Light emission of very low density hydrogen excited by an extremely hot light source; applications in astrophysics.

Jacques Moret-Bailly.

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Abstract

Light emitted by an extremely powerful and hot source ionises a Strömgren sphere of very low density hydrogen. Light is not scattered incoherently by quasi-collisionless hydrogen; it is slightly absorbed in the outer region of the sphere where some excited atomic hydrogen emits spectral lines. A pulse of light coherently scattered by hyperfine Raman resonances in 2S or 2P states interferes with the exciting pulse, redshifting it. Various paths of light emitted into a direction generate various redshifts, making an extremely wide line (Lyman forest). Out of the sphere, supposing that column densities of excited atoms or atoms dressed by the radial rays emitted by the source, are large, superradiant beams appear; their competition leaves only those corresponding to the largest column densities of excited atoms, tangent to Strömgren sphere. Superradiance depopulates strongly the excited states, cooling, de-ionising hydrogen into excited atoms; thus a self amplifying process may become catastrophic. The fall of density of excited atoms almost stops the redshifting, except for radial beams intense enough to induce non-linear "Impulsive Stimulated Raman Scattering" (ISRS) which brings progressively a wide spectrum to dress the atoms at resonance. Thus a wide spectrum generates tangent, competing modes at Lyman alpha frequency; within a given direction, the remaining modes make columns of light and seem emitted by a virtual ring; the columns of light excite cold atoms and molecules which radiate collinear superradiant lines. Energy lost by redshifts blueshifts, that is amplifies thermal radiations in similar modes. This model may help understanding supernova remnant 1987A.

La lumière émise par une source très chaude et puissante ionise une sphère de Strömgren d'hydrogène à basse pression. La lumière est légèrement absorbée dans la région externe de cette sphère où de l'hydrogène atomique excité émet des raies spectrales. Sans collisions durant ses impulsions, le lumière n'est diffusée que cohérente par les résonances hyperfines des niveaux 2S et 2P, et l'interférence des ondes excitatrice et diffusée donne une fréquence unique, réduite (rougissement). Dans une direction donnée, divers chemins de la lumière émise donnent, par divers rougissements, une raie extrêmement large (forêt Lyman). Extérieurement à la sphère, lorsqu'une densité de colonne d'atomes excités ou habillés par les rayons issus de la source, est grande, un rayon superradiant apparaît. La compétition des modes ne laisse que les rayons sensiblement tangents à la sphère. La superradiance dépeuple intensément les niveaux excités, ce qui refroidit le gaz et génère par de-ionisation des atomes qui contribuent la superradiance; ce processus s'auto-accélère, peut devenir catastrophique. La desexcitations quasi complte supprime presque les rougissements sauf pour les rayons radiaux si brillants qu'ils induisent par non-linéarité l'effet Raman impulsionnel cohérent stimulé (ISRS); ainsi tous les intervalles spectraux des rayons radiaux sont diffusés en superradiance lorsqu'ils atteignent une fréquence de résonance. Dans une direction, les rayons superradiants tangents à la sphère semblent issus d'un anneau virtuel et forment des colonnes de lumière qui excitent des atomes ou molécules froids susceptibles d'émettre des raies superradiantes. L'énergie perdue par ISRS bleuit, amplifie le rayonnement thermique dans des modes analogues. Ce modèle paraît expliquer simplement l'apparence de la supernova 1987A.

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1 Introduction

Many astrophysicists have tried to explain “anomalous frequency shifts” in very low pressure gas by using incoherent scatterings; however, the obtained shifts are too low, and, more fundamentally, doesnt work properly as the fluctuations (collisions) needed to introduce the stochastic phases of incoherent scatterings during the light pulses, almost disappear at very low pressure.

They probably havent tried coherent interactions of electromagnetic waves with matter because these interactions are generally studied using laser or microwave sources which do not exist in space. However, the most common coherent interaction, refraction, works with all electromagnetic beams, and the luminance of a supernova illuminates low pressure gas more than the flash bulb pumping a gas laser.

The aim of this paper is to show theoretically and qualitatively that the effects produced by a very simple model, an extremely hot source O in a low density huge cloud of initially cold hydrogen, are close to the ones observed under the appearance of a supernova, and that the tools thus introduced may help understanding other observations.

Section 2 sets notations and describes optical effects involving coherence of light-matter interactions, except subsection 2.1 which reminds of elementary thermodynamic conditions in optics:

Subsection 2.2 reminds of the theory of Rayleigh scattering.

In subsection 2.3 this theory is transformed by substituting Raman scattering to Rayleigh scattering. The new theory is applied to low pressure atomic hydrogen.

Subsection 2.4 studies the superradiance of a spherical shell of excited atomic hydrogen surrounding for instance a Strömgren sphere (Strömgren [1]).

Subsection 2.5 reminds that in a strongly illuminated medium, for instance a laser medium pumped up by light- emitting diodes, or a gas illuminated by a supernova, the intensity of a superradiant beam is multiplied through the induced scattering.

Section 3 studies the optical emission of a system constituted of an extremely hot source of light surrounded by a huge, very low pressure cloud of hydrogen:

Subsection 3.1 studies the propagation of light emitted by the source in a Strömgren sphere of mainly ionized ($\mathrm{H}_I I$) hydrogen, and the incoherent light emitted by excited atoms.

Subsection 3.2 studies a similar problem beyond this sphere.

Section 4 suggests applications in the area of astrophysics:

Subsection 4.1 compares the appearance of the previous model with the present appearance of supernova remnant SNR1987A.

Subsection 4.2 suggests other possible applications.

2 Coherent optics and notations

The density of gas is supposed low, so that we need not take any index of refraction into account.

2.1 Thermodynamics in optics.

Set a and b two states of identical atoms of a gas, and $E_a < E_b$ the corresponding energies. Set N_a and N_b the populations of these atoms (number of atoms in an unit volume); at a temperature of equilibrium $T_{a,b}$, $N_a/N_b = \exp[(E_b - E_a)/kT_{a,b}]$. If the atoms are in a blackbody at temperature T_n, $T_{a,b} = T_n$. In the blackbody, Planck's law [2, 3] correlates the amplitude of the electromagnetic field, the spectral brightness of a monochromatic beam with temperature T_n and wavelength $\lambda = c/\nu = hc/(E_b - E_a)$. Out of a blackbody, Planck's relation remains true provided that T_n is replaced by $T_{a,b}$, defining the temperature of a monochromatic beam based on its spectral brightness and its wavelength.

Approximation in geometrical optics is limited by diffraction. A beam invariant by rotations may be limited by two circular pupils of surfaces s and s', distant of L. Supposing L large enough to apply Fraunhofer theory of diffraction, few energy is absorbed by the pupils if Clausius invariant ss'/L^2 is at least equal to $1.5\lambda^2$; in the limit case, the beam is qualified as an "elementary ray"(or beam).

Suppose that two pupils obeying this condition are drilled in the blackbody, being small enough for a negligible perturbation of its behaviour. The coherent amplification coefficient of a beam propagating through the holes is larger than 1 (true amplification) if its initial temperature is lower than T_n , otherwise it is lower than 1 (absorption).

If the output brightness of the beam does not depend on the path, this brightness corresponds to temperature T_n, and the gas is said optically thick.

2.2 Space-coherent Rayleigh scattering (refraction).

Dressed by an electromagnetic field, an atom emits a wave generally well-modelled by a multipole because the size of the source is smaller than the distance between the sources. Assuming transparency, the phase of Rayleigh diffracted field is, at the atom, delayed by $\pi/2$, so that, using Huygens' construction, the interference of the fields diffracted on an incident wave surface generates diffracted wave surfaces identical to the incident wave surfaces. Thus, the computation of the sum of both fields is identical in all points of a wave surface. Set $E_0 \sin(\Omega t)$ the incident field and $E_0 K\epsilon\cos(\Omega t)$ the scattered field, where ϵ is the infinitesimal thickness of an emitting sheet defined by two close wave surfaces, and K a diffusion coefficient; the total field is:

$$E = E_0[\sin(\Omega t) + K\epsilon\cos(\Omega t)] \tag{1}$$

$$\approx E_0[\sin(\Omega t)\cos(K\epsilon) + \sin(K\epsilon)\cos(\Omega t)] = E_0\sin(\Omega t - K\epsilon). \tag{2}$$

This result defines the index of refraction n by the identification

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

Incoherent fluctuations during light pulses are needed to shift stochastically the phases of scattered waves and obtain an incoherent scattering; therefore, the incoherent scattering is very low in a crystal while it is large in a liquid or a dense gas, in particular close to the critical point; in a gas, the fluctuations result from collisions, so that, if density is very low, incoherent scattering disappears. Remark that, assuming that all conditions of coherence are fulfilled, coherent scattering is intrinsically much larger than incoherent scattering because the amplitudes are added rather than the intensities. An example is the comparison of Rayleigh scatterings in water:

Where the refracted wave is delayed by $\pi/2$ with respect to the virtual incident wave, we can say that the incident wave was fully absorbed and reemitted with the delay $\pi/2$; this corresponds to a path e verifying equation $Ke - 2\pi e/\lambda = \pi/2 = 2\pi(n-1)e/\lambda$; for $\lambda = .5\mu m$, and $n = 1.33$, $e = 0.75\mu m$; in a swimming pool we just see an object at 75 m: the ratio of intensities of coherent / incoherent scatterings is of the order of 10^8.

If the electromagnetic field is intense, K and n become anisotropic, increasing functions of the field, producing for instance, in a laser beam, an auto-focusing of an initially plane wave.

2.3 Coherent Raman Effect on Incoherent Light (CREIL).

Incoherent scattering requires changes of phase as usually provided by fluctuations of density, that is collisions in a low pressure gas; those, whose number is proportional to the square of the pressure, are so exceptional during a light pulse that incoherent scattering almost disappears. Therefore light can only be scattered coherently. It is a sign that a Raman coherent scattering appears [4, 5].

A coherent Raman scattering generates wave surfaces identical to the incident ones, exactly as a Rayleigh scattering does. But the problem of the interference of the scattered beam with the incident one is very different because in a Raman scattering, the difference of phases between these beams at a scattering atom, equal to zero at the beginning of an exciting pulse, increases linearly with time unless a collision destroys this behaviour. Thus, beats generally appear, and an elementary spectroscopy is able to split the incident and scattered frequencies. However, if the duration of the exciting light pulse is shorter than the period of the beats and than the collisional time, it will be shown that the interference produces mainly a single frequency, the remainder being eliminated by destructive interferences dues to the scattering on different wave surfaces. This is a particular case of a condition of space coherence and constructive interference which is, according to G. L. Lamb Jr [6]: the pulses must be “shorter than all relevant time constants”. Setting ω the Raman frequency, $K' > 0$ the anti-Stokes diffusion coefficient, formula 1 becomes:

$$E = E_0[(1 - K'\epsilon)\sin(\Omega t) + K'\epsilon\sin((\Omega+\omega)t)]. \tag{4}$$

In this equation, incident amplitude is reduced to obtain the balance of energy for $\omega = 0$.

$$E = E_0\{(1 - K'\epsilon)\sin(\Omega t) + K'\epsilon[\sin(\Omega t)\cos(\omega t) + \sin(\omega t)\cos(\Omega t)]\}. \tag{5}$$

$K'\epsilon$ is infinitesimal; suppose that between the beginning of a pulse at $t = 0$ and its end, ωt is small; the second term cancels with the third, and the last one transforms:

$$E \approx E_0[\sin\Omega t + \sin(K'\epsilon\omega t)\cos(\Omega t)]$$
$$E \approx E_0[\sin(\Omega t)\cos(K'\epsilon\omega t) + \sin(K'\epsilon\omega t)\cos(\Omega t) = E_0\sin[(\Omega + K'\epsilon\omega)t]. \tag{6}$$

Hypothesis ωt small requires that Raman period $2\pi/\omega$ is large in comparison with the duration of the light pulses; this is a first Lamb's condition; the second is that collisional time must be larger than this duration.

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 nearly a constant, if the atoms are far from resonances; thus, K' and K'' are proportional to Ω, and $K' + K''$ to $\Omega\omega/T$. Therefore, the frequency shift is:

$$\Delta\Omega = (K' + K'')\epsilon\omega \propto \epsilon\Omega\omega^2/T. \tag{7}$$

The relative frequency shift $\Delta\Omega/\Omega$ is nearly independent on Ω.

There remains a problem: The atoms dressed by the electromagnetic fields must return to their eigenstate after a light pulse; as usual in coherent spectroscopy (frequency doubling, mixing...) the solution is an interaction between several waves, with a zero balance of energy for the atoms. To increase entropy, the hot beams, usually light, must loose energy through a decrease of frequency while the coldest, usually radio-waves, in particular thermal background, are heated by increases of frequencies.

Usual incoherent light may be modelled by pulses of some nanoseconds, so that applying Lamb's conditions, the pressure of gas must be low and Raman frequency must be lower than 1GHz. As the shift $\Delta\Omega$ is proportional to ω^2, a strong shift requires a Raman frequency as large as allowed by first Lamb's condition. With atomic hydrogen, frequency 1420 MHz of the hyperfine transition in 1S state is too large; in the first excited state 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.

K' and K'' are increasing functions of strong fields as K, so that using femtosecond laser pulses, the CREIL interactions increase, making laboratory experiments easy (Yan et al. [7], Dhar et al. [8] ...). The CREIL becomes the "Impulsive Stimulated Raman Scattering"(ISRS).

2.4 Superradiance in a spherical shell of excited atoms.

Define a "column density"as the path integral of the density of a type of atoms, and a "spectral column density"as the path integral of $N_b - N_a$; following Einstein [9] the amplification of light is an exponential function of the spectral column density. In weak homogeneous sources, assuming a constant amplification coefficient, the total field remains close to the zero point field, so that the increase of field is nearly proportional to the column density, that is to the path. The total field is an exponential function of the path, and the lines become sharper because their centres are more amplified than their feet; this is called the superradiance.

The amplification of a superradiant line depopulates the high level of the corresponding transition, decreasing the amplification coefficient, and the lines saturate. In a strong, optically thick source, if the depopulation is negligible, the temperature of light tends to temperature $T_{a,b}$ for any input temperature.

Consider two beams converging to a point M of a superradiant medium. The beam which crossed the largest column density of excited molecules has a larger amplitude, so that, with the same amplification coefficient, it extracts more energy at M; if the medium is initially optically thick, the strongest beams de-excite so strongly the medium that the other beams remain weak: it is the "competition of the modes" which explains that the lasers have few, often a single bright mode.

If the excited gas is in a spherical shell, that is between two concentric spheres, the longest paths are tangent to the inner sphere of radius R, so

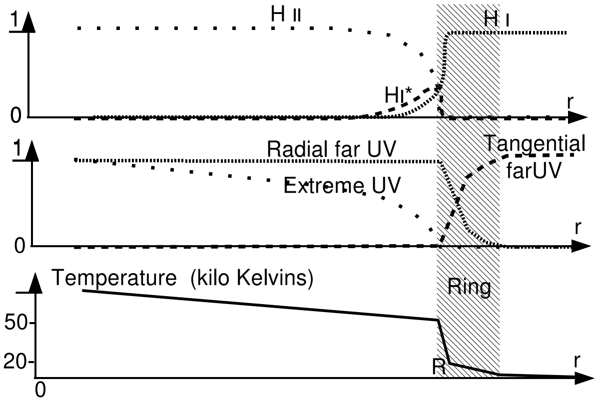

Figure 1: Variation of the relative densities of H_I, H_{II} and excited atomic hydrogen H_I*, relative intensities of light, and temperature along a radius.

that into a given direction, the superradiant beams are along the generators of a cylinder. These beams depopulate the high levels of atoms at all radius larger than R, preventing an amplification of other types of superradiant modes (Figure 1). Thus, into a given direction, the superradiant beams are inside a hollow cylinder whose base is a *virtual* ring centred on the source. Observed elementary beams (modes) are defined by the pupil of the observer (in astrophysics, the mirror of the telescope) and a just resolved region of the ring; a mainly angular competition of modes making columns of light lets appear spots of light corresponding to orthogonal modes. If the source is strong, several contiguous virtual rings may appear. Such competitions of modes, providing similar images, are observed from laser systems emitting light on a cone.

2.5 Stimulated scattering of radial beams by the superradiant beams.

Suppose that the shell is enlightened by the “primary beams”of light emitted by a central powerful source O. In the ring, neutral atoms de-excited by superradiance may be re-excited by resonant absorption of light radiated by the source, then de-excited again by superradiance; this process is weaker than a resonant stimulated scattering.

The superradiant beams induce a resonant scattering of the primary beams, that is a de-excitation of atoms dressed by these beams; the induction of emission generates a space-coherent and time-coherent amplification exactly in the same fashion that it transforms the emission of excited atoms: The largest fraction of energy radiated from the virtual ring comes from dressed atoms rather than from excited atoms.

A slightly non-resonant induced scattering emits a frequency different from the inducing frequency, generating beats. The set of these non-resonant scatterings generates pulses, destroys the time-coherence, but neither the space-coherence nor the induction of the scattering. The modes which are amplified are pulses with geometry of the resonant scattered light beams. These non-resonant scatterings tend to increase slightly the bandwidth of induced scatterings and the transfer of energy from the primary beams to the tangential beams.

The density of excited atoms decreases quickly for $r > R$, so that the CREIL effect is negligible. As radial beams are extremely bright, they perform an ISRS which shifts progressively all frequencies of the spectrum to Ly_α frequency; thus, as long as there remains some extreme UV, the population of 2P H_I is not strictly zero, thus ISRS works, and thus the resonant scattering transfers energy to the monochromatic beams, mainly Ly_α. The energy of a wide spectral band is transferred to a single frequency, except for the loss of energy corresponding to the redshift which is transferred to thermal frequencies, coherently amplified in modes similar to the light modes. The process is nonlinear, very sensitive to the initial concentration of 2P or 2S hydrogen, so that the decrease of scattered intensity along the radius may start fast.

To increase entropy, the spectral brightnesses of the tangential beams tend to be equal to the spectral brightnesses of the radial, primary beams; if the diffraction- limited solid angle of observation of a spot of a ring is much larger than the geometrical solid angle of observation of the source, the intensity received by an observer from the spot is much larger than the intensity received from the source which becomes invisible. The incoherent beams emitted inside Strömgren sphere are not bright, they are not scattered to superradiant beams in the shell.

3 Description of a model.

The studied system is made of:

- a relatively small very hot source O of light able to emit light in far ultraviolet, up to X rays.

- a huge cloud of hydrogen in radiative equilibrium, supposed cold at its outside.

A spherical symmetry is assumed around the centre of the source O.

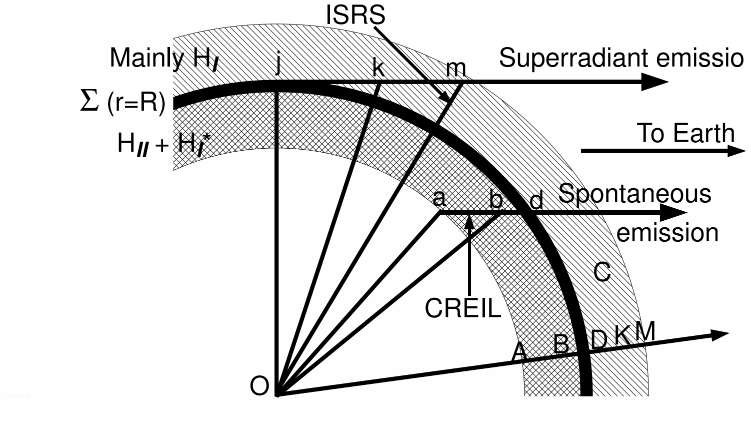

Figure 2: Paths of luminous energy to Earth, which involve Lyman alpha resonances. On an arbitrary ray, the light-matter interactions at points A, B, D (=J), K, M are identical to the interactions at points a, b, d, j, k, m placed at same distances of O. Spontaneous emissions following absorptions at a or b are redshifted by CREIL along ad or bd, getting different frequencies. Along D K M, the extremely bright radial beam is redshifted by ISRS, and scattered to amplify the superradiant emission where, in j, k, or m, a spectral element reaches Ly_α frequency; excited states are so depopulated by superradiance in C region that CREIL is negligible along jkm, so that the Lyman line remains sharp.

Interaction of light with external molecular hydrogen or high levels of atomic hydrogen is neglected.

3.1 The "Strömgren sphere".

Close to the source, hydrogen is ionised by absorption of extreme UV (beyond Lyman lines) into protons and electrons which do not absorb or scatter light except during rare collisions. Traces of impurities may be ionised several times, and then emit lines. This very hot hydrogen cools slowly with an increase of distance r to O, so that excited atomic hydrogen $\text{H}_I{}^*$ appears, loses its energy through a radiation of its lines which is abundant enough around 50 000 K to accelerate the cooling of the gas (figure 2).

Thus a Strömgren sphere [1] of surface Σ and radius R is generated; out of this sphere hydrogen is mainly atomic until molecules appear under 10 000 K.

In the external region inside Strömgren sphere, atoms of excited hydrogen emit lines, in particular Ly_α lines; some atoms of hydrogen are in the 2S or 2P states, so that the spectra are redshifted. The redshifts of the emitted lines depend on the column density of 2S or 2P hydrogen crossed.

Suppose that the density of 2P H_I is proportional to the density of 2S H_I, and set p the difference of column densities between 2P and 1S H_I from an emission point to outside. Neglecting scatterings, reabsorptions and induced emissions; a fixed Ly_α emission Δi requires a fixed variation of column density Δp corresponding to a fixed variation of redshift $\Delta\lambda$; thus the emitted spectrum is represented by a parallel to the axis of wavelengths.

As the scattered intensity is low, reabsorption is larger than induced amplification, not negligible, and the intensity decreases with the redshift.

3.2 Interaction of light out of Strömgren sphere.

Out of Strömgren sphere, for $r > R$, the mixture of atoms and ions in a spherical shell C is similar to the gas in a discharge tube, the atoms are generally highly excited. Supposing that temperature continues decreasing, at around 10 000 K the atoms start to combine into diatomic molecules. Thus the density of atoms in an excited state is *a priori* large in a spherical shell C .

At Lyman lines frequencies, the interactions of light with atomic hydrogen are strong, the oscillator strength being, for instance 0.8324 for α line. The amplification of "tangential beams"emitted at radius R nearly tangentially to Σ depopulates the outer regions, forbidding an outspurt of different emissions. This depopulation cools the gas, limiting the thickness of the shell of H_I*.

Subsection 2.5 shows that a large spectrum of radial beams is converted to Lyman alpha frequency, into columns of light whose clausius invariant is of the order of 1.5 λ^2 (figure 2) . The energy lost by redshift is transferred to radio (thermal) beams which become superradiant, collinear to light columns.

Out of shell C, the emitted rays excite various mono- or poly-atomic, neutral or ionized molecules, generating long columns of cold, excited molecules. These molecules radiate various lines possibly superradiant in the direction of the columns, so that these lines appear to have the same origin than hydrogen lines; as the gas is cold, the lines are sharp.

4 Possible applications to astrophysics.

4.1 Supernova remnant 1987A.

Supernova remnant 1987A appears as a full application of the present paper. Our model is much simpler than an astrophysical system for which the spectroscopy of various atoms and molecules, and higher states of H_I may play an important role; in particular, the spectroscopy of the emissions around year 1990 [10] or in the pearls is not covered by our model. However, this simplified model shows qualitatively many presently observed features and, although limited to Ly_α of H_I line, could help understanding the complexity of the spectra and respond, at least partly, to Heng et al. in their wish that: "…a detailed explanation will require theoretical modeling …"[11].

The similarities are:

The rings appear in a region where temperature is around 50000 K , where density of H_I and H_{II} is low ($10^{10}m^{-3}$), but the available paths, of the order of 0.1 light-year, are widely sufficient for an optical thickness at Lyman lines. Its rings show bright spots similar to optical modes, so beautiful that the main, bright ring is sometimes named "pearl necklace" ; this main ring shows brighter inner modes (Lawrence et al. [12]).

The supernova disappeared when the main ring appeared, showing a nearly full transfer of energy from the star to the rings.

All thermal emissions arise from the main ring (Bouchet et al. [13]). A redshift is observed inside the rings, even in soft X rays (Park et al. [14]).

The problems are:

Our model is extremely simplified, its spectroscopy is limited to Lyman alpha line of H_I; but this line plays a particularly important role due to its enormous intensity and its strong interaction with H_I (Pun et al. [15]).

The remnant does not have a spherical symmetry; this may be the result of a non uniform repartition of hydrogen (Sugerman et al. [16]).

It is difficult to explain the existence of the outer rings (Burrows et al. [17]); maybe the surfaces on which they appear are H_I shells around Strömgren spheres generated by the extreme UV radiation of two accreting neutron stars ejected during a first, old explosion of the supernova which produced the axisymmetric structure they observed. Crotts & Heathcote [18] criticize an hypothesis close to our, which says that a ring corresponds to a limb-brightened ellipsoid; for the outer rings, Sugerman et al. [16] found by photon echoes two lumbers, on which they drawed the emitting rings; slightly moving the weakest parts of the lumbers to obtain ellipsoids, the rings are where the direction of Earth is tangent to the ellipsoids.

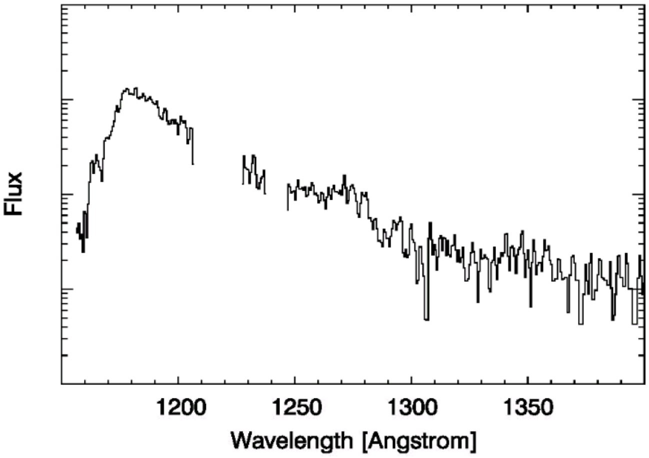

Figure 3: Spectrum of SN1987A inside the main ring, from Michael et al. [19].

A measure of the distance of SN 1987A may use two methods generally considered as reliable:

- When the magnitude of a star varies quickly, it is possible to observe the delay of propagation of light through a direct observation of the star, and the observation of an object enlightened by the star (photon echoes), so that the complete position of the object can be found. Panagia et al. [20] measured, by photon echoes, the absolute radius of the main ring; a division by the angular radius gives a distance of 168000 light-years.
- The spectra observed on and inside the main ring show large red- or blue-shifts whose interpretation by jets of gas is uneasy (Sonneborn et al. [21]). In particular, a spectrum (figure 3) observed inside the main ring of SN 1987A and published by Eli Michael and 20 co-authors [19] is mainly a Lyman forest. Applying Hubble's law shows a distance larger than 2.10^9 light-years. As the shape of the source of the spectrum is wide, limited by the main ring, the origin of the spectrum cannot be a punctual quasar beyond the supernova or gas jets. Michael et al. reject *implicitly* the Hubble interpretation while any other interpretation contests the foundation of Big Bang theory.

4.2 Other applications

Pioneer 10 and 11 probes show "anomalous accelerations"when they reach, beyond 5 UA, a region where the solar wind starts to condensate into excited atomic hydrogen (Anderson et al. [22]). A transfer of energy by CREIL effect from solar light to radio-waves catalysed by 2S or 2P hydrogen produces an increase of their frequencies usually assigned to a Doppler shift due to this anomalous acceleration. A similar amplification of microwave background may explain that some space harmonics seem bound to the ecliptic, that is to the Sun through anisotropies of its wind (Schwarz et al.[23]). .

The microwave thermal radiation is anomalously hot in the surroundings of many redshifted bright objects, or hydrogen clouds; for instance,: Croft et al. observed a strong relation between the mean effective optical depth over Ly_α forests and the CMB temperature [24]; Verschuur [25] found an association of diffuse interstellar neutral H_I structure with the brightest peaks in the WMAP ILC map; the origin of these heatings may be a transfer of energy from light redshifted in 2S or 2P atomic hydrogen.

Some bright arcs of circle are observed in the sky. Their explanation by an improbable alignment of objects and gravitational lensing, or by shock waves is much more complex than the simply founded, ordinary spectroscopy developed here.

5 Conclusion.

Except in laser and microwave technologies, or in refraction, coherent light-matter interactions seem negligible. However, the quasi absence of collisions in a low density gas, forbids the generation of stochastic phase shifts needed, in particular, for incoherent scatterings; on the contrary, in this gas, coherent interactions are not perturbed by collisions.

Induced emissions and impulsive Raman scatterings allowed us to build a complex physico-optical system from the simple hypothesis of an extremely hot source in a huge cloud of low density hydrogen. The image of this system is very close to the present image of supernova remnant 1987A. Other not easily understandable astrophysical observation could probably be explained using coherent spectroscopy: laser spectroscopists and astrophysicists would have a lot to gain from a closer cooperation.

Unhappily, the introduction of apparently new coherent optics sets problems, supporting, for instance, the implicit denial of the validity of Hubble' law expressed by Eli Michael et al. [19], in spectra containing Lyman forests. It may be considered as an attack against the main pillar of the Big Bang theory.

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