Anti-photon.

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Abstract

The purpose of this article is neither a compilation, nor a critique of the article by W. E. Lamb of which it gets the name: It adds arguments and applications. Quantum electrodynamics quantizes "normal modes" chosen arbitrarily among the infinity of sets of orthogonal modes of the electromagnetic field. Changing the choice of normal modes splits the photons which are not physical objects. The classical field of electromagnetic energy is often, wrongly, considered as linear, so that Bohr's electron falls on the nucleus and photon counting is false. Using absolute energies and radiances avoids doing these errors. Considering the photons as small particles interacting without pilot waves with single atoms, astrophysicists use Monte-Carlo computations for the propagation of light in homogeneous media while it works only in opalescent media as clouds. Thus, for instance, two theories abort while, they are validated using coherence and Einstein theories, giving a good interpretation of the rings of supernova remnant 1987A, and the spectrum found inside. The high frequency shifts of this spectrum can only result from an interaction of light with excited atomic hydrogen which is found in many regions of the universe.

1 Introduction.

Despite criticism of the use of the concept of photon in W. E. Lamb's paper [1] whose title I adopt, this concept related to quantum electrodynamics is the official theory of the interaction between light and matter. The purpose of this paper is to supplement papers [1, 2] by correcting common mistakes in classical and quantum theories and to illustrate the danger of using the concept of photon : "The free-electron laser is an excellent example of how the "photon-picture can obscure the physics "" [2]. This danger is particularly destructive in astrophysics since it eliminates simple and efficient theories, benefit of a theory too wonderful to be convincing. A classical theory which considered wrongly the field of density of electromagnetic energy as a linear field, fails to explain experiments using photon counting, so that quantum electrodynamics seems better. On the contrary, quantum electrodynamics is unable to interpret the too fast start up of a laser.

The first section presents the photon specifying some knowledges of electrodynamics too often misjudged:

- definition of optical modes, a consequence of the linearity of Maxwell's equations, including in matter, thanks to the cunning of Schwarzschild and Fokker.

- Planck's formula corrected by the author in 1911.

- quantization of normal modes of the electromagnetic field and geometric expansion of the photon.

The next section shows how to override the use of photons by simple and reliable Einstein's theory [3]. Using absolute radiance is first recalled. A correct use of the field of density of electromagnetic energy explains both absorption and emission of light.

A coherent Raman scattering is substituted in the theory of the refraction of light, to Rayleigh coherent scattering. The spatial coherence is preserved only in certain media and using time-incoherent light. Several simultaneous scatterings are required to obtain a parametric effect in which energy transfers produce frequency variations.

The next section applies the principles to some aspects of a well observed astrophysical system, whose properties are not well explained by the standard theory. It shows that outstanding models are rejected for lack of use of optical coherence.

2 The photon.

2.1 Linearity of Maxwell's equations.

The equations of the electromagnetic field in vacuum, united under the name of Maxwell's equations are linear, so that any linear combination of electromagnetic fields is an electromagnetic field. Matter is usually introduced as a continuous medium, through the approximation of permeability μ and permittivity ϵ, often depending on the field, and the linearity is lost. We can calculate the delayed electromagnetic field radiated by an accelerated charge. By time reversal, the delayed field becomes an advanced field. By subtraction, the charges are removed, while the field remains in the future. Fokker and Schwarzshild preserve the linearity of Maxwell's equations by replacing the charges by advanced fields, which modify only the boundary conditions of the equations.

2.2 The optical modes.

The solutions of a system of linear equations are represented by points of a vector space S. A mode is a set of solutions that differ only by a multiplicative real constant, it is represented by a radius of S. We set the norm of a solution of Maxwell's equations is its electromagnetic energy *calculated assuming no other electromagnetic field*. Scalar products and orthogonality of solutions and modes are deduced from the norms.

An astronomer is interested in the beams of light defined by the entrance pupil of a telescope and the figure of diffraction of a far point (star). These beams are, a bit improperly, qualified "single-mode"[1]. The time-incoherent usual "monochromatic" light sources, emit pulses whose spectral width corresponds to a pulse long of a few meters. A "monochromatic" pulse propagating in a "single-mode" beam defines an optical mode which may be qualified "normal".

2.3 Planck's Formula.

Planck's formula which gives the spectral radiance of a single-mode light beam in a blackbody remains valid if a small hole in the blackbody allows an escape of the beam into a transparent medium. Then, the temperature T_P of a light beam may be defined without black body, from the spectral radiance I_ν and frequency ν.

The atomic theory shows that charged particles which emit fields are small using the scale of their distances. Thus, the field emitted by a particle in its neighborhood is much more intense than the field created at the same point by other particles. Thus, the absorption of the emitted field (which is the addition of an opposite field) requires many particles. It remains a "residual field" [2] that would lead to Planck's constant h if we could calculate it directly.

[1] They are single-mode only for a continuous, infinite sine wave.

[2] The residual field has many other qualifications, for instance: stochastic, zero-point, and even quantum though awareness of its existence is older than quantum theory.

In response to numerous criticisms, such as non-equivalence of energy of a mode to kT_P for T_P large, Planck amended his law in 1911 [4, 5], obtaining the absolute spectral radiance of a black body:

$$I_\nu = \frac{h\nu^3}{c^2}\{1 + \frac{2}{\exp(h\nu/kT_P) - 1}\} \quad (1)$$

2.4 Quantization of light: the photon.

The modes deduced from Fourier developments are often qualified "normal". This choice is arbitrary: wavelets developments are more physical because they do not involve infinity, and they appear more efficient in particular to represent images. Anyway, this choice would be arbitrary too.

The energy of a normal mode is identified with the energy of a harmonic oscillator representing the photon. This changes the interpretation of Planck's formula by transforming average quantities, as residual energy, into exact quantities. But any system of orthogonal modes can be considered as a system of normal modes. A photon defined from a system of orthogonal modes is thus a mathematical object which may simplify calculations, but it represents a physical quantity only if the choice of orthogonal modes of the system is dictated by physics.

In acoustics, the normal modes correspond to the best linear approximation of the non-linear laws of propagation of the sound. Some modes of emission of a laser build a small system of orthogonal modes stabilized by imperfections of the laser. But it remains dangerous to use the concept of photon, even in the case of a single pulse propagating in a diffraction limited ray.

The electromagnetic field of a normal mode corresponds to Schrödinger's wave function Ψ although it has not exactly its properties. With usual time-incoherent light, the geometric expanse of a photon wave function is a few meters in the direction of propagation, but can become very large in perpendicular directions. Also *the photon does not interact with a single atom, but with the quantum system consisting of all atoms that are "dressed" by the field of the mode.* A transition of a particular atom is the result of a "quantum decoherence" which transfers the very low energies dressing each atom to a single atom. In a classical interpretation, all atoms located in the mode are weakly excited and the equivalent of quantum decoherence is a purely radiative process, subject to propagation time.

3 The photon leads to a failure of optical coherence.

Ignoring the relationship of the photon with its Ψ function, the photon, a particle of low energy, is seen as small and does not seem to interact coherently with all the atoms of a vast cloud of gas. Consequently neglecting the coherence, many computations are absurd.

3.1 Propagation of light in a resonant medium.

Einstein's theory gives the variation of the spectral radiance of a single mode beam propagating in a resonant medium.

How to introduce the coefficient A for a quasi-monochromatic beam that undergoes several successive amplifications and absorptions? It is tempting but false to introduce, after each complete absorption, a spontaneous emission with a new arbitrary phase. The use of absolute radiance avoids the error: formally, by making coefficient A nil; more fundamentally by considering that the interactions of a beam of light with matter are amplifications or attenuations of spectral radiance [3].

In the resonant medium, set N_2 and N_1 the populations of upper and lower levels (assumed nondegenerate) of the transition of frequency ν and set T_B the Boltzman temperature of the transition [4], solution of equation $N_2/N_1 = \exp(-h\nu/kT_B)$. The sign of the amplification, or B is simply deduced from $T_B - T_P$ by the second law of thermodynamics. 5 A monochromatic beam of unknown origin has a phase change only by propagation including refraction either if it has a recoverable energy, i.e. if it is visible, or if its radiance is only $h\nu^3/c^2$, i.e. if it is invisible. Thus, all interactions are coherent. The use of "spontaneous emission" remains to qualify a low level amplification although it has no fundamental meaning.

3.2 Field of electromagnetic energy.

The electromagnetic energy field is often implicitly regarded as linear. Thus, some physicists calculate the energy radiated by the electron of the classical Bohr's atom with implicit assumption that there is no external field. They conclude that the electron loses energy and must fall on the nucleus. With the residual field (including its fluctuations to reflect the "Lamb shift"), the electron does not lose energy in the average, although it emits a field while on a stationary orbit.

Although the energy corresponding to the minimum $Z^2 = h\nu^3/c^2$ absolute radiance is not recoverable, it must not be neglected. In particular, upon detection of a field of low radiance $(Z+f)^2$ by "photon counting", the photocell receives a flow of energy $(Z+f)^2$ and leaves in the beam the flow of energy Z^2. The cell gets a flow of energy $2Zf + f^2$. If f is small compared to Z, the detected energy is a linear, not quadratic, function of f. The wrong calculation suggest that the classical theory is less reliable than the quantum theory.

The absorption of an electromagnetic field is often studied by strange theories that ignore the magnetic fraction of the electromagnetic field, or introduce quantities such as the "radiation reaction".

Emission and absorption of a quantum $h\nu$ of energy by an atom are very similar: emitting permanently a field in its "spherical" mode of frequency ν, the atom exchanges energy with the external fields, in the average a null energy, just as Bohr's electron. A large fluctuation of this energy may pump the atom to a pass of its potential function, so that a transition occurs. The positive or negative, quantized transition energy $h\nu$ changes phase and amplitude of the field emitted in the spherical mode of frequency ν, so that the transition energy is exchanged with the external field.

For an excitation of an atom by a plane wave, the plane mode must be projected on the spherical mode of the atom, leaving a diffracted wave. This process is observed at the start up of a laser: to emit a spontaneous wave, an atom amplifies first the residual field of5 its spherical mode, then after starting the laser, the emissions are induced by the projection of the laser plane wave: the residual field appears twice as effective as the laser field.

3.3 Parametric interaction of pulses.

Modify the theory of refraction by replacing the coherent Rayleigh scattering which generates the refraction, by a scattering at a shifted (Raman) frequency.

[3] It is agreed that the component of the field whose phase is shifted by $\pi/2$, producing the refraction, and the in-phase component that produces absorption or emission, are treated separately.

[4] To simplify, we assume that $N_2 < N_1$ that is that there is no inversion of population

The atoms located between two wave surfaces, separated by ϵ small, are dressed by an electromagnetic field represented by an amplitude $A = A_0 \sin(\Omega t)$. For refraction, these atoms radiate a field that, according to Huygens, reconstructs a wave surface. The out of phase component radiated by the atoms is: $A = K\epsilon A_0 \sin(\omega t)$, where K is a diffusion coefficient. The resulting field is

$$A_0[\sin(\Omega t) + K\epsilon\cos(\Omega t)] \approx A_0[\sin(\Omega t)\cos(K\epsilon) + \sin(K\epsilon)\cos(\Omega t)] = A_0\sin(\Omega t - K\epsilon). \tag{2}$$

This result defines the index of refraction n by the identification:

$$K = 2\pi n/\lambda = \Omega n/c. \tag{3}$$

Atoms can radiate a higher (anti-Stokes) frequency, whose in-phase component introduces a diffusion coefficient K'. With ω, K'¿0:

$$A = A_0[\sin(\Omega t) + K'\epsilon\sin((\Omega+\omega)t)]$$
$$A = A_0\{\sin(\Omega t) + K'\epsilon[\sin(\Omega t)\cos(\omega t) + \sin(\omega t)\cos(\Omega t)]\}.$$
$$A = A_0\{[1 + K'\epsilon\cos(\omega t)]\sin(\Omega t) + K'\epsilon\sin(\omega t)\cos(\Omega t)\}. \tag{4}$$

As ϵ is infinitesimal and K' small, $[1 + K'\epsilon\cos(\omega t)]$ is close to 1. Assuming that ωt is small:

$$A \approx A_0[\sin(\Omega t) + \sin(K'\epsilon\omega t)\cos(\Omega t)]$$
$$A \approx A_0[\sin(\Omega t)\cos(K'\epsilon\omega t) + \sin(K'\epsilon\omega t)\cos(\Omega t)] = A_0\sin[(\Omega + K'\epsilon\omega)t. \tag{5}$$

$K'\epsilon$ is an infinitesimal term, but the hypothesis ωt small requires that the Raman period $2\pi/\omega$ is large in comparison with the duration of the experiment t.

Stokes contribution, obtained replacing K' by a negative K'', must be added. Assuming that the gas is at equilibrium at temperature T, $K' + K''$ is proportional to the difference of populations in Raman levels, that is to $\exp[h\omega/(2\pi kT)] - 1 \propto \omega/T$.

K' and K'' obey a relation similar to relation 3, where Raman polarisability which replaces the index of refraction is also proportional to the pressure of the gas P and does not depend much on the frequency if the atoms are far from resonances; thus, K' and K'' are proportional to $P\Omega$, and $(K' + K'')$ to $P\Omega\omega/T$. Therefore, for a given medium, the frequency shift is:

$$\Delta\Omega = (K' + K")\epsilon\omega \propto P\epsilon\Omega\omega^2/T. \tag{6}$$

The relative frequency shift $\Delta\Omega/\Omega$ is nearly independent on Ω. It must be integrated along a path ℓ of the light ray, setting $d\ell = \epsilon$.

Hypothesis ωt small requires that Raman period $2\pi/\omega$ is large in comparison with the duration of the light pulses; to avoid large perturbations by collisions, the collision-time must be larger than this duration. This is a particular case of the condition of space coherence and constructive interference written by G. L. Lamb: "The length of the pulses must be shorter than all relevant time constants" [6].

Refraction is a parametric interaction, an interaction in which the atoms return to their original state. To obtain a balance of energy with Raman resonances, so that the interaction is parametric, at least two rays of light must be involved. The coldest rays receive energy lost by the hottest. The thermal background radiation provides cold isotropic rays. Their irradiance is large.

The path needed for a given (observable) red-shift is inversely proportional to $P\omega^2$. At a given temperature, assuming that the polarisability does not depend on the frequency, and that P and ω may be chosen as large as allowed by Lamb's condition, this path is inversely proportional to the cube of the length of the pulses: an observation, easy in a laboratory with femtosecond pulses, requires astronomical paths with the nanosecond pulses of ordinary incoherent light.

The 1420 MHz spin recoupling resonance of hydrogen atoms is too high, but the frequencies 178 MHz in the $2S_{1/2}$ state, 59 MHz in $2P_{1/2}$ state, and 24 MHz in $2P_{3/2}$ are very convenient: The Coherent Raman Effect on Incoherent Light (CREIL) is this parametric transfer of energy between beams propagating in *excited* atomic hydrogen.

4 Coherent interactions in astrophysics.

Using Einstein's theory, now usual in laser spectroscopy, has presented great difficulty for most physicists who claimed "Townes' maser will not work". But astrophysicists continue to follow Menzel's sentence [7]: "The so-called "stimulated" emissions which have here been neglected should be included where strict accuracy is required. **It is easily proved**, however, that they are unimportant in the nebulae". For Menzel, the photon is a small particle which interacts with a single atom, losing its phase.

To calculate the propagation of light in a resonant medium without coherence, the astrophysicists apply the method of Monte Carlo to photons. The interaction is modeled by a statistical law and the conditions of interaction are drawn. This method is efficient in problems where the interaction of a particle with an atom is complex, so the phase of the pilot wave of the particle does not play a significant role. The Monte Carlo gives excellent results in the calculation of the interaction of neutrons with uranium atoms, or photons with the inhomogeneities of an opalescent medium like a cloud. But wave optics, particularly the theory of refraction show that the phase of the photons is only lost when density fluctuations [5] produce Rayleigh or Raman incoherent sources of blue sky. In a dilute gas, the most frequent density fluctuations are binary collisions, whose number per unit volume is inversely proportional to the square of the density. Contrary to the opinion of Menzel, it is incoherent interactions that cannot occur in the nebulae.

One could argue that the atmosphere is a transparent medium. But the refraction of light in resonant homogeneous environments such as colored liquids or glasses does not show a significant scattering.

4.1 Superradiance in the Strömgren model [8].

Strömgren has studied a model consisting of a vast cloud of very low pressure, initially cold hydrogen in which a star is extremely hot. In the vicinity of the star, hydrogen is fully ionized into protons and electrons so it is completely transparent if rare collisions are neglected. By increasing the distance r to the star, traces of atoms appear. These atoms radiate and cool the gas, accelerating exponentially the production of atoms. Strömgren shows the formation of a relatively thin spherical shell that absorbs much of the star's radiation and re-emits the atomic hydrogen lines into all directions. This shell is seen as a disk, particularly bright near the limb.

In the years immediately following the explosion of supernova 1987A, a region in the shape of an hourglass and scattering fairly high light could be observed and measured by comparing travel times of direct and indirect light ("photons echo"). Later, a system of three discrete rings (pearl necklace) appeared [9]. Burrows and al. [10] have verified that the geometry of these rings could be interpreted by a emission of the hourglass near the limb. Thus, they likened the hourglass to

[5] or phosphorescence of complex molecules

a Strömgren shell distorted by variations in gas density. But the rings are very thin so that they have not been able to keep this interpretation.

Strömgren did not take into account the possibility of a strong induced emission, i.e. a strong superradiance. Let's break the Strömgren's shell into infinitesimal shells centered at O. Set ρ the distance of a beam of light from the star O. For ρ small, the angle of incidence of a beam on an infinitesimal shell is an increasing function of ρ, so the beam path and its amplification in each shell are increasing functions of ρ. If ρ is larger than the radius of the outer shell, the amplification is zero. Thus there are at least a maximum amplification. Choose the smallest, setting R. The most intense rays, tangent to the sphere of radius R emitted into a given direction, are generators of a cylinder of revolution seen as a circle.

As the increase of radiance of a ray is proportional to its initial radiance, the most intense rays, tangential to the sphere of radius R, absorb at each point more energy than others whose radiance is lower. Thus, there is a single maximum R. This "competition of modes" works also on the cylinder defined by a given direction, so that the circle is seen dotted. By light diffraction, the dotted circle gets the appearance of TEM(l,m) modes of a laser for which l has a nonzero value imposed for example by a circular screen.

Hydrogen emits several spectral lines, an observation in black and white blends multiple monochromatic systems. The dots are not independent because, for example, emitting a superradiant line depopulates the upper level of the transition, which favors emissions with this level as lower level. However, the complexity of the superradiant system does not hide the analogy of the central ring of Supernova 1987A with certain systems of laser modes.

4.2 Parametric interactions in the Strömgren's model.

The absorption spectrum of atomic hydrogen obtained with a low radiance source shows only the lines of hydrogen, so that only a low fraction of the energy is absorbed. With the high radiance rays from the star, multiphoton interactions involving a few virtual levels allow for full absorption to resonant final states. Although superradiant rays are far from achieving the radiance of the stellar emission, they depopulate the excited levels intensely, so that complete cycles of white light absorption and emission lines of hydrogen become virtual. They form a multiphoton scattering induced by superradiant rays.

Suppose that the induced scattering is efficient enough to reduce the temperature of the stellar rays to the order of magnitude of the temperature of the superradiant lines. A volume with the dimensions of the thickness of the Strömgren's shell has in all tangential directions a luminance a bit lower than the remaining luminance of the star. If this volume is much larger than the volume of the star, it radiates more than the star which is no longer visible.

Suppose that light crosses a huge amount of cold gas outside the shell. A parametric effect may split the frequency of an hydrogen superradiant line into the resonant frequency of some atom or molecule and the frequency of an idler. The length of the path may allow the generation of weaker, sharp lines emitted collinear with the hydrogen lines.

Concluding, Burrows' model explains the geometry of three rings of supernova remnant 1987A from a previously observed scattering region in the shape of an hourglass. Superradiance explains the sharpness of the rings and their discontinuities. Parametric interactions explain the high brightness of the rings by a transfer of most of the energy radiated by the star into the rings. Similar superradiances can probably replace gravitational effects which require proper alignment of massive stars (Einstein Cross, etc...).

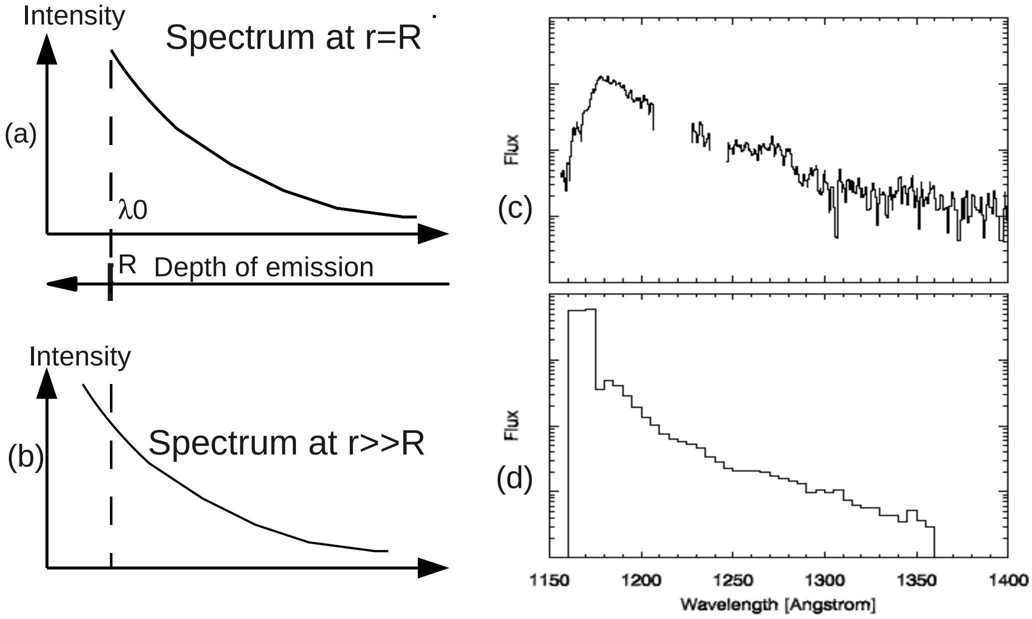

Figure 1: Spectrum of weak light emitted inside the ring: (a), (b) present theory, observed at distances R (a) and larger (b); (c) experimental and (d) theoretical from Michael et al. [11]. $\lambda 0$ is Ly_α wavelength (122 nm).

5 Spontaneous emission of a Strömgren sphere.

At a distance from the star r slightly less than R, the plasma contains few, very excited, hydrogen atoms that may slightlyamplify a light ray propagating at distance ρ from O, in particular, its Lyman alpha line. This low, "spontaneous emission" is a rapidly growing function of r.

At very low pressure, the incoherent scatterings are negligible. On the contrary, the parametric, coherent interactions are not disturbed by collisions, they can be intense. In particular, the scattering of light by hydrogen atoms in the 2S or 2P states exchanges energy between present radiations, causing an increase of entropy and frequency shifts. The slightly "spontaneously" amplified rays absorb energy lost by the stellar radiation and lose energy absorbed by the continuum, so that their frequencies are shifted. What is the balance? The irradiance of the continuum is high, so we can assume that the balance is negative for spontaneous emission. The intensity of the amplification is an increasing function of r, while the redshift increases with the path to outside, therefore decreases with r. For $r = R$, the emitted intensity is maximum and observed at the laboratory frequency. At this point, the intensity drops sharply to 0 at higher frequencies (fig.1,a).

This fall, called "Lyman break" is observed in the spectra of objects called far galaxies.

For r slightly above R, the density of excited atomic hydrogen, initially quite high to start superradiance falls fairly quickly. Simultaneously, the induced scattering decreases the radial propagation speed of light energy well below the speed of light. Thus, a large hot irradiance provides much energy to the spontaneously emitted rays, whose spectrum is shifted towards shorter wavelengths (fig. 1,b).

The amplifications and frequency shifts depend on ρ. In the observation, the spectra add for various values of ρ. In particular, the observed Lyman break is not very sharp. 5 Michael et al. [11] observed this Lyman alpha spectrum inside the main ring of SNR1987A (fig 1,c). They could not interpret this spectrum by an expansion of the universe applied to a very distant star observed behind SNR1987A because the solid angle of observation of the ring is relatively large. A Doppler effect of gas emitters was not plausible because the speed should be too fast. It only remained the assumption of a redshift by propagation in hydrogen, but the Monte-Carlo computation, shows a high peak, cut by the recorder, at Lyman α wavelength λ_0 (fig 1,d). The coherent, parametric, Raman effect corrects simply their spectrum.

Indeed, the high redshifts interpreted by the expansion of the universe, coincide *always* with a presence of hot hydrogen: This is a disaster for the foundations of the Big Bang theory.

6 Conclusion.

Quantum electrodynamics is founded on quantification of normal modes whose selection among an infinity of systems of orthogonal modes is arbitrary. Thus the notion of photon should be used with so much caution that it seems desirable to reject it and to interpret the propagation of light in a resonant medium from Einstein's theory.

Taking the field of density of electromagnetic energy for a linear field, and computing this field from relative values of the electromagnetic field, some spectroscopists believed to show that the electron of Bohr's atom falls on the nucleus, and they have falsely interpreted photon counting experiments, deducting the inaccuracy of the classical theory.

These errors are particularly disastrous in astrophysics. For instance, neglecting coherent interactions in the study of supernova remnant SNR1987A, wrong computations aborted precise explanations validated here:

Its dotted rings result simply from a superradiant emission of the "hourglass" observed in the years which followed the explosion of the supernova.

The dots appear very quickly, showing a non-linear effect. The appearance of the rings was simultaneous with the disappearance of the star because an induced multiphotonic scattering transfers almost all radiation of the star to the rings. This explains the persistent radiation of the rings.

Michael et al. showed that the spectrum observed inside the rings must result from an interaction of light with the plasma of hydrogen, but their incoherent redshift process was too weak, so that they observed a strong peak at the resonance frequency. The coherent Raman parametric effect involving the hyperfine frequencies of excited hydrogen atoms explains the blue-shifted peak of the spectrum, the fast decrease of its intensity at the short wavelength side, and the regular, slow decrease at the other side.

Coherence seems to have many other applications in astrophysics.

Interpreting the strong redshifts as a consequence of the propagation of light in a medium containing excited atomic hydrogen, coherent spectroscopy undermines the foundations of the Big Bang.

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