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Quantum nature of photon signal emitted by *Xanthoria parietina* and its implications to biology

R P Bajpai

Sophisticated Analytical Instruments Facility, North Eastern Hill University, Shillong 793 022, India
and
International Institute of Biophysics, IIB e.V. Raketenstation, ehemalage, Kapellener Strasse, Neuss D41472, Germany

The properties of living systems are usually described in the semi-classical framework that makes phenomenological division of properties into four classes— matter, psyche, soft consciousness and hard consciousness. Quantum framework provides a scientific basis of this classification of properties. The scientific basis requires the existence of macroscopic quantum entity entangled with quantum photon field of a living system. Every living system emits a photon signal with features indicating its quantum nature. Quantum nature of the signal emitted by a sample of *X. parietina* is confirmed by analysing photo count distributions obtained in 20000 measurements of photon number in contiguous bins of sizes of 50, 100, 200, 300 and 500 ms. The measurements use a broadband detector sensitive in 300-800 nm range (Photo count distributions of background noise and observed signal are measured similarly. These measurements background noise corrected squeezed state parameters of the signal. The parameters are signal strength expressed in counts per bin, r =0.06, θ = 2.76 and ϕ = 0.64. The parameters correctly reproduce photo count distribution of any bin size in 50ms-6s range. The reproduction of photo count distributions is a credible evidence of spontaneous emission of photon signal in a quantum squeezed state for macroscopic time by the sample. The evidence is extrapolated to other living systems emitting similar photon signals. It is suggested that every living system is associated with a photon field in squeezed state. The suggestion has far reaching implications to biology and provides two ways of observing and manipulating a living system- either through matter or field or a combination of the two. Some implications and possible scenarios are elaborated.

Keywords: Background noise correction, Biophotonic channel, Consciousness, Quantum entity, Quantum photon signal, Squeezed state

Many issues of life and consciousness have been at the top of the agenda in art, metaphysics and philosophy for ages. These issues have now started appearing on the agenda of sciences. The issues were considered intractable in sciences and were thought to belong to domains of metaphysics and philosophy. Different wisdom traditions have been addressing the issues for ages but are unable to find solutions and satisfactory descriptions[1]. Wisdom traditions fail to perceive "life" as physical attribute and living or biological system as physical system. Some properties of living system are different from the properties of its non-living counterpart and a few of them appear paradoxical. The paradoxical properties give rise to various issues of life and consciousness. It is our contention that paradoxical properties emanate from the use of semi classical framework used in the description of living systems. The semi classical framework is a phenomenological framework of classical character, in which a few ad hoc quantum aspects are added. The semi classical framework respects integrity of biomolecules and successfully describes many biological properties using biomolecules. The descriptions incorporate long chains of cause and effect connections, biochemical pathways and genetic code. The semi classical framework is either partially successful or unsuccessful in describing the remaining biological properties. The nature of success of description in the semi classical framework divides biological properties in three classes, microscopic, macroscopic and consciousness. The descriptions of properties in the three classes are respectively successful, partially successful and unsuccessful. The semi classical framework invokes non-local effects in partially successful and unsuccessful descriptions. The non-local effects are invoked to ensure coordinated and cooperative functioning of biomolecules. The origin

Telephone: +91 364 2550299
Fax: +91 364 255076
E-mail: rpbajpai@yahoo.com

of nonlocal effects appears knowable in partially successful descriptions and unknowable in unsuccessful descriptions. The properties of consciousness class are considered beyond science because of the unknowable origin of invoked non-local effects. The origin of invoked non-local effects in descriptions of various properties of macroscopic class only appears knowable but has not been found so far. The properties of macroscopic class should also be considered beyond science. The invoked non-local effects are perhaps, only artefacts and indicate a deeper malady. The malady is the inadequacy of semi-classical framework to describe the properties of a composite quantum system. If a living system contains composite quantum structure then the semi classical framework may not be successful in describing some properties of the living system that originate from its quantum structure. Perhaps, there is no need to go beyond science. There is only a need to envisage a composite quantum structure in every living system.

A composite quantum structure constituted from biomolecules will have two types of properties, local and holistic. A local property is correctly described by the properties of constituents both in semi classical and quantum frameworks. A holistic property is correctly described only in the quantum framework. Its constituents function in cooperative and coordinated manner in its description in the semi classical framework, which is detected as correlations in a few properties at different space-time points and is ascribed to non-local effects of unspecified origin in the semi classical framework. Correlations in a property are measurable, indicate the presence of a composite structure of quantum nature and provide information about the quantum state of composite structure. The properties of macroscopic and consciousness classes require correlations and are therefore, indicators of the existence of composite quantum structure in a living system. These properties do not require a living system as a whole to be a composite quantum structure; only its parts responsible for holistic properties need to constitute a composite quantum structure. The quantum structure will be referred as a quantum entity. It can explain many paradoxical issues of biology. As an illustration, consider the issue of high efficiency of conversion of chemical energy into mechanical work[2]. The estimated efficiency is more than 50% in human subjects and even higher in photosynthetic tissues. It far exceeds the thermodynamic efficiency of nearly 4% of an ideal heat engine operating between physiological temperature of $37^{o}C$ and room temperature of $25^{o}C$. High efficiency is attainable if chemical energy is converted directly into mechanical work or electrical energy, which requires direct coupling between sources of chemical energy and macroscopic chunks of living matter doing work. The attempts to discover direct coupling of classical nature have failed so far and the prevalent prejudice of considering only classical states of macroscopic chunks of living matter forbids direct coupling of quantum nature. The presence of a quantum entity in living system will discard the prejudice and will permit direct coupling of quantum nature between macroscopic chunks of living matter doing work and sources of chemical energy provided macroscopic chunks of matter are in a quantum state. Perhaps, macroscopic chunks of matter are parts of a quantum entity. It will resolve another paradoxical issue related to up conversion of biochemical energy lying in the infrared region into visible (or UV) range. A quantum entity can appear emitting visible range photons by absorbing biochemical energy at different locations of its constituents in the semi classical framework.

A quantum entity will participate in metabolic processes too and some biological phenomena should provide definitive evidence of the existence of quantum entity and its identifiable signatures. Spontaneous emission of photon signal of quantum nature by a living system is such a biological phenomenon. The phenomenon provides definitive evidence and identifiable signatures of quantum entity. The phenomenon has been observed in many living systems and thought to occur in all living systems at all times. Quantum nature is indicated by many unusual features observed in the emitted photon signal. The signal is called biophoton signal and its photons biophotons in order to highlight unusual features and biological connection[3,4]. The prominent unusual features indicating quantum nature are non-decaying shape, ultra weak intensity and broadband spectrum mainly in the visible region. Measurement of statistical properties of emitted photons constituting a signal can confirm its quantum nature. The photon signals emitted spontaneously by lichen samples are most appropriate for demonstrating quantum nature of biophoton signals because a lichen sample due to its slow growth and decay emits signal of constant average intensity for many hours and one can measure the number of emitted photons in a fixed interval many times. Measuring interval is called bin and its duration bin size. Photon number in a signal is measured in a large number of contiguous bins. The measurements determine the digitised signal and its statistical properties. Average number of photons detected in a bin is equal to the signal strength. The measurements determine probabilities of detecting different number of photons in a bin. The set of probabilities is called photo count distribution. Photo count distribution is different in quantum and classical signals of same strength and its measurement can distinguish between classical and quantum signals. Photo count distributions with small average number of photons per bin are more discriminative. Photo count distributions measured with bin sizes giving average number of photons of around 0.01 photons per bin contain only one significant probability, the probability of detecting at least a photon in a bin. This probability is very effective in determining the nature of photon signal. Its limiting value as signal strength per bin goes to zero is the same in a signal in pure quantum nature. Its limiting value in classical signal of thermal photons is twice of its limiting value in a quantum signal. The approach to limiting value is different in different quantum signals. This probability was measured for different bin sizes in two signals of similar strengths emitted by a leaf and a micro lamp. The signal emitted by the leaf was of quantum nature but not that emitted by the micro lamp[5]. Similar measurements have been performed in signals emitted by a few other living and non-living systems. Only signals emitted by living systems are of quantum nature.

Many probabilities are significant in photo count distributions of a signal measured with large bin sizes. These probabilities can provide detailed information of quantum state of the signal. The extraction of information requires an assumption about the quantum state. It is assumed that quantum state of biophoton signal is a squeezed state[6]. The assumption explains all unusual features of biophoton signals[7]. A squeezed state has four undetermined parameters. A photo count distribution having more than four significant probabilities can estimate these parameters. Nearly same estimates of parameters if obtained from photo count distributions measured with different bin sizes in a signal will justify the assumption of squeezed state. In an earlier experiment[8], photo count distributions were measured with 14 bin sizes in the range (50-500ms) in the signal emitted by a sample of lichen species *Parmelia.tinctorum* and squeezed state parameters common to various combinations of three or more photo count distributions were estimated. Different combinations yielded nearly same values of common parameters. It was the first definite evidence of squeezed state. The evidence was not conclusive because the estimates were based on least square fit of two sets of probabilities, one set was calculated for single mode photon field and the other set was measured using a broadband detector. The effect of broadband detection was investigated in another experiment in which photo count distributions in 21 spectral decompositions of a signal emitted by a sample of another lichen species *Parmelina wallichiana*[9] were measured. Different photo count distributions yielded nearly same estimates of squeezed state parameters. It implies strong mode coupling in the signal and same photo count distribution at same signal strength in different modes. The experiment justifies the use of observed multi modes probabilities and calculated single mode probabilities in least square fitting. There remains a small in accepting the results of above two experiments as conclusive evidence of squeezed state. The problem pertains to the neglect of background noise in above experiments. Noise is substantial and its neglect means that above two experiments provide evidence of squeezed state of observed signal made up from pure biophoton signal and background noise. Photo count distribution of background noise is stable in our measuring system and hence, neglect of background noise retains the inference of quantum nature but makes estimated squeezed state parameters dependent on measuring system.

A procedure that makes correction for background noise in estimation of squeezed state parameters has been developed by observing that detection of photon number in a bin is a compound event made from events of two independent sources— biophoton signal and background noise. The observed probability of detecting a definite number of photons is a convolution of probabilities of biophoton signal and background noise. The convolution is invertible and probabilities for biophoton signal can be obtained from probabilities in observed signal and background noise. The inversion procedure is impracticable because of compounding of errors in inversion. The problem is circumvented by changing the function in least square fitting. The squeezed state parameters are estimated by least square fitting probabilities of observed signal to probabilities obtained by convoluting calculated probabilities of signal and observed probabilities of background noise. The new function considerably improves the quality of a fit and yields squeezed state parameters independent of measuring system. The new function is used in the estimates of squeezed state parameters from photo count distributions measured with five bin sizes 50, 100, 200, 300 and 400ms in the photon signal emitted by a sample of yet another lichen species *Xanthoria parietina*. The estimated parameters correctly describe photo count distributions with any bin size in the range (50ms-6s). The measurements were completed in more than 5 hr. Hence, the photon signal remained in its squeezed state at least for 5 hr. The results of three experiments when considered together conclusively demonstrate quantum nature of photon signals emitted by three lichen species. The squeezed state parameters of signals are their measurable digitized signatures. The evidence if extrapolated to any other living system emitting a photon signal with similar unusual features allows us to conclude that emission of photon signal in squeezed state is a characteristic property of living systems. The conclusion has many implications to biology.

Materials and Methods

A photo multiplier sensitive in the region (300-800) nm is used for detecting photons emitted spontaneously by a wet sample of lichen species *Xanthoria paritiana*. The sample grew naturally on a tree outside the laboratory. The sample was detached along with its substrate from the tree two days earlier and put in a cuvette. The cuvette was placed in the dark measuring chamber for 2 hr before the start of measurements to eliminate contribution of delayed luminescence caused by exposure of the sample to ambient light. The sample in side the chamber spontaneously emitted a photon signal. The photons of emitted signal passed through a quartz window and were counted by the detector in 20000 contiguous bins of one size. The measurements constituted a set representing a digitized portion of the signal. The bin size was then increased to make another set representing subsequent digitized portion of the signal. Five sets were obtained from measurements made one after the other without any break with bin sizes 50, 100, 200, 300, and 400ms. The five sets represent five contiguous portions of increasing duration of the signal. The measurements were repeated with same protocol with the empty cuvette in the measuring chamber to obtain five digitized data sets of background noise.

Classical statistical moments mean and variance and probabilities of detecting different numbers of photons in a bin are calculated for each data set. Mean gives signal strength in counts per bin and is represented by k. Variance gives standard deviation of signal strength and is used in calculating Mandel Q factor by

$$Q = \frac{\text{Variance}}{\text{Mean}} - 1 \cdot \quad \ldots (1)$$

Q is an indicator of quantum nature of signal and provides some information about its state[10]. The sets representing different portions of a pure quantum signals should have nearly same values of Q. P^n represent the probability of detecting n photons in a bin where n = 0,1, ... The set of probabilities $P = \{P^n\}$ is a photo count distribution. Subscript obs, bg, or sig is added to the calculated properties for indicating observed signal, background noise or biophoton signal. Thus k_{obs}, Q_{obs}, P^n_{obs} and Pobs are properties of observed signal, k_{bg}, Q_{bg}, P^n_{bg}, and P_{bg} are properties of background noise and k_{sig}, Q_{sig}, P^n_{sig}, and P_{sig} are properties of biophoton signal. The properties indicated by subscripts obs and bg are calculated from observed sets of data but the properties indicated by subscript sig are inferred from measured quantities by a suitable procedure called background correction. The photons detected in a bin in the observed signal is a compound event made up from events of two independent photon emitting processes, biophoton signal and background noise. The two processes are independent and hence, a classical statistical moment of observed signal is the sum of corresponding statistical moments of biophoton signal and background noise. Mean is first statistical moment and it gives

$$k_{sig} = k_{obs} - k_{bg} . \quad \ldots (2)$$

Variance is second statistical moment and satisfies similar relation that is used in calculation of Q_{sig}. The independence of two photon emitting processes also implies that photo count distribution of compound events is the convolution of photo count distributions of biophoton signal and background i.e.

$$P_{obs} = P_{sig} \otimes P_{bg} , \quad \ldots (3a)$$

The convolution expresses following recursive algebraic equations among probabilities:

$$P^n_{obs} = \sum_{j=0}^{n} P^j_{sig} P^{n-j}_{bg} . \quad \ldots (3b)$$

The recursive equations can be solved to obtain all P^n_{sig} starting with n=0. The procedure fails after a few recursions because errors of observed and background probabilities get compounded. The error in calculated P^n_{sig} increases with n and is always more than the error in P^n_{obs}.

A pure quantum photon signal is a signal in a definite quantum state and its properties can be calculated from the knowledge of its quantum state. It is assumed living system emits a pure quantum photon signal in squeezed state $|\alpha,\xi\rangle$, which is specified by two complex parameters α and ξ or equivalently by four real parameters, the magnitudes and phases of two complex parameters i.e. $\alpha = |\alpha| \exp(i\phi)$ and $\xi = r \exp(i\theta)$. The calculated properties of signal in the squeezed state $|\alpha,\xi\rangle$ are expressible in terms of these four parameters. The parameters can be time dependent but time dependence is not needed for representing a signal of constant average intensity and hence time dependence of parameters is ignored for ease of calculations. The calculated expression of signal strength k_{sig}(cal) is:

$$k_{sig}(cal) = |\alpha|^2 + \sinh^2 r . \quad \ldots (4)$$

k_{sig}(cal) is equated to k_{sig} given in eq.(2) for k_{sig} is well determined and has very small error in a signal of constant average intensity. Eq.(4) is therefore, used to express $|\alpha|$ as a function of r and k to reduce unknown parameters of a signal to three namely, r, θ and ϕ. The calculated expression of probability P^n_{sig}(cal) of detecting n photons in a bin in the squeezed state is given by

$$P^n_{sig}(cal) = |\langle n|\alpha,\xi\rangle|^2 \quad \ldots (5)$$

where $|n\rangle$ is an eigen state of number operator with eigen value n. The scalar product of number and squeezed states for a single mode photon field is given[11] by

$$\langle n|\alpha,\xi\rangle = \frac{1}{\sqrt{n!\cosh r}}\left[\frac{1}{2}\exp(i\theta)\tanh r\right]^{\frac{n}{2}} \exp\left[-\frac{1}{2}\left(|\alpha|^2 + \alpha^{*2}\exp(i\theta)\tanh r\right)\right]$$

$$\times H_n\left[\frac{\alpha + \alpha^*\exp(i\theta)\tanh r}{(2\exp(i\theta)\tanh r)^{\frac{1}{2}}}\right] \quad \ldots (6)$$

where α^* is complex conjugate of α and H_n is Hermite polynomial of degree n. The least square fitting of P^n_{sig}'s to $P^n_{sig}(cal)$'s can in principle, estimate unknown parameters but is not attempted due to high errors in P^n_{sig}'s. The problem of high errors is less severe in least square fitting of P^n_{obs}'s to $P^n_{obs}(cal)$'s because $P^n_{obs}(cal)$'s have small errors. $P^n_{obs}(cal)$'s are calculated by convoluting $P^n_{sig}(cal)$ and P^n_{bg} i.e.

$$P^n_{obs}(cal) = \sum_{i=0}^{n} P^{n-i}_{sig}(cal) P^i_{bg} \quad \ldots (7)$$

$P^n_{sig}(cal)$'s are exact expressions without any errors. Convolution of eq.(7) compounds small errors of P^n_{bg}'s only. The three parameters are estimated by minimizing the function

$$F = \sum_{sets} \sum_{i=0}^{n} \left(P^i_{obs}(cal) - P^i_{obs}\right)^2 \quad \ldots (8)$$

where n is the maximum number of photons detected in a bin in a set. The minimum value of the function F_{min} is an indicator of the quality of estimation.

The data set of bin size 400ms is used for generating data sets of higher bin sizes by merging photo counts in consecutive bins e.g. the data set of bin size 2s is generated by merging photo counts in five consecutive bins. The new data set has 4000 points in place of 20000 points of the original set. Twenty four new data sets are generated by merging photo counts in 2 to 25 consecutive bins. The probabilities in the generated data sets are calculated using already determined squeezed state parameters.

Results and Discussion

Figure 1 depicts mean and standard deviation of five data sets of the signal emitted by a sample of the lichen species *Xanthoria.Paritiana* placed in a cuvette. The data sets correspond to measurements with bin sizes 50, 100, 200, 300 and 400ms. The figure depicts almost linear increase of mean with bin size as expected in a signal of constant intensity. The

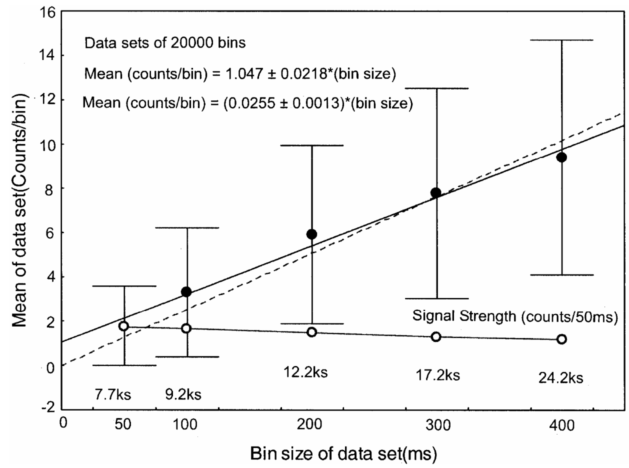

Fig. 1—Signal strength at varying bin sizes: Signal strength of data sets of five bin sizes is depicted both in counts/bin and counts/50ms. The time at the middle points in each set is indicated in the figure. The linear regressions with and without intercepts and their parameters are also indicated.

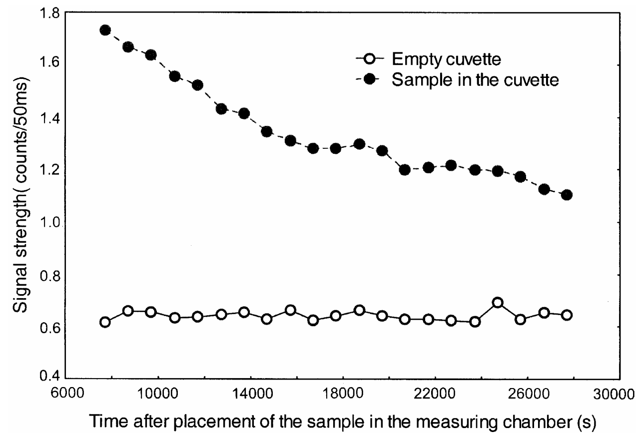

Fig. 2—Drying of the lichen sample: Signal strength in counts per 50ms is depicted as a function of time for observed signal and background noise.

figure also depicts regression lines of mean with bin size obtained with and without intercept. The parameters of two regressions are also given in the figure. The regression without intercept shows a small systematic deviation of observed mean with the regressed value indicating a small decrease of signal strength with time. The small decrease in signal strength is also indicated by unfilled circles connected with lines that express signal strength in counts/50ms. The time at mid point of a data set is depicted in the figure as well. The decrease in signal strength is attributed to evaporation of water from cells of lichen sample. The evaporation does not occur uniformly and hence the decrease is also not uniform.

Figure 2 depicts strengths of background noise and observed signal at intervals of 1000s during the course of measurement. The data points of background noise are labelled as empty cuvette and of observed signal as sample in the cuvette. The strength of background noise is almost constant and does not show any appreciable variation. The constancy of background noise indicates stability of the measuring system. The strength of observed signal is not constant but slowly decreases with time in a non uniform manner. The rate of decrease is higher during measurements with bin sizes of 50ms and 100ms but durations of these measurements are small. The rate of decrease is smaller during measurements with bin size of 400ms but its duration of measurement is more. The decrease in signal strength during measurement with any bin size is sufficiently small and is ignored for the determination of photo count distribution. The decrease in signal strength in measurements with different bin sizes is, however, not ignored. Measurements with different bin sizes are measurements at different strengths of the signal. Different signal strength is used in the estimation of quantum parameters from measurements with different bin sizes.

The Mandel Q factor does not vary in any systematic way in measurements with five bin sizes. The mean and standard deviation of Q are $Q_{obs} = 1.63 \pm 0.40$, $Q_{bg} = 2.39 \pm 1.46$, and $Q_{sig} = -0.04 \pm 0.30$. The variations of Q_{sig} and Q_{obs} is much smaller than the variation of Q_{bg}, which indicates that five portions of observed and biophoton signals are more likely to be in a quantum state than five portions of background noise. Q_{sig} is very small suggesting that biophoton signal has only a small amount of squeezing. Higher values of Q_{obs} and Q_{bg} indicate larger squeezing in observed signal and background noise.

Three squeezed state parameters were estimated separately from five data sets. The different data sets yielded nearly same estimates of parameters, which suggested the possibility of estimating squeezed state parameters common to all data sets. The parameters based on least square estimation from 451 probabilities of five data sets are r =0.06, $\theta = 2.76$ and $\phi = 0.64$. The sum of squares of residuals of probabilities in this estimation is $F_{min} = 1.92.10^{-4}$. The value of F_{min} indicates very small difference between calculated and observed values of significant probabilities and the fit is good. The excellent agreement between calculated and observed probabilities in all five data sets is depicted in Fig. 3. The figure portrays statistical behaviour of the signal over a period of 5h 50m observed with five bin sizes.

The observed signal strength k_{obs} vary from 1.73 to 9.41counts per bin in these measurements.

The statistical behaviour of signal at higher bin sizes is studied by generating data sets of higher bin sizes from measurements made with bin size of 400ms. The generated data sets will have fewer bins. The probabilities of detecting photons in a bin of higher size are calculated using common squeezed state parameters. The observed and calculated probabilities are depicted in Fig. 4 for three representative bin sizes 2, 4 and 6s along with similar probabilities for bin size 0.4s. The generated data sets for the three bin sizes were obtained by adding the observed photo counts in 5, 10 and 15 contiguous bins. The agreement between observed and calculated probabilities is quantitative at bin sizes of 0.4, 2 and 4s and qualitative at bin size of 6s. The agreement worsens with further increase of bin size and is absent in data sets obtained with bin size larger than 8s. Worsening of agreement with increase of bin size beyond 4s is a consequence of poor determination of probabilities in the generated data sets. The data sets at higher bin sizes have fewer bins but more outcomes. Consequently errors are large in the probabilities. Consider the data set of bin size 6s. It has 1333 bins and 112 possible outcomes. The calculated probability of outcome is less than 0.02 and expected frequency of an outcome is less than 25. The measuring error in the probability with expected frequency 25 of outcome will be more than 20% $\left(1/\sqrt{25}\right)$. The measuring error will be higher in a probability whose calculated value is smaller than 0.02. The expected frequency of an outcome needs to be increased for reducing its measuring error. Expected frequency of around 625 will provide a reasonable determination of probability but it will require a data set of 33000 bins in place of 1333 bins. The qualitative agreement in such a small data set of bin size 6s should be considered remarkable. The quantitative agreement between observed and calculated probabilities measured with bin sizes in the range (50ms-4s) and qualitative agreement at higher bin sizes along with the above explanation demonstrate that one squeezed state correctly describes photo count distribution of the signal measured with any bin size. The sample of lichen spontaneously emits quantum photon signal in a squeezed state for many hours and parameters of the state are measurable with reasonable accuracy in about 1000s using a bin size of 50ms.

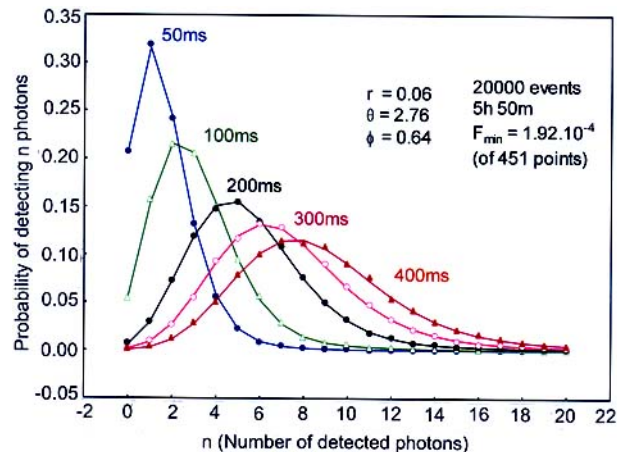

Fig. 3—Probability distribution at five bin sizes: The measured and calculated probabilities of detecting photons in a bin are plotted for different number of photons detected in a bin. The observed probabilities are depicted by symbols and calculated probabilities are depicted without symbols but joined by lines. The parameters of measurements and of the fitted squeezed state are also given in the figure.

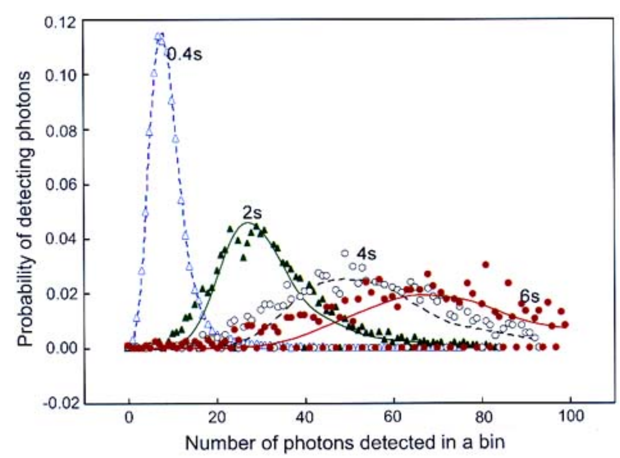

Fig. 4—Probability distribution in data sets obtained by merging measurements in contiguous bins: Probability distributions obtained by merging measurements of 5, 10 and 15 bins of the data set of bin size 400ms are depicted along with the probability distribution for bin size 400ms. The observed probabilities are depicted by symbols and calculated probabilities are depicted without symbols but joined by lines.

Implications for living systems playing passive role

The spontaneous emission of quantum photon signal in squeezed state is not restricted to lichens. Other living systems also emit photon signals with similar unusual features. The squeezed state parameters have been determined in the signals emitted spontaneously by many samples of three lichen species and by some human subjects. The parameters are different in signals emitted by different systems and appear to be a signature of four characters of the emitting system. It is a new signature and its identification has profound implications for biology. The identification is the culmination of following four inferences drawn from the statistical properties of photon signals:

1. Every living system spontaneously emits a quantum photon signal.
2. The quantum state of the emitted signal is a squeezed state.
3. A squeezed state is specified by four parameters that take continuous values.
4. The emitted photon signal remains in its quantum state for macroscopic time.

The nature of evidence and implications of each inference will be elaborated. The first inference is most crucial and radical. It contradicts expectations of the conventional picture of photon emission. In the conventional picture, photon emission from an isolated system is probabilistic. The signal in probabilistic emission decays exponentially. The distribution of photons in an almost non-decaying portion of the signal is Bose Einstein. The conventional picture does not permit any non-decaying portion in the signal. Any observed non-decaying portion in photon signal indicates its quantum nature that can be confirmed by the behaviour of its photo count distribution. A photon signal of quantum nature is in a pure quantum state and is also called quantum photon signal. A quantum photon signal can emanate only from some material system in a definite quantum state. Quantum nature of spontaneously emitted photon signal therefore, implies a definite quantum state of the parts of living system responsible for photon emission. The parts constitute a quantum entity and every living system has a quantum entity because every living system spontaneously emits a non-decaying photon signal. Photo count distribution measured in the signal of whichever system confirms its quantum nature.

Molecular biology requires biological properties to originate from and be expressed by biomolecules. Hence, a quantum entity has to be made up of biomolecules. It is probably, a composite quantum structure of bio-molecules and its properties are of two types, local and holistic. Its local properties are biomolecule centric and are described correctly in quantum and semi classical frameworks. Its local properties cannot reveal its quantum nature. The microscopic or matter class of properties of living systems are local properties of quantum entities and of other parts of living systems not included in quantum entities. The holistic properties of quantum entities are holistic properties of living systems. The description of a holistic property in semi classical framework requires correlations among biomolecules. The origin of correlations appears knowable in some properties and unknowable in others. The origin of correlations is perceived knowable if correlations can be established by exchanging information among biomolecules via physical signals. These correlations are called causal. The origin of correlations is perceived unknowable if correlations cannot be established by exchanging information among biomolecules via physical signals. These correlations are called acausal. Holistic properties requiring causal correlations constitute psyche class of properties and holistic properties requiring acausal correlations constitute consciousness class of properties. It is pointed out that no physical signal exchanging information among biomolecules required for establishing causal correlations has been identified so far. Perhaps, information exchange is only a perception and not a reality. An unbridgeable gap exists between perception and reality of the properties of psyche class. The gap was visualised earlier and called psychosomatic gap. Establishing of acausal correlations needs exchanging information in a mode that either violates a fundamental law or requires superluminal communication. The properties requiring acausal correlations are, therefore, said to belong to a reality beyond science. Existence of quantum entity changes the scenario by attributing the problems faced in describing holistic properties to the semi classical framework. Quantum framework is the correct framework of description of living systems. All properties are holistic in the quantum framework. Local properties are of special type holistic properties, whose descriptions in the semi classical framework require zero correlation. The existence of quantum entity thus, implies three classes of properties of living systems, matter, psyche and consciousness. Some living systems show properties that appear neither local nor holistic. These are incomprehensible properties and are included in the consciousness class. The consciousness class therefore, consists of two sub classes, soft and hard[12]. Soft consciousness class contains holistic properties of quantum entity requiring acausal correlations among biomolecules. Hard consciousness class contains properties that are truly incomprehensible. Some new inputs besides biomolecules and correlations are needed .for their comprehension.

Another ramification of quantum entity is the mood of a living system. Mood is an attribute of a living system in the semi classical framework introduced for describing those properties of the system that changes with time or situation. The changing properties imply changes in the state of quantum entity. A quantum entity can exist in many states and may change its state with time or situation. Its different states may have different properties that are wrongly ascribed to its different moods. Mood is therefore, not a genuine attribute but only a manifestation of state specific properties of quantum entity. The quantum state of photon signal is also a state specific property, which should be able to detect and measure mood of a living system.

A quantum entity will participate in many biological processes. Some biological processes may occur only through quantum transitions i.e. by taking quantum routes. Quantum routes imply parallel processing and make biological processes faster and more efficient. The biological processes responsible for the emission of quantum photon signal must be taking quantum routes and must be occurring at all times in every living system. Since fundamental biological processes of transcription, replication and protein synthesis occur at all times in every living system, it is suggested that fundamental biological processes take quantum routes and are responsible for the emission of quantum photon signals. Quantum route of fundamental biological processes was speculated earlier[13] for explaining basic facts of genetic code, namely occurrence of four types of nucleotide bases, codons made up of three nucleotides and twenty amino acids. Quantum route of fundamental biological processes implies that selections of partners in these processes are quantum selections. An object can select its desired partner in one step from four possible partners and in three steps from twenty possible partners[14] in quantum selections. The selections in fundamental biological processes are of two types, a nucleotide selects its partner in one step selection and by a codon selects its partner in three steps selection. The basic facts of genetic code therefore, reflect the use of a most efficient selection machinery and optimal utilisation of resources. The necessary condition for operation of quantum selection machinery is the quantum character of various objects -nucleotides, codons and amino acids – participating in selection processes. These objects need not remain quantum at all times. Only the subset of objects involved in selections at any time needs to be quantum. It permits quantum selections among objects that loose quantum character after a while because of de-cohering interactions of environment provided there is some cohering mechanism in a living system to counter the effects of environmental interactions. It is therefore, visualised that the objects like nucleotides, amino acids and codons constituting a quantum entity exist in both classical and quantum structures and these objects continuously transform from classical to quantum structures and vice versa under the influence of cohering mechanism and de-cohering interactions. The transition of an object from classical to quantum structure requires energy that is supplied by the usual biochemical machinery. A quantum structure grows to a macroscopic patch by recruiting more and more objects from neighbouring classical structures. De-cohering interactions limit the growth of a quantum patch and convert the patch into a classical structure after awhile. The transition from quantum to classical structure also occurs after quantum selections. A quantum entity will therefore, appear as a collection of continuously changing quantum patches of different sizes in the semi classical framework. The distribution and sizes of quantum patches will be specific to a system and will characterise its instantaneous quantum state. The distribution and sizes of quantum patches will determine the spectral distribution of intensity in the quantum photon signal. The similarity in spectral distribution of intensity in quantum signals emitted by different living systems suggests similarity in distribution and sizes of quantum patches in different living systems. The above visualisation implies that quantum photons originate mainly from regions where transcription replication and protein synthesis occur.

The second inference, namely squeezed state of quantum photon signal, is based on the success in reproducing photo count distributions at any bin size in the range (50ms-6s) observed over a period of more than 5hr by three squeezed state parameters and signal strength. Squeezed state of quantum photon signal was proposed to explain delayed luminescence and spontaneous photon signals in a unified scheme[15]. It is the only scheme that successfully reproduces all aspects of delayed luminescence and spontaneous photon signals. The scheme confers few other advantages. A squeezed state is a minimum uncertainty state and photon signal in a squeezed state carries information for a long time without any appreciable loss. The signal can transmit information to far off places with very little expense of energy and is detectable even if its energy is below the noise level. Squeezed state of the photon signal suggests the possibility of a new mode of information transfer. The information content in the new mode is measurable and will, hopefully, be deciphered soon. The deciphering of information will open up many hidden planes of experience and awareness for investigations[16].

The third inference, namely four parameters specifying a quantum photon signal, suggests the existence of three additional measurable attributes of a living system besides signal strength. Signal strength and squeezed state parameters are quantum attributes of a living system. The quantum attributes take continuous values and hence can faithfully capture immense diversity of living systems and their moods. Mood includes holistic qualities of living systems e.g. health, vivacity, germination capacity, etc. These and other similar qualities are quantifiable and measurable in terms of quantum attributes. The range of variation of quantum attributes is suspected to be species specific. There is a need to determine the ranges of different species and to calibrate the variation in a specific living system with holistic qualities. The measurements made in human subjects indicate that $r = 2.72.10^{-10}$, $\theta = 101.8^{o}$ and $\phi = 69.5^{o}$ in signals emitted at different anatomic locations in healthy human subjects. The signal strength varies with anatomic locations and with subjects.

The fourth inference, namely, stability of quantum photon signal for macroscopic time, is based on stability of squeezed state parameters. It is most difficult to implement and comprehend. The determination of photo count distribution implicitly assumes stability of quantum state of photon signal and of quantum entity. Quantum field theory can only provide the correct scheme for implementing two stabilities and understanding their linkage. It is possible to visualize three scenarios of linkage between two stabilities in the semi classical framework, stability of photon signal is primary and photon signal coordinates the behaviour of spatially separated quantum patches for maintaining the stability of quantum entity; two, stability of quantum entity is primary and photon signal merely reflects energy balance in various spontaneous acts of the quantum entity; and three, both stability of photon signal and of quantum entity are at the same footing for photon signal and quantum entity are in entangled quantum states. The linkage between photon signal and quantum entity has an important consequence. It shifts the emphasis of investigations from living system to non-living photons. The holistic properties of a living system are properties of its quantum entity and these properties can be studied by investigating properties of its photon signal. The last scenario is philosophically more appealing. It provides two equivalent ways to describe and manipulate a living system, one based on quantum entity made up of matter and the other based on photon field made up of energy. The state of a living system can be ascertained either by observing the behaviour of its matter content through various pathological and diagnostic tests or equivalently by determining squeezed state parameters of its quantum photon signal. Similarly a state can be changed say, from a sick state to a healthy state, by manipulating either matter content of living system or its entangled field or a combination of the two. Modern medicine employs corrective measures based on manipulations of matter but there can also be corrective measures based on manipulations of field. The optimum strategy for a managing a disease may turn out to be a combination of the two types of manipulations. The optimum strategy requires knowledge of various correlations between quantum parameters and state of health and of ways of manipulating quantum photon signal of a subject.

The far reaching nature of above implications demands a closer look on implicit assumption in the procedure followed in identifying the quantum state of a photon signal. The procedure assumes that detections of photon number in successive bins are measurements in different copies of an ensemble representing the quantum state of signal. The procedure uses two time scales, sampling time and measuring interval. Sampling time is the time spent in sampling a quantum copy; it is equal to the bin size. Measuring interval is the time spent in measuring an attribute of a living system; it is equal to time interval of twenty thousand bins. Measuring interval has to be much larger than sampling time and has to be small enough not to change the state of a living system. Sampling time has to be much larger than switching time in data collection and has to be larger than the characteristic time of metabolic activities. It is our experience that sampling times larger than 50ms yield good results. The squeezed state of the emitted photon signal is established by measurements made with many sampling times. The measurement of any other property of the quantum entity completed in a time lying in the above noted range of sampling times (50ms-6s) will be a measurement in a copy of the ensemble and outcomes of repeated measurements will not be normally distributed. Normal distribution is not obtained in repeated measurements of many physiological properties. These properties perhaps, have some connection with properties of quantum entity. The conductivity of a portion of human hand is an example of such properties and its distribution in repeated measurements is thought to be an indicator of human health.

The above considerations are based on the passive role of living system. A living system is treated as a black box from which photons of quantum nature continuously leak out. The capability of a living system to use and manipulate quantum photons is ignored. At least some living systems do have the capability to use quantum photons and they can play active roles leading to newer implications. A few implications are elaborated in the next section.

Implications for living systems playing active roles

The capabilities needed for active roles are the capability to measure properties of quantum photon signal, to decipher information contained in these properties and to generate quantum photon signals with desired properties. Physical laws permit these capabilities in a physical system but evidence of living systems with these capabilities is only scanty at present. Hence, the implications based on these capabilities have to be considered speculative. The speculative nature will be indicated by using biophotons for photons of quantum nature emitted by living systems. A few living systems give measurable responses to some but not all biophoton signals. These living systems have been used as biological detectors. It is speculated that squeezed state parameters of biophoton signals detectable by a biological detector lie in specific ranges and the type of a biophoton signal is determined by the range of its squeezed state parameters. Onion roots, yeast cells and amphibian eggs are well known examples of biological detectors[15]. These living systems detect biophoton signals they themselves emit and a few more. Selective detection implies that biological detection is not based only on the intensity of detected signal but also on some other characteristics as well. Our knowledge of a biological detector depends on the perceptibility of its response to biophoton signals. A living system capable of detecting but not showing perceptible response will remain oblivious to us. We therefore, speculate that every living system is capable of detecting biophoton signals of the type it emits and a few more biophoton signals of similar types but the response is perceptible only in few systems. The speculation permits biophotonic channel of information transfer at least among living systems emitting same or similar types of biophoton signals. If all systems of a species happen to emit biophoton signals of similar type then biophoton field can be identified with morphogenic field (and its many variants) that was mainly envisaged to provide a new channel of information transfer. Many laboratories routinely detect biophoton field using non-living detectors. The information content of a biophoton field will hopefully, be deciphered in near future. It will then clarify many aspects of morphogenic field.

The speculated capability is problematic in human beings for a human subject capable of detecting biophoton signals will know one's own capability and will be able to tell its existence to other human beings. Since a human subject receiving information via biophoton channel does not seem to exist, one has to reconcile the speculated capability of human subjects to detect biophoton signals and their ignorance of its existence. A new born child, perhaps, senses biophoton signals emitted by other human beings but does not know how to decipher information from them. The child also senses photon signals received from sensory channels and does not also know how to decipher information and extract meaning from these signals. Every child has to learn the art of deciphering information received and communicating its experiences. The signals from sensory channels are strong, classical and easy to interpret. The society assists a child in deciphering information from signals of sensory channels and teaches it the art of communicating experiences. In contrast, the signals of biophoton channel are weak, quantum in nature and difficult to interpret. The society does not teach a child the technique of extracting information from a quantum signal. As a result, the child starts filtering out biophoton signals and concentrates attention only on classical sensory signals. Perhaps after a period of bewilderment, the child associates meaning only to classical signals. The child is rewarded for the proficiency to ignore obstructions caused by biophoton signals. The child treats biophoton signals as noise to be ignored and brushes aside the innate ability to detect biophoton signals. The innate ability, however, remains intact and can be used in future if the child learns to decipher information from quantum biophoton signals. The learning will enable the child to access information about other objects via biophoton channel and see some objects not visible otherwise. The child can be in communion with the entire world via biophoton channel. Many religious traditions envisage acquiring of such a capability by a few persons. It is an additional capability and one may not always relish it. Imagine the horror of a person who has acquired it by chance and then starts using it to know the guarded secrets of acquaintances. Even a true narration of splendour and beauty of nature learnt via biophoton channel will fetch him the epithet paranormal. The knowledge gained through the additional capability will make him nonconformist. The society packs nonconformists to solitary confinement either in jail or in jungle.

The resources required in determining the classical state of a biophoton signal are only a small fraction of the resources required in determining its quantum state. The classical state is determined by the intensity whose determination requires a few measurements of photon number in a bin of large size. The quantum state is determined by quantum parameters whose determination requires many thousand measurements, the assumption about the quantum state and estimates of its parameters from measured data. The determination of the quantum state is a big drain on resources. The determinations of quantum states of many biophoton signals may strain a living system to the point of breakdown. Every living system should avoid determining quantum state and should resort to inferences based on determinations of classical states as often as possible for survival. There may however, be situations in which determining of quantum state is imperative e.g. in noisy environment, where some combination of quantum parameters of a signal are unaffected by noise and are therefore, detectable.

The capability to determine quantum state of a biophoton signal confers evolutionary advantage to a living system. The system can get access to information of the other living systems not otherwise available. The system will know all events of other systems affecting their biophoton signals. The system will have the power of remote sensing of these events. Perhaps, remote sensing is involved in clairvoyance and extra sensory perception, and it arises from the use of information obtained via biophoton channel. A living system will be able to use biophoton channel for remote intervention by sending coded biophoton signals that influence another living system. Do wishful thinking and blessings generate coded biophoton signals? It is feasible but it needs experimental verification. The power of remote intervention is achievable more easily if living system is entangled with its biophoton field. The living system intending to intervene has to set its biophoton detecting machinery to some desired state and wait for the detection of biophoton field of targeted living system in the desired state. The act of detection accomplishes the desired intervention. The targeted living system attains the state entangled with the detected photon state. There are many interesting questions connected with this mode of remote intervention. Which living systems have biophoton detection machinery? How does a living system adjust its photon detecting machinery to a desired state? How much time does a system wait for detection? Can a human subject acquire the capability to detect quantum state of a biophoton signal? Do prayer, meditation, breathing exercises and drugs help in acquiring this capability? We do not know the answers of these questions but we suspect that answers will provide physical basis of the phenomena like memory transcendence, paranormal perception, remote healing and some alternative therapies.

Lastly, it is conceivable that a living system having the capability to determine quantum state of a biophoton signal can determine quantum state of its own biophoton field. Such a living system will be able to self introspect. Self introspection is more poignant in the scenario of system entangled with biophoton signal. Since entangled biophoton field is a true image of the quantum entity, the system will be able to observe and analyse itself. The possibility to observe and analyse one self is the additional ingredient needed for showing the supervenience of hard problems of consciousness. It will t to integrate metaphysical and philosophical vision of life with physical sciences.

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