_{+x}}$ = 1) photon to make them become two linear-polarized ($\overrightarrow{s_{-y}}$ = 1) photons (with or without passing through any optical material), although mathematically you can directly add a left circular to a right circular to become a linear. (Note: This is only a citizen scientist leveled prediction. Readers please let me know if I am wrong). On the other hand, under the {N,n} QM field theory, when combining one left circular-polarized ($\overrightarrow{s_{-x}}$ = 1) photon and one right circular-polarized ($\overrightarrow{s_{+x}}$ = 1) photon, we may can reorient them to be one $\overrightarrow{s_{-y}}$ = 1 and one $\overrightarrow{s_{+y}}$ = 1 circular polarized photons, and then (under the special relativity) they may can appear to be two ±z directional linear polarized (but with a 180° phase difference).

Question: If a photon's $\vec{s}$ = 1ℏ vector is doing RF (RotaFusion, or rotation diffusion), then what we can see?

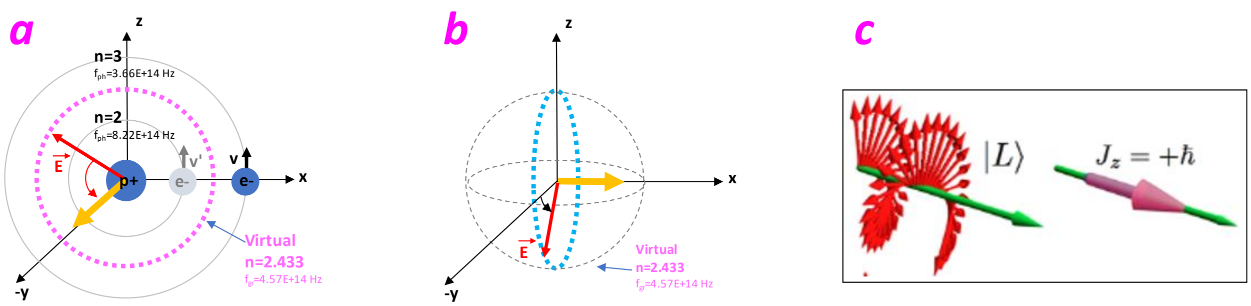

Figure 10a. Illustration of a virtual electron at the virtual orbit n=2.433 for the n=3 to n=2 transition (in H-atom). Notice that the spin vector (of the spinning $\vec{E}$ vector) is $\vec{s}$ = $\overrightarrow{s_{-y}}$ = 1 in -y direction, and emitted photon propagated in +x direction.
Figure 10b. To illustrate that an original $\vec{s}$ = $\overrightarrow{s_{-y}}$ = 1 photon has been transformed into a $\vec{s}$ = $\overrightarrow{s_{+x}}$ = 1 photon (after passing through one optical material, while propagating in x direction), so now its $\vec{E}$ vector spinning in yz-2D plane.
Figure 10c. To illustrate that the trajectory of the spinning $\vec{E}$ vector for a $\vec{s}$ = $\overrightarrow{s_{+x}}$ = 1 photon (while propagating in x direction). Figure copied form wiki "Spin angular momentum of light". Author: E-karimi. Copyright CC BY-SA 3.0. (Note: In the figure, "J_z= +ℏ" should be changed to "J_{+x}= +ℏ").

VI. More discussions (Note: Some of these are the memos for myself).

By far, I have designed and developed a new {N,n} QM field theory (either semi-quantitatively, or conceptually) to describe the process of an H-atom's de-excitation from n=3 to n=2 QM state and the emission and the propagation of a 656.1 nm photon. Now let me summarize it:

1) An n=3, electron can be described by either a NBP density map with |n=3,*l*,m> QM state, or by a 3D wave packet with many shells and one core. After it transited to n=2 state (that also can be described by either a NBP density map with |n=2,*l*,m> QM state, or by a 3D wave packet with many shells and one core), the n=3 electron's outmost shell of the 3D wave packet is dis-entangled from the rest main part (note: the rest main part become the n=2 electron's 3D wave packet), and become a "newborn photon" (or a "low-f photon", with λ = 656.1 nm) that spun-off (or emitted) in x-direction (at the position of the perihelion site in the "|nL0> elliptical/parabolic/hyperbolic orbital transition model", due to it has high uncertainty of $\Delta\vec{p}$ and $\Delta\vec{x}$, and also due to that it is electrically neutral, not attracted by the proton at the center of the H-atom).

2) During the emission process, this newborn photon also developed its own new 3D wave packet. Note: for any 3D wave packet, the wavelength of each shell or core is approximately equals to the diameter of this shell or core, so that the core of a

3D wave packet always has the highest wave frequency while the outmost shell of the same 3D wave packet always has the lowest wave frequency. Based on that "*different frequency-components of the wavepacket travel at different speeds*, …" (see wiki "Group velocity"), in {N,n} QM field theory, we believed that during the propagation, a 3D wave packet's high-frequency core is always propagating a little bit faster than the low-frequency outer shells.

3) For a newborn photon's 3D wave packet, all centers of its 3D wave packet spherical shells and core are not at the same position, they are spread along the propagation direction (i.e., x-axis) with the core's center falling behind the outer shells' centers (see SunQM-6s1's Fig-7j). Then, after propagated for ~ 3 mm away from the H-atom, the new born photon now has all centers of the shells and the core (of its 3D spherical wave packet) concentrated (roughly) at a single point (because of the high-frequency core is propagating a little bit faster than the low-frequency outer shells), and we say that this is a matured photon. Then, after further propagation, all centers of its 3D wave packet spherical shells and core spread again along the propagation direction (i.e., x-axis) with the core's center a little bit ahead of the outer shells' centers (see SunQM-6s1's Fig-9, again because of the high-frequency core is propagating a little bit faster than the low-frequency outer shells), and we say that this is an old photon.

4) During propagation, a 3D wave packet (of a matter wave) always has a tendency to increase its size by expending the size of its shells (or, equivalently, by increasing the width of the wave envelope that is characterized by the wave's group frequency). I believed that the mass of a particle (or a celestial body) will suppress this tendency (or even reverse the size-growing process to become a size-collapsing process, like a star collapsed to be a black hole). Because it is massless, a photon doesn't have this suppression, so that a photon has an intrinsic property of forever size-growing. However, once the expended outmost shell is too big, then it will be trimmed off (and I believe that this actually is the origin of the Hubble's constant, see SunQM-6s2). For example, a 656.1 nm photon, after propagating each ~2.7E+10 meters (that equivalent to its outmost shell grown to r = 2.7E+10 meters), its outmost shell will be trimmed off. In other words, we can say that after it is too old, an old photon's outmost shell is no longer able to keep entangling with the rest main 3D wave packet (because the outmost shell has the largest size of shell, equals to the largest wavelength, or the lowest frequency, or the slowest propagating speed, in comparison to the rest main 3D wave packet), then it is dis-entangled as a newborn low-f photon. Then, this old photon lost tiny amount of energy, or began to red-shift, or began to "decay". This process will be repeated again and again. Thus, I believed that the red-shift is the intrinsic property (or the natural attribute) of a propagating photon. Therefore, for the cosmic red-shift, I believed that we may don't have to use the space expansion to explain. If this description is correct, then all the descendent theories of the expending universe theory, including the expending universe, the dark energy, the big bang, etc., may need to be re-thought.

5) In the {N,n} QM field theory, a photon's propagation can be described as that its n QM state is increasing (from the low n to high n). We can setup a H-atom{N,n//q} QM system to quantitatively describe the n quantum number increasement for a photon that emitted from an H-atom and propagated to anywhere in the space (see Table 1). We also can use the similar method to setup a specified {N,n//q} QM system to quantitatively describe the n quantum number increasement for a photon that emitted from an Sodium atom (or any atom, or from a Sun) and propagated to anywhere in the space, or a gamma photon from any nucleus, or a radio frequency wave from any galaxy cloud, or an alpha particle from any nucleus, or a beta particle from any nucleus, or even a G-photon from the Triton (during the capturing by Neptune), or the G-photon wave from a crash event of two black holes, etc.

6) Alternatively, in the {N,n} QM field theory (see SunQM-6s1's section V), we can use the ground state |1,0,0> to describe an (H-atom's) n=3 electron 3D wave packet's outmost shell (i.e., the 656.1 nm photon that before emitted and still entangled with a n=3 orbital moving electron), and use the excited state |2,1,1> to describe an (H-atom's) n=3 electron 3D wave packet's outmost shell that dis-entangled (or spun-off) from the n=2 orbital moving electron and emitted as the 656.1 nm photon. For the propagation, this photon can be described by using the same excited state |2,1,1> but with $r_1 \propto ct$ (i.e., r_1 is increasing with the propagation distance).

7) For an old and decaying photon, its 3D wave packet's outmost shell has the highest n state, and we can treat this extreme high (and forever-growing) n as that it is moving away from the center of the photon (see SunQM-6s3's Fig-8, or the current paper's Figure 11), and eventually dis-entangled (or excited to the n = ∞ level by the virtual dragging force, see Figure 12).

8) In the {N,n} QM field theory, during the propagation, a photon's $\vec{\mathbf{E}}$ & $\vec{\mathbf{B}}$ vector oscillation inside the photon's 3D wave packet can be described by the ABCBA cycle (see Figure 3 through Figure 7). I believed that a photon's 3D wave packet ABCBA cycle description is more accurate than a photon's 1D transverse electromagnetic wave. I need to emphasize again that in the {N,n} QM field theory, although a static charge's static electric field is described by the regular static electric field (in nL0 mode), a photon's electric field is described by the inversed static electric field (in nLL mode), i.e., a spinning static electric field, or a spinning nL0 mode, not the regular static electric field itself.

9) In the {N,n} QM field theory, when using the ABCBA cycle to describe a propagating photon, the |2,1,±1> and |2,0,0> states can be either in the {N,n//6} QM's n=2 state, or in the {N,n//3} QM's n=2 state. However, if we want to use {N,n//2} QM to describe the ABCBA cycle, then it means the |1,0,0> sphere is like a solid ball that spins either in left, or in right, or in zero. Alternatively, we can use the |1,0,0> sphere's surface equator residue |2,1,±1> to describe. (Note: for the concept of "residue nLL", see SunQM-6s4's Appendix A item-7). The advantage to use |1,0,0> QM state with the residue |2,1,±1> to describe a photon is that, the |1,0,0> QM state has a true ball structure (so that we can use a true ball to describe a photon), and the residue |2,1,±1> equivalents to the Y*lm* cycle theory (see Appendix E, so that it automatically links to the cycle between a equatorial fast-flow and a equatorial (effective) negative fast-flow).

10) Let's directly compare a static charge's point-centered electric filed (see SunQM-6s4's Figure 5) and a photon's point-centered electromagnetic field (see SunQM-6s5's Figure 7):
10a) Both of their fields propagate in r-1D in light speed c (from their point center);
10b) While both propagating in r-1D in light speed c, the static charge's electric filed does not lose energy, but the photon's point-centered electromagnetic field does lose energy (at the rate of Hubble constant, if it is too old);
10c) Although both of them can be described by using 3D wave packet (in the NBP form), the static field (at any time point) has its electric field force $\vec{\mathbf{E}}$ vector in nL0 mode, pointing to all 4π directions, and its magnetic field force $\vec{\mathbf{B}}$ vector in nLL mode, in the complete RF mode; while the photon's electromagnetic field has a spinning $\vec{\mathbf{E}}$ vector (that is inversed from nL0 mode to nLL mode), in one of ABC states (at any time point), and $\vec{\mathbf{B}}$ vector (that is inversed from nLL mode to nL0 mode) in one of ABC states (at any time point).

11) I believed that the above descriptions formed a self-consistent and completed {N,n} QM field theory for an H-atom's n=3 to n=2 de-excitation and a 656.1 nm photon's emission and the propagation. I also believed that {N,n} QM field theory and "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model" should be able to describe all general "decay" processes (including the emission of a photon, a G-photon, or an alpha-particle, etc.), as it had been explained in SunQM-6s3.

Conclusion

In the {N,n} QM field theory, we can describe a propagating photon as a single ball-like structure (i.e., the 3D spherical wave packet, in the form of NBP). It not only contained all character of the 1D transverse wave, but also provided many more accurate information for a propagating photon. For example: the structure of multiple shells and a core in a 3D wave packet; the (intrinsic) higher frequency and the higher energy for the core than that for the shells; the (intrinsic) faster propagating speed for the core than for that the shells; the (intrinsic) forever size-growing for all the shell; the (intrinsic) trim-off mechanism for the outmost shell once it is overly grown; a photon always has the spin of $1\hbar$, although this spin vector can be reoriented in the 3D space, so that it can appear as either the (pseudo) linear polarized, or the right/left circular polarized, or the elliptical polarized light; etc.

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Special thanks to: Fudan university, theoretical physics (class of 1978, and all teachers), it had made my quantum mechanics study (at the undergraduate level) become possible. Also thanks to Chen-Ning Yang and Tsung-Dao Lee, they made me to dream to be a physicist when I was eighteen. Also thanks to Shoucheng Zhang (张首晟, Physics Prof. in Stanford Univ., my classmate at Fudan Univ. in 1978) who had helped me to introduce the {N,n} QM theory to the scientific community.

Also thanks to a group of citizen scientists for the interesting, encouraging, inspiring, and useful (online) discussions: "职老" (https://bbs.creaders.net/rainbow/bbsviewer.php?trd_id=1079728), "MingChen99" (https://bbs.creaders.net/tea/bbsviewer.php?trd_id=1384562), "zhf" (https://bbs.creaders.net/tea/bbsviewer.php?trd_id=1319754), Yingtao Yang (https://bbs.creaders.net/education/bbsviewer.php?trd_id=1135143), "tda" (https://bbs.creaders.net/education/bbsviewer.php?trd_id=1157045), etc.

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Reference:

[1] Yi Cao, SunQM-1: Quantum mechanics of the Solar system in a {N,n//6} QM structure. http://vixra.org/pdf/1805.0102v2.pdf （original submitted on 2018-05-03）

[2] Yi Cao, SunQM-1s1: The dynamics of the quantum collapse (and quantum expansion) of Solar QM {N,n} structure. http://vixra.org/pdf/1805.0117v1.pdf （submitted on 2018-05-04）

[3] Yi Cao, SunQM-1s2: Comparing to other star-planet systems, our Solar system has a nearly perfect {N,n//6} QM structure. http://vixra.org/pdf/1805.0118v1.pdf （submitted on 2018-05-04）

[4] Yi Cao, SunQM-1s3: Applying {N,n} QM structure analysis to planets using exterior and interior {N,n} QM. http://vixra.org/pdf/1805.0123v1.pdf （submitted on 2018-05-06）

[5] Yi Cao, SunQM-2: Expanding QM from micro-world to macro-world: general Planck constant, H-C unit, H-quasi-constant, and the meaning of QM. http://vixra.org/pdf/1805.0141v1.pdf （submitted on 2018-05-07）

[6] Yi Cao, SunQM-3: Solving Schrodinger equation for Solar quantum mechanics {N,n} structure. http://vixra.org/pdf/1805.0160v1.pdf （submitted on 2018-05-06）

[7] Yi Cao, SunQM-3s1: Using 1st order spin-perturbation to solve Schrodinger equation for nLL effect and pre-Sun ball's disk-lyzation. http://vixra.org/pdf/1805.0078v1.pdf （submitted on 2018-05-02）

[8] Yi Cao, SunQM-3s2: Using {N,n} QM model to calculate out the snapshot pictures of a gradually disk-lyzing pre-Sun ball. http://vixra.org/pdf/1804.0491v1.pdf （submitted on 2018-04-30）

[9] Yi Cao, SunQM-3s3: Using QM calculation to explain the atmosphere band pattern on Jupiter (and Earth, Saturn, Sun)'s surface. http://vixra.org/pdf/1805.0040v1.pdf （submitted on 2018-05-01）

[10] Yi Cao, SunQM-3s6: Predict mass density r-distribution for Earth and other rocky planets based on {N,n} QM probability distribution. http://vixra.org/pdf/1808.0639v1.pdf (submitted on 2018-08-29)

[11] Yi Cao, SunQM-3s7: Predict mass density r-distribution for gas/ice planets, and the superposition of {N,n//q} or |qnlm> QM states for planet/star. http://vixra.org/pdf/1812.0302v2.pdf (replaced on 2019-03-08)
[12] Yi Cao, SunQM-3s8: Using {N,n} QM to study Sun's internal structure, convective zone formation, planetary differentiation and temperature r-distribution. http://vixra.org/pdf/1808.0637v1.pdf (submitted on 2018-08-29)
[13] Yi Cao, SunQM-3s9: Using {N,n} QM to explain the sunspot drift, the continental drift, and Sun's and Earth's magnetic dynamo. http://vixra.org/pdf/1812.0318v2.pdf (replaced on 2019-01-10)
[14] Yi Cao, SunQM-3s4: Using {N,n} QM structure and multiplier n' to analyze Saturn's (and other planets') ring structure. http://vixra.org/pdf/1903.0211v1.pdf (submitted on 2019-03-11)
[15] Yi Cao, SunQM-3s10: Using {N,n} QM's Eigen n to constitute Asteroid/Kuiper belts, and Solar {N=1..4,n} region's mass density r-distribution and evolution. http://vixra.org/pdf/1909.0267v1.pdf (submitted on 2019-09-12)
[16] Yi Cao, SunQM-3s11: Using {N,n} QM's probability density 3D map to build a complete Solar system with time-dependent orbital movement. https://vixra.org/pdf/1912.0212v1.pdf (original submitted on 2019-12-11)
[17] Yi Cao, SunQM-4: Using full-QM deduction and {N,n} QM's non-Born probability density 3D map to build a complete Solar system with orbital movement. https://vixra.org/pdf/2003.0556v2.pdf (replaced on 2021-02-03)
[18] Yi Cao, SunQM-4s1: Is Born probability merely a special case of (the more generalized) non-Born probability (NBP)? https://vixra.org/pdf/2005.0093v1.pdf (submitted on 2020-05-07)
[19] Yi Cao, SunQM-4s2: Using {N,n} QM and non-Born probability to analyze Earth atmosphere's global pattern and the local weather. https://vixra.org/pdf/2007.0007v1.pdf (submitted on 2020-07-01)
[20] Yi Cao, SunQM-5: Using the Interior {N,n//6} QM to Describe an Atom's Nucleus-Electron System, and to Scan from Sub-quark to Universe (Drafted in April 2018). https://vixra.org/pdf/2107.0048v1.pdf （submitted on 2021-07-06)
[21] Yi Cao, SunQM-5s1: White Dwarf, Neutron Star, and Black Hole Explained by Using {N,n//6} QM (Drafted in Apr. 2018). https://vixra.org/pdf/2107.0084v1.pdf （submitted on 2021-07-13)
[22] Yi Cao, SunQM-5s2: Using {N,n//6} QM to Explore Elementary Particles and the Possible Sub-quark Particles. https://vixra.org/pdf/2107.0104v1.pdf (submitted on 2021-07-18)
[23] Yi Cao, SunQM-6: Magnetic force is the rotation-diffusion (RF) force of the electric force, Weak force is the RF-force of the Strong force, Dark Matter may be the RF-force of the gravity force, according to a newly designed {N,n} QM field theory. https://vixra.org/pdf/2010.0167v1.pdf (replaced on 2020-12-17, submitted on 2020-10-21)
[24] Yi Cao, SunQM-6s1: Using Bohr atom, {N,n} QM field theory, and non-Born probability to describe a photon's emission and propagation. https://vixra.org/pdf/2102.0060v1.pdf (submitted on 2021-02-11)
[25] Yi Cao, SunQM-7: Using {N,n} QM, Non-Born-Probability (NBP), and Simultaneous-Multi-Eigen-Description (SMED) to describe our universe. https://vixra.org/pdf/2111.0086v1.pdf (submitted on 2021-11-17)
[26] Yi Cao, SunQM-6s2: A Unified Description Of 1D-Wave, 1D-Wave Packet, 3D-Wave, 3D-Wave Packet, and |nlm> Elliptical Orbit For A Photon's Emission and Propagation Using {N,n} QM. https://vixra.org/pdf/2208.0039v1.pdf (submitted on 2022-08-08)
[27] Yi Cao, SunQM-6s3: Using {N,n} QM and "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model" to Describe All General "Decay" Processes (Including the Emission of a Photon, a G-photon, or An Alpha-particle). (submitted on 2022-08-31, but has not been able to get posted out, I don't know the reason)
[28] Yi Cao, SunQM-6s4: In {N,n} QM Field Theory, A Point Charge's Electric Field Can Be Represented by Either the Schrodinger Equation/Solution, Or A 3D Spherical Wave Packet, In Form of Born Probability. https://vixra.org/pdf/2306.0136v1.pdf (submitted on 2023-06-23)
[29] Douglas C. Giancoli, Physics for Scientists & Engineers with Modern Physics, 4th ed. 2009, p819, Fig-31-9
[30] Stephen T. Thornton & Andrew Rex, Modern Physics for Scientists and Engineers, 3rd ed. 2006. p223, Fig-6.3.
[31] 周世勋, 量子力学教程, (Shi-Xun Zhou, Quantum Mechanics Tutorial) 1979 edition, p40, Fig-11.
[32] David J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., 2015, p367, eq-9.78, and Figure 10.6.
[33] Douglas C. Giancoli, Physics for Scientists & Engineers with Modern Physics, 4th ed. 2009, p1049.

Note: A series of SunQM papers that I am working on:
SunQM-6s6: Using {N,n} QM Field Theory to Study the Atomic Electron … (drafted in Apr. 2023).
SunQM-6s7: {N,n} QM Field Theory Development On the E/RFe-force … (drafted in Apr. 2023).
SunQM-6s8: {N,n} QM Field Theory Development On the G/RFg-force … (drafted in Apr. 2023).
SunQM-6s9: {N,n} QM Field Theory Development On the S/RFs-force … (drafted in May. 2023).
SunQM-6s10: Schrodinger equation and {N,n} QM ... (drafted in January 2020).
SunQM-4s4: More explanations on non-Born probability (NBP)'s positive precession in {N,n}QM.
SunQM-7s1: Relativity and non-linear {N,n} QM
SunQM-9s1: Addendums, Updates and Q/A for SunQM series papers.

Note: Major QM books, data sources, software I used for SunQM series papers study:
Douglas C. Giancoli, Physics for Scientists & Engineers with Modern Physics, 4th ed. 2009.
David J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., 2015.
Stephen T. Thornton & Andrew Rex, Modern Physics for Scientists and Engineers, 3rd ed. 2006.
John S. Townsend, A Modern Approach to Quantum Mechanics, 2nd ed., 2012.

Wikipedia at: https://en.wikipedia.org/wiki/
(Free) online math calculation software: WolframAlpha (https://www.wolframalpha.com/)
(Free) online spherical 3D plot software: MathStudio (http://mathstud.io/)
(Free) offline math calculation software: R
Microsoft Excel, Power Point, Word.
Public TV's space science related programs: PBS-NOVA, BBC-documentary, National Geographic-documentary, etc.
Journal: Scientific American.

Note: I am still looking for endorsers to post all my SunQM papers (including the future papers) to arXiv.org. Thank you in advance!

Note: With my 28 of SunQM papers that have been posted out so far, I believe that the framework of the {N,n} QM has been fully established. It is clear now that the {N,n} QM description is not only suitable for the mass field, but also suitable for the force field (or potential field, or energy field, etc.). Thus, my (10 years of close-door) research phase on the {N,n} QM will be ended in about one year (most likely in the summer of 2024). After that, I will re-write the SunQM papers (~ 35 of them) in the form of a text book.

Appendix A. (Note: This explanation should be moved to SunQM-6s2's Fig-2).

In SunQM-6s2's Fig-2a, when an electron (inside a H-atom) is in the |3,2,0> QM state, I used a BP density map (and its contour lines) to describe this electron's orbital motion trajectory. According to the {N,n} QM field theory, the electron's orbital motion (inside a H-atom) should be described by using NBP density map (that is guided by BP density map), but not directly by BP density map itself. For example, within a short-time duration (e.g., for the time duration that the electron orbited the proton for ~ 10^3 rounds, (note: 10^3 is a randomly chosen number)), the electron's orbital motion (inside a H-atom) should can be described by using NBP density map (in a form of BP density map that is deleted either the top half or the bottom half of the density, similar as SunQM-6s5's Figure 1j or Figure 1q). However, only for a long-time duration (e.g., for the time duration that the electron orbits the proton for ~ 10^{10} rounds, (note: 10^{10} is a randomly chosen number)), then the electron's orbital motion (inside a H-atom) can be approximated as a time-averaged standing wave mode, and thus can be directly described by the BP density map.

Appendix B. (Note: This is a memo for myself).

When we use three of |2,1,m$_{=0,\pm1}$> equal-probability mixed QM states (see Figure 2) to describe a photon's state B (in an ABCBA cycle, see Figure 3) where the sum of the spinning $\vec{\mathbf{E}}$ equals to zero, it actually means the synergic $\overrightarrow{\mathbf{E}_{\varphi}}$ vector component of the $\vec{\mathbf{E}} = \overrightarrow{\mathbf{E}_r} + \overrightarrow{\mathbf{E}_{\varphi}}$ vector equals to zero (at any point in the 3D space), or the nLL mode of the $\vec{\mathbf{E}}$ vector equals to (or added-up to) zero. (Note: For more discussion on $\vec{\mathbf{E}} = \overrightarrow{\mathbf{E}_r} + \overrightarrow{\mathbf{E}_{\varphi}}$, see SunQM-6s7's Fig-1). In contrast, (in theory) we also can use the same three of |2,1,m$_{=0,\pm1}$> equal-probability mixed QM states to describe a static positive charge's electric field (in SunQM-6's Fig-1b, or in Figure 6s4's Fig-5), it actually means the $\overrightarrow{\mathbf{E}_r}$ vector component of the $\vec{\mathbf{E}} = \overrightarrow{\mathbf{E}_r} + \overrightarrow{\mathbf{E}_{\varphi}}$ vector, or the nL0 mode of the $\vec{\mathbf{E}}$ vector (at any point in the 3D space), and it does not equals to zero. (Note: In this case, it is better to use |1,0,0> rather than |2,1,m$_{=0,\pm1}$> equal-probability mixed QM states for the description of the $\overrightarrow{\mathbf{E}_r}$ vector). Alternatively (and similarly), we can use |1,0,0> QM state to describe a photon's state B (in an ABCBA cycle), as well as a static positive charge's electric field. The point-symmetry of |1,0,0> QM state has different meanings in these two cases: for a static positive charge's electric field, it means that the isotropic $\vec{\mathbf{E}}$ field vector (i.e., the $\overrightarrow{\mathbf{E}_r}$ of the $\vec{\mathbf{E}} = \overrightarrow{\mathbf{E}_r} + \overrightarrow{\mathbf{E}_{\varphi}}$) points to all 4π direction uniformly (at any time point), so it has the point-symmetry, and it has the net charge, and it has no synergic effect; On the other hand, for a photon's state B (in an ABCBA cycle), it means that the spinning $\vec{\mathbf{E}}$ field vector (i.e., the $\overrightarrow{\mathbf{E}_{\varphi}}$ of the $\vec{\mathbf{E}} = \overrightarrow{\mathbf{E}_r} + \overrightarrow{\mathbf{E}_{\varphi}}$) is added-up to zero (i.e., the spin in one direction is neutralized by the spin in the opposite direction), so it also has the point-symmetry, but it has the zero charge, and it has the synergic effect.

Furthermore, in SunQM-6's Fig-3, moving a positive charge in +z direction is equivalent to decrease the RF of $\vec{\mathbf{E}}$ vector by decreasing the probability pointing to -z direction (and this may be the original of the special relativity, see more discussion in SunQM-7s1), and causing the $\vec{\mathbf{B}}$ vector to show up (also by decreasing the RF).

Appendix C. More explanation on the three distinctive QM states A, B, and C (that shown in Figure 3):

In an alternative description, we can say that a real photon (that always in one of three distinctive QM states A, B, and C) is composed of three (equal magnitude) probability parts, the |2,1,1> part (here we named it as the "**positive-part**"), the |2,1,0> part (here we named it as the "**zero-part**"), and the |2,1,-1> part (here we named it as the "**negative-part**"). We also defined that a "positive-part" and a "negative-part" stay together equals to two of the "zero-part". Then, **1)** a photon's "B" QM state (that always has equal amount of |2,1,0>, |2,1,1> and |2,1,-1> probabilities for $\vec{\mathbf{E}}$) can be described as that the state B has one "positive-part", one "negative-part" and one "zero-part" (which equals to three "zero-part", and or **a photon's base QM state**); **2)** a photon's "A" QM state (that always has 100% of |2,1,1> probability for $\vec{\mathbf{E}}$) can be described as that the state A has three "positive-part" (meaning both the original "zero-part" and "negative-part" in a photon's base state have been changed into "positive-part" under the QM state oscillation of ABCBA cycle); and **3)** a photon's "C" QM state (that always has 100% of |2,1,-1> probability for $\vec{\mathbf{E}}$) can be described as that the state C has three "negative-part" (meaning both the original "zero-part" and "positive-part" in a photon's base state have been changed into "negative-part" under the QM state oscillation).

Notice that if we rename these three "parts" as three "particles", then this description (of a photon's QM structure) may be similar as the description for a nucleon's QM structure (that containing three particles of "up-quark" and "down-quark") in some way. Thus, can we use the similar description for S-force, or three quarks in a nucleon, etc.?

Appendix D. Inside a photon's 3D wave packet, we may can use the differentiated n (or the high-frequency n' quantum number) QM states to describe the speed difference for each shells and core. (Note: This Appendix should go to SunQM-6s3).

(Note: This is only a qualitative assumption. It has not been worked out quantitatively yet). According to wiki "Group velocity", "*different frequency-components of the wavepacket travel at different speeds, with the faster components moving towards the front of the wavepacket and the slower moving towards the back. Eventually, the wave packet gets stretched out*". In the {N,n} QM field theory, for a propagating photon's 3D wave packet, because the core has the shorter wavelength and higher frequency than that of the outer shells, so, in SunQM-6s2 and SunQM-6s3, we proposed that a photon's 3D wave packet's core (that has the light speed of c) is propagating slightly faster than the outer shells. Now, we try to use the differentiated n (or the high-frequency n') quantum numbers to describe the speed difference for each shells and core (inside photon's 3D wave packet).

As shown in SunQM-6s1's Fig-3, Table-2, Table-3, and SunQM-6s3's Table-3, and the current paper's Table-2, at any specific time, assuming that the core (of a 3D wave packet) has the (base) quantum number n (according to the propagated distance $r_n = r_1 n^2$ away from the H-atom where it started), we may be able to derive out an appropriate high-frequency n' number (see in Figure 11) to satisfy that:

1) For a newborn photon, because it has the core center behind the outer shells center, so the core can be described as in n' QM state, and the 1st outer shell can be described as in n' + 1 QM state, the 2nd outer shell can be described as in n' + 2 QM state, and so on so forth;

2) For a matured photon, because it has the core center overlap with all the outer shells' centers, so that the core and all outer shells can be described as that they are all in the same n' QM state;

3) For an old and decaying photon, because it has the core center ahead of the outer shells center, so that the core can be described as in n' QM state, and the 1st outer shell can be described as in n' - 1 QM state, the 2nd outer shell can be described as in n' - 2 QM state, and so on so forth. So, in the case of an old photon, each outer shell (from inner to the most outside) is "de-excited" the QM state by Δn' =1;
4) Therefore, in all three above cases, the core is always propagating Δn' =1 faster than the 1st outer-shell, and Δn' =2 faster than the 2nd outer-shell, and so-on-so-forth;
5) Then, the spin-off of the outmost shell process (to be a newborn 0.02 Hz low-f photon from a 656.1 nm photon) should be a major "de-excitation", and it should be much larger than the Δn' =1 "de-excitation" of the QM state from the 2nd outmost shell. We may use Δn" = 1 "de-excitation" of the QM state from the 2nd outmost shell to describe, and n" is a much smaller (high-frequency) number than that of n', (or may even to be a base-frequency Δn =1 smaller). Here is an illustration of above saying by using the purely guessed values: at the time t, suppose a (old) photon is propagated to the distance $r_n = r_1 n^2$ (away from the H-atom) and can be described with the base-frequency $n = 2\times6^6$, its 3D wave packet shells can be described by $n' = 2\times6^{12}$ for the core, and by $n' - 1 = 2\times6^{12} - 1$ for the 1st out shell, and by $n' - 2 = 2\times6^{12} - 2$ for the 2nd out shell, etc. After the spin-off the outmost shell, the 2nd outmost shell may can be described at $n'' = 2\times6^7$ QM state, and dis-entangled outmost shell may can be described at $n'' = 2\times6^7 - 1$ QM state. Therefore, in the spin-off, $\Delta n'' = 1$ equivalents to $\Delta n' = 1\times6^5$. (Note: These values are fake ones, we need to derive the real correct values for n, n' and n", and I may will try it in the future when I have time).

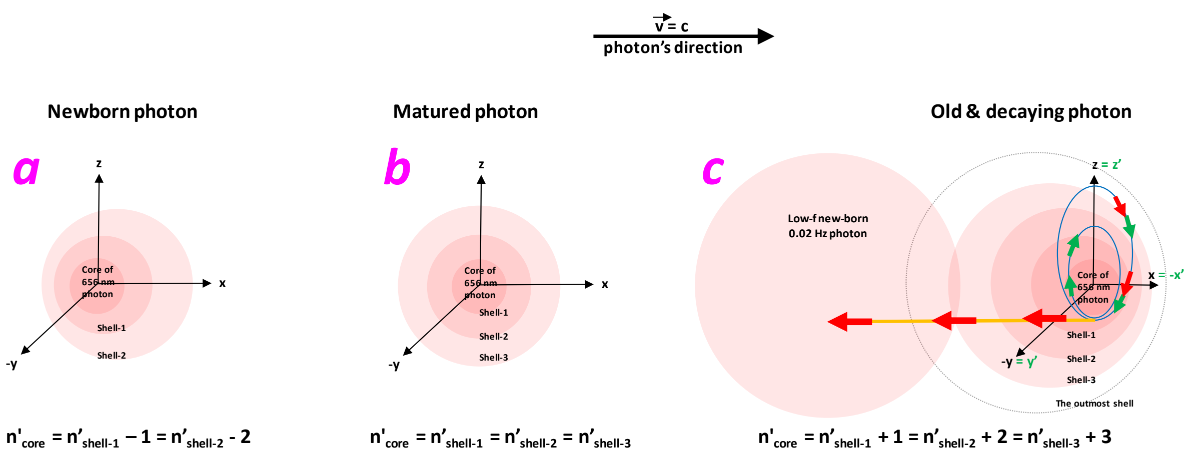

Figure 11. Illustration of using the differentiated n' QM states to describe the speed difference for each shells and core for a photon's 3D wave packet.

Appendix E. The "residue nLL" is equivalent to the "Y*lm* cycle" model in SunQM-3s9 (Note: This appendix should go to SunQM-4s4)

In SunQM-6s4's Appendix A item-8, I said: "*One interesting question: we know that Earth was accreted from the < 1% leftover mass in the {1,5//6}o orbit shell space (after the {2,1//6} sized pre-Sun ball collapsed to be the {1,1//6} sized pre-Sun ball), but now, should we treat the Earth as the |5,4,4> QM state in the {1,5//6}o orbital shell, or, as the residue |5,4,4> QM mode that embedded on the surface of the {1,4//6}o orbital shell?*". The "residue nLL" explanation actually equivalent to the "Y*lm* cycle" model in SunQM-6s9, it has half period of fast phase and other half period of slow phase (or, a equatorial fast-flow and a equatorial (effective) negative fast-flow). In the case of Earth's orbiting movement, the acceleration phase (from aphelion to perihelion, or from t_1 to t_2 to t_3 in SunQM-6s2's Fig-5b) caused the fast-speed half at the perihelion region (from t_2 to t_3 to t_4 in SunQM-6s2's Fig-5b, notice that there is ¼ period lag behind), the deceleration phase (from perihelion to aphelion, or from t_3 to t_4 to t_1 in SunQM-6s2's Fig-5b) caused the slow-speed half at the aphelion region (from t_4 to t_1 to t_2 in SunQM-6s2's Fig-5b, also ¼ period lag behind). (Note: Although I figured out this result in the early 2020, but retained this result for the paper SunQM-4s4. However, due to I have planned to finish my close-door research in one year, I may not have enough time to finish the paper of SunQM-4s4 before the summer of 2024. So I opened this result here).

Appendix F. (Note: This is a memo only for myself)

In SunQM-6s2, we had estimated that for a 656.1 nm photon, after propagating each ~2.7E+10 meters, it will split-out a 0.02 Hz low-f photon. This estimation was based on the {N,n//q} QM with q = 6 and Δn = 1 (see SunQM-6s1's section IV and Table 5). If based on {N,n//q} QM with q = 6^j (where the integer j > 1, which means less quantum effect and more like a classical process, see SunQM-5s2's section IV) and Δn = 1, then, will the old and decaying 656.1 nm photon spit-out the low-f photons more frequently, with each low-f photon that has much lower energy (or with frequency << 0.02 Hz)? I guess that it is not correct. Because the size of r = 2.7E+10 meters is fixed by the Hubble's constant, so the 0.02 Hz is a fixed frequency for the spit-out low-f photon. If spitting-out the low-f photons more frequently, then the propagation distance will be shorter, and the outmost shell will be shorter wavelength, so the dis-entangled low-f photon will have higher frequency and energy, and that will cause the "decaying" photon to red-shift more than the Hubble's constant.

Appendix G. Should we use n=1 or n=1/2 for the ground state? (Note: This is a memo only for myself)

Argument-1 (that favors n=1/2 as the ground state): pre-Sun ball collapse from {N,n=1..5//6}o = {N+1,1//6} size to {N,1//6} size, I guessed that the n number for the shell space of {N,1} size should not be n=0, but n=1/2. So for {N,n} QM, n=1 is the 1st excited state, the ground state is n=1/2. This may can be illustrated by SunQM-4s1's Fig-3d where j = 1/2 is the ground state of 1D circular QM. Note: in the pre-Sun ball quantum collapse, the n=1 shell space of {N,1//6}o = {N-1,n=6..11//6}o, and it belongs to the "ball-torus-6-11-gap effect".
Argument-2 (that favors n=1 as the ground state): for |1,0,0> state, its |Y(0,0)|^2 is perfect sphere, it is perfect for a base-state photon in which both $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ equals zero, so is perfect to say n=1 is ground state.

Appendix H. An alternative description for the low-f photon production (see SunQM-6s3's Fig-8) and for the α-decay (see SunQM-6s3's Fig-5). (Note: This Appendix should go to SunQM-6s3).

See SunQM-6s3's section V-a "More discussion (on section V-a)": "*The rule of "|nL0> elliptical/parabolic/hyperbolic orbital model", the daughter particle is always moved-away or ejected-out from the perihelion site (following the elliptical/parabolic/hyperbolic orbit) in near z-direction, while the low-f "newborn particle" is always emitted in x-direction*". In the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model", when a (mother) particle moving to the perihelion site of an (extreme) elliptical orbit (that has extremely high eccentricity), it may have two ways to go:

1) With gaining extra energy/momentum (that always in x' direction, we can adjust x'y'z' coordinate to get this direction), it may be excited to a higher n elliptical orbit, and if n = ∞, it flies away in the averaged z' direction following a parabolic (or even a hyperbolic) orbit. (See SunQM-6s3's Fig-5b for the example of the α-particle emission, or SunQM-6s3's Fig-4c for the example of the photoelectric effect);
2) Without gaining extra energy/momentum, it may split into two particles, the daughter particle (that always carries the major mass and energy/momentum) de-excited to a lower n orbit, moving out in the averaged z' direction; and the newborn

particle (that always carries the minor energy/momentum and mass, or even zero mass, i.e., the dis-entangled outmost shell of the mother particle's 3D wave packet) always emitted in x' direction. (See SunQM-6s2's Fig-5b for the example of an H-atom's n=3 electron de-excited to n=2 and emitted a 656.1 nm photon). If the newborn particle is neutral to the point-centered force, than it flies away in the true x' direction; if the newborn particle is still attracted by the point-centered force, than it may fly away in the average +z' direction following a parabolic (or a hyperbolic) orbit; if the newborn particle is repelled by the point-centered force, than it flies away in the average -z' direction following a parabolic (or a hyperbolic) orbit.

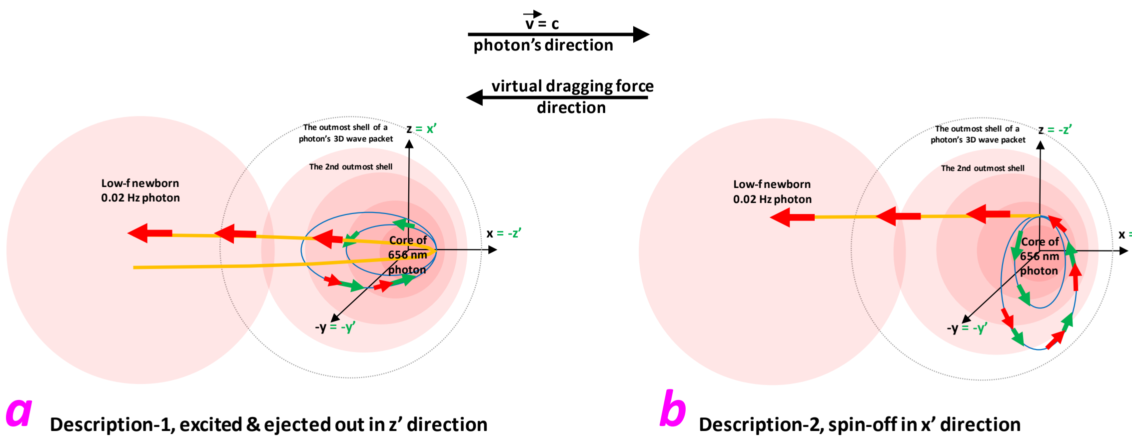

Figure 12a. Illustration of the description-1, excited & ejected out in z' direction.
Figure 12b. Illustration of the description-2, excited & ejected out in x' direction.

After the second thought, I realized that in the case of a 656.1 nm (old) photon spin-off a 0.02 Hz low-f photon, or in α-decay producing an α-particle, they should can be described in either way among the above two descriptions. Here are the two-way descriptions for the production of a 0.02 Hz low-f photon:

Description-1 for a 0.02 Hz low-f photon that "ejected out" in z' direction (see Figure 12a): At beginning, the outmost shell and the 2nd outmost shell of the 656.1 nm photon's 3D wave packet formed a single entity (the "mother particle"), and this entity's center is doing elliptical orbital movement around the center of the 656.1 nm photon at the relative high n number. Then, the 2nd outmost shell de-excited to a lower n number orbit (to become a "daughter particle"), and transferred energy to the outmost shell, so that the outmost shell is excited to n = ∞ and dis-entangled away from the 656.1 nm photon (or "ejected out" in z' direction and following a parabolic trajectory) to become a 0.02 Hz low-f photon (the newborn, see Figure 12a). (Note: this is the preferred description among the two descriptions).

Description-2 for a 0.02 Hz low-f photon that spin-off in x' direction (see Figure 12b): At beginning, the outmost shell and the 2nd outmost shell of the 656.1 nm photon's 3D wave packet formed a single entity (the "mother particle"), (so now the outmost shell also become the outmost shell of this new entity's 3D wave packet), and this entity's center is doing elliptical orbital movement around the center of the 656.1 nm photon at the relative high n number. Then, the 2nd outmost shell de-excited to a lower n number orbit (to become a "daughter particle"), and the outmost shell (of this entity) is spun-off as a newborn 0.02 Hz low-f photon (as the newborn) flying away in x' direction (in a straight line, see Figure 12b). (Note: Why we need to create the description in Figure 12b? This is because (in one way) the low-f photon (0.02 Hz) is more likely to be a newborn particle, so it should be emitted in x' direction, but in SunQM-6s3's Fig-8 it is in z' direction. Therefore, we re-designed the Figure 12a description to be Figure 12b, and satisfied the emission direction at the x' direction).

Similarly, here are the two-ways to describe the production of α-particle:

Description-1 for an α-particle that "ejected out" in z' direction (see SunQM-6s3's Fig-5): At beginning, all "virtual He-nucleus particles" (inside a heavy nucleus) are in the same high n number QM state (the mother particles). Then, most of them (except one) transit to the low n number QM state (to become daughter particles), and transferred all their energy to the last single "virtual He-nucleus particle", and made it excited to n = ∞, so it is ejected out from the nucleus in z' direction and following a parabolic trajectory (as the newborn). (Note: this is the same description in SunQM-6s3's Fig-5).

Description-2 for an α-particle that spin-off in x' direction (similar as shown in Figure 12b): At beginning, all "virtual He-nucleus particles" (inside a heavy nucleus) are in the same high n number QM state, and they formed a new entity (the mother particle). This new entity also has a 3D wave packet, and any one of a single "virtual He-nucleus particle" can be treated as the outmost shell of this new entity's 3D wave packet. Then, most of them (except one) transit to the low n number QM state (to become a daughter particle), while the outmost shell of this entity's 3D wave packet (i.e., the last single "virtual He-nucleus particle") is spun-off in x' direction, and become a real α-particle (as the newborn). Its trajectory may be in parabolic/hyperbolic, (not a straight line), because it may still have the E/RFe and/or G/RFg interaction with the nucleus.

Appendix *i*. One more example for the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model"

(Note: This Appendix should go to SunQM-6s3).

In the early {N,n} QM studies, the modeling suggested that during the quantum collapsing process of the pre-Sun ball, at the stage when it had collapsed to the size of {2,1//6}, a H-fusion ball first started (probably) at the size of {-7,1//6}, and then quantumly expanded one-by-one to the size of {1,1//6}, and then the pre-Sun's light/heat generated ice-evap-line expanded to the {2,1//6}. Then, large amount of the gas (that are made of atom and or molecules with the light element such as H, H_2, He, H_2O, NH_3, CH_4, etc., total estimated as 1.1× of current Jupiter's mass) inside the {2,1//6} sized pre-Sun started to evaporate to the {2,n=1..5//6}o super shell space, and ~ 80% of it was caught by the Jupiter at {2,2//6} orbit, and ~20% was caught by the Saturn at {2,3//6} orbit. In QM words, these atoms/molecules were excited from the {1,n=1..5//6}o orbits to the {2,n=1..5//6}o orbits, (see SunQM-1s1's Table 3b).

Here I added one more example for the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model". Let us use "how the original atmosphere of the Earth was evaporated" as the example. In SunQM-1s1's modeling, the original Earth (that had 25x of current Earth's mass) had an original atmosphere (that had 24x of current Earth's mass, and at the earth{2,1//2}o shell space, using current Earth's r as r_1) at the outside of the current terrestrial planet Earth. Now let's assume that the original atmosphere was made by pure H_2O molecules. Let's treat all these H_2O molecules as one entity, so its forms a (virtual) 3D wave packet, and any single one H_2O molecule can be treated as the outmost shell of this entity's 3D wave packet. Then, we can use the exact the same description as that for the α-decay (see in Appendix H) to describe how each single H_2O molecule was evaporated by using the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model":

Description-1 for one H_2O molecule that "ejected out" in z' direction (see Figure 13a): At beginning, all H_2O molecules inside this entity (i.e., the mother particle) are in the same high n number QM state (after absorbing the Sun light energy). Then, most of them (except one) transit to the low n number QM state (to become daughter particles), and transferred all their energy to the last single H_2O molecule, and made it excited to n ≈ ∞, (or from Earth's {1,5//6} orbit to Jupiter's {2,2//6} = {1,12//6} orbit, Δn increase by 12 – 5 = 7, if doesn't counter the Earth's own attraction force), so it is ejected out from the original Earth in z' direction and following a parabolic trajectory (as the newborn). After repeating this process many times, the whole original atmosphere of Earth was evaporated completely. (Note: this is the preferred description among the two descriptions).

Description-2 for one H_2O molecule that spin-off in x' direction (see Figure 13b): At beginning, all H_2O molecules inside this entity (i.e., the mother particle) are in the same high n number QM state (after absorbing the Sun light energy). Then, most of them (except one) transit to the low n number QM state (to become a daughter particle), while the outmost shell of this entity's 3D wave packet (i.e., the last single H_2O molecule) is spun-off in x' direction (as the newborn). The newborn's trajectory may be in parabolic/hyperbolic, (not a straight line), because it has the E/RFe and/or G/RFg interaction with the Earth. After repeating this process many times, the whole original atmosphere of Earth was evaporated completely.

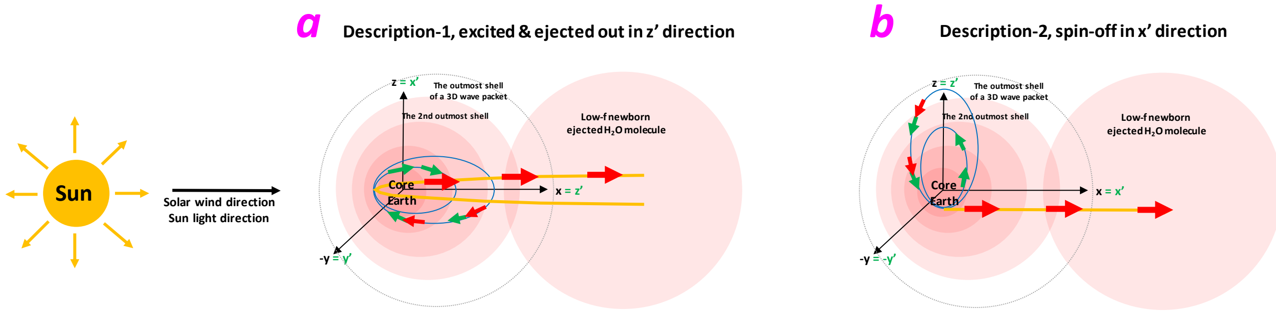

Figure 13. Using the "|nL0> Elliptical/Parabolic/Hyperbolic Orbital Transition Model" to describe that how a atom/molecule of H, H2, He, H2O, NH3, CH4, etc., in {1,n=1..5//6}o super shell was excited to the {2,n=1..5//6}o super shell, after the expanding of Sun's ice-evap-line.

Appendix J. (This appendix should go to SunQM-6s3's Appendix A).

In {N,n} QM field theory, an object's 3D wave packet (especially the outmost shell) is a dynamic definition, not a fixed definition. It depends on what the process you want to describe. Example-1: to describe the 656.1 nm photon emission process, you can use either the n=3 orbital electron's 3D wave packet to describe, or the n=3 H-atom's 3D wave packet to describe. Example-2: for an electron's 3D wave packet, its core is always the electron body that has the size close to {-17,1//6}, (see SunQM-7's Table 1), its outmost shell could be the n=3 electron's outmost shell size (if you want to describe the n=3 to n=2 transition), or the n=2 electron's outmost shell size (if you want to describe the n=2 to n=1 transition).