The parametric light-matter interactions in astrophysics.

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Abstract. After the computation of the frequency shifts observed in the Solar System produced by the Doppler and gravitational effects, there remain “anomalous” extra shifts, such as the redshift at the limb of the Sun and the blueshift of the radio frequencies of Pioneers 10 and 11. Other anomalous, Doppler-like redshifts are observed in the Universe.

The parametric (coherent) light-matter interactions (refraction, photon echoes, phase conjugation mirrors, photon splitting, ...) are strong effects which transfer energy and (or) momenta without quantification if the matter returns to its initial state. While these effects are commonly studied in the lab, they are ignored in astrophysics (except refraction) because they require uncommon conditions.

Atomic hydrogen in its states 2S or 2P (called H*) is able to “catalyse” transfers of energy from beams of ordinary light which have a high Planck temperature (given by Planck’s blackbody law) to colder beams, producing frequency shifts. The effect, made by several simultaneous “Coherent Raman Effects on Incoherent Light" (CREIL), does not blur the images and the spectra, and the relative frequency shifts are constant if the dispersions of the spectroscopic parameters are neglected.

H* may be found where hydrogen is heated enough to become atomic (T>10 000 K), then excited either by a much higher temperature (100 000 K), provided that a sufficient density limits the ionisation, or by Lyman alpha pumping.

These conditions are fulfilled around accreting neutron stars, leading to a very complicated spectrum which has the characteristics of a quasar spectrum. The complexity of the spectrum is, in particular, a consequence of an instability due to the coupling of the Lyman alpha absorption with the frequency shift it provides through the CREIL in the produced H*. Thus, the periodicity of redshifts z=0.062 observed by several authors results from the spectroscopy of hydrogen.

The proximity of a hot source (quasar) produces H*, so that the objects close to a quasar appear anomalously redshifted. The transfers of energy to and among the low frequencies produce a thermal, isotropic radiation whose temperature may reach several hundreds of kelvins close to bright, much redshifted objects.

The CREIL in the photosphere of the Sun explains the extra redshifts at the limb. The CREIL explains simply the frequency shifts at the surface of the Sun, the extra blueshift of the radio-signals of the Pioneer probes, and why the anisotropy of the CMB seems bound to the ecliptic.The Pioneer 10 and 11 probes have reached a region of the space where the protons and electrons of the solar wind are cold enough to combine, producing some H* which allows a transfer of energy from the solar light to the radio-waves which are blueshifted. The anisotropy of the repartition of this hydrogen is transferred to the microwave background while it is blueshifted, that is amplified.

Conclusion: The largest part of the redshifts results from the column density of excited atomic hydrogen H*.

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1. INTRODUCTION

For a long time, it seemed that the Doppler effect and gravitation together would be unable to explain all observed frequency shifts [1]. But the proposed light-matter interaction, an incoherent Raman scattering, does not work either, blurring the images and the spectra. Since then, coherent optics has been developed, allowing a study of Raman coherent effects which preserve clean wave surfaces and good spectra. The observation of Raman coherent effects requires complicated laboratory experiments using lasers, so that it seems that this effect cannot work in space with ordinary light. This paper shows that this conclusion is wrong in very particular media which may exist in space.

The first section of the paper is pure spectroscopy, studying the Coherent Raman Effects and the spectra generated while a continuous spectrum of UV light propagates in atomic hydrogen.

Subsection 2.1 shows the conditions which are required to obtain a Doppler-like frequency shift, that is, a frequency shift without any blur of the images and the spectra, for a constant relative frequency shift, at least in a first approximation.

Subsection 2.2 compares coherent Raman scattering with coherent Rayleigh scattering, the origin of the refraction, and finds the conditions for obtaining a coherent Raman wave able to interfere with the exciting wave, so that a single, redshifted wave is obtained. Strong conditions enable only a few low pressure gases to produce this interference in low pressure excited atomic hydrogen.

Sub section 2.3 studies the propagation of an UV rich beam through atomic hydrogen. In particular, a nonlinearity results from the transformation of unexcited atomic hydrogen into H* by Lyman alpha pumping which is favoured by the renewal of light intensity at the Lyman frequency produced by the redshift. This feedback may produce oscillations which generate a whole spectrum of sharp lines from a single transition.

The second section suggests possible applications in astrophysics.

Subsection 3.1 applies the results of sub section 2.3 to an elementary model of accreting neutron stars (accretors), showing that the quasars seem different from the micro-quasars only by a surrounding cloud of hydrogen, and that these objects are accretors.

Subsection 3.2 indicates other possible applications, in particular in the Solar system where "anomalous observations" remain although the Solar system is well known. The anomalies occur where the physical conditions favour the presence of H*, so that a coherent interaction becomes a trivial explanation.

2. SPACE-COHERENT INTERACTIONS OF TIME-INCOHERENT LIGHT WITH MATTER.

2.1. Conditions for Doppler-like frequency shifts by interaction with matter.

- A Doppler-like redshift must avoid a blur of the images. Therefore, it must be space-coherent, so that the wave surfaces are not disturbed. For an involved molecule, there exist relations between the local phases of all involved electromagnetic fields and the phases of all molecular oscillators. “Space coherence” means that these relations are identical for all involved molecules. Consequently, assuming that the number of involved molecules is large, Huygens’ construction shows that the radiated fields generate clean wave surfaces related to the wave surfaces of the exciting fields.
- For a time-coherent source, “frequency shift” means that while the source emits n cycles, the detector receives a different number m. Thus, the number of cycles between the source and the receiver is increased by $n-m$; it is an increase in the number of wavelengths, thus an increase of the distance, therefore a Doppler effect. Consequently, a Doppler-like redshift is only possible with time-incoherent light; a parameter measuring this incoherence must appear in the theory to forbid an application to time-coherent light.
- The energy absorbed by the redshifting process must not be quantised in order to avoid a blur of the spectra: If a light beam exchanges a quantified energy with a molecule, a fraction of the intensity of the beam gets a finite shift. In a parametric process, the molecules leave their stationary state only temporarily, their states becoming “dressed” during their interactions with the light; the light beams exchange not-quantified energy, the matter plays the role of a catalyst[1].

Two weak conditions may be added:
- In a Doppler effect, the relative frequency shifts are constant. This should be verified for the lines of multiplets because they have the same origins, but some authors write that the rule is not strictly verified in some astrophysical observations (Webb et al. [2]).
- The energy provided by the redshifts must be dissipated. An efficient dissipative process must exist even at low pressure. This condition is, by definition, fulfilled in a parametric process.

2.2. The Coherent Raman Effects on Incoherent Light (CREIL)

2.2.1. Reminding the semi-classical theory of refraction.

Macroscopic theory.
To simplify the explanations, suppose that the refracting medium is perfectly transparent.

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[1] We do not follow an extended definition of “parametric” interactions in which the matter may be (des)excited during the interaction (for instance in a He-Ne laser medium), “parametric” becoming synonymous of “coherent”.

A sheet of matter between two close wave surfaces separated by ε is excited at a pulsation Ω. The sheet radiates a Rayleigh coherent wave delayed by $\pi/2$ whose amplitude is a small fraction $K\varepsilon$ of the exciting amplitude E_0. From Huygens' construction it generates the same wave surfaces, so that the fields add into

$$E = E_0[\sin(\Omega t) + K\varepsilon\cos(\Omega t)]$$
$$\approx E_0[\sin(\Omega t)\cos(K\varepsilon) + \sin(K\varepsilon)\cos(\Omega t)] = E_0\sin(\Omega t - K\varepsilon). \quad (1)$$

This result defines the index of refraction n by the identification

$$K = 2\pi n/\lambda = \Omega n/c. \quad (2)$$

Microscopic, quantum theory.

Suppose that the light interacts with free identical molecules, initially in the same non-degenerate stationary state ϕ_0. The perturbation of a molecule by an electromagnetic wave mixes ϕ_0 with other states ϕ_i , producing a non-stationary state $\Phi = C_0\phi_0 + \sum_i C_i\phi_i$, where the C_i are very small.

We must consider the set of all interacting molecules, adding an upper index k to distinguish the molecules. Without a field, the total stationary state is $\Psi_0 = \prod_k \phi_0^k$. Its degeneracy is the number of molecules.

Perturbed by an external field, the refracting medium radiates a scattered, coherent field delayed by $\pi/2$, generating the same wave surfaces as in the exciting field; therefore, the dynamically excited, non-stationary, "dressed " (or "polarisation") state ψ^m which emits this field is characterised by an index m representing the exciting mode.

Considering other refracted modes, Ψ splits as $\prod_m \psi^m$.

Remark that the coherent interactions are much stronger than the incoherent: A refraction by $\approx 0.25\mu m$ of water delays the light by $\pi/2$, that is the light is fully scattered by the coherent Rayleigh scattering. In a swimming pool, we see well through 25 metres of water, only a fraction of the light is scattered by the incoherent Rayleigh scattering; the factor is 10^8.

2.2.2. Principle of the CREIL.

The CREIL results from an interaction between dressed states ψ^m; as these states have the same parity, the interaction must be of Raman type, for instance quadrupolar electric. Thermodynamics says that the entropy must increase, so that the floods of energy are from the modes which have a high Planck's temperature [2] to the colder ones. For an astrophysical application we consider a purely parametric effect: the matter, a low pressure gas in low fields, returns to its initial state after an interaction.

The dressed state ψ^m radiates a mixture of the coherent Rayleigh scattering which produces the refraction and coherent Raman scatterings. These locally weak scatterings may be studied independently, so that the CREIL may be considered as a set of *simultaneous* Stokes and anti-Stokes coherent Raman scatterings with a zero balance of energy for the molecules [3]. The scattered beams have the same wave surfaces as the exciting beams, so that these beams may interfere, as in the coherent Rayleigh scattering making the refraction. Because the scattered fields are much weaker than the exciting field, they may be added independently to it. The pulsations of the Raman beams are shifted by $\pm\omega$, and, at the beginning of a pulse, in phase because the resonance introduces a $-\pi/2$ phaseshift. The sum of the exciting wave and the coherent anti-Stokes scattered wave is:

$$E = E_0[\sin(\Omega t) + K'\varepsilon\sin((\Omega+\omega)t)] \quad (\text{with}(K' > 0)$$
$$E = E_0[\sin(\Omega t) + K'\varepsilon[\sin(\Omega t)\cos(\omega t) + \sin(\omega t)\cos(\Omega t)]]. \quad (3)$$

Supposing that ωt and $K'\varepsilon$ are small, the second term may be neglected, and the last one transformed:

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[2] Temperature deduced from the application of Planck's law to a mode of the light.

[3] "Coherent Raman Scatterings on Incoherent Light" (CREIL) is ambiguous, relative either to a single Raman interaction (ignoring the quasi-resonant, easy transfer of the Raman energy to the thermal radiation), or to the whole set of interactions.

$$E \approx E_0[\sin\Omega t + \sin(K'\varepsilon\omega t)\cos(\Omega t)]$$
$$E \approx E_0[\sin(\Omega t)\cos(K'\varepsilon\omega t) + \sin(K'\varepsilon\omega t)\cos(\Omega t) = E_0 \sin[(\Omega + K'\varepsilon\omega)t]. \quad (4)$$

$K'\varepsilon$ 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.

This condition was set by G. L. Lamb Jr. for the definition of “ultrashort pulses” : “shorter than all relevant time constants” [3]. With ordinary light, the time coherence plays the role of length of the pulses: thus, the time-coherence, some nanoseconds, must be “shorter than all relevant time constants”.

We have found a first relevant time constant. A second is the collisional time constant, because the collisions destroy the space-coherence, producing an ordinary, weak, incoherent Raman scattering; a low pressure gas is needed.

The same computation, replacing K' by a negative K'' gives the Stokes contribution, so that we replace K' by $K' + K''$ in formula 4. $K' + K''$ depends on the difference of population in both levels, that is on $\exp(-h\omega/2\pi kT) - 1 \propto \omega/T$, where T is the temperature of the gas.

The theory of the refraction shows that the index of refraction is nearly constant in the absence of resonance close to Ω, so that, using for the polarisability a formula equivalent to formula 2, $K' + K"$ appears nearly proportional to $\Omega\omega/T$, and the frequency shift is :

$$\Delta\Omega = (K' + K")\varepsilon\omega \propto \varepsilon\Omega\omega^2/T. \quad (5)$$

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

All required properties are obtained: space coherence, limitation of the time-coherence, no excitation of the gas, nearly constant relative frequency shift. As the shift is proportional to ω^2, a strong effect requires a Raman pulsation ω as large as allowed by the preservation of the coherence. As the time-coherence of ordinary light is some nanoseconds, a good Raman frequency is of the order of 100 Mhz.

2.2.3. Laboratory observation of the CREIL effect

Usually, it is not necessary to take into account the radiations which receive energy because we are surrounded by thermal radiations whose blueshift is simply a heating. In a convenient medium, the CREIL effect also transfers energy between the radio frequencies which make the thermal radiation as long as the thermal equilibrium, including the isotropy, is not reached; this CREIL effect is strong because, all involved frequencies being low, it is nearly resonant, so that the radio frequencies get quickly a thermal equilibrium.

The CREIL in optical fibres is so easily obtained that it makes problems for the use of short pulses in telecommunications. With the high peak power of femtosecond lasers, the index of refraction and the components of the tensor of polarisability become increasing functions of the intensity, allowing a study of the effect in small cells. This non-linear effect named "Impulsive Stimulated Raman Scattering" (ISRS) allows an easy study of the properties of the coherent Raman effect on incoherent light: transfer of energy from a laser beam to another produces frequency shifts, a verification of Lamb’s conditions (Yan et al. [4]).

When the lengths of the laser pulses increase, the experiments become more and more difficult: To increase the collisional time, it becomes impossible to use dense matter, a gas less and less dense must be used. While it is easy to find strong Raman resonances at the rotational and vibrational frequencies of molecules, resonances close to 100 MHz appear generally in highly excited states, almost unpopulated.

To fulfill Lamb’s conditions, the collisional time of the refracting medium must be longer and longer :

- Dense matter may be used with femtosecond pulses, but a low pressure gas is needed with the nanosecond pulses of the incoherent ordinary light. The lower density matter decreases the interaction.

- Femtosecond periods of Raman resonances correspond to vibrational and rotational spectra of molecules but it is difficult to find nanosecond Raman resonances. Formula 5 shows that a decrease of the Raman pulsation ω decreases the redshift.

Therefore, an observation of a CREIL effect using ordinary incoherent light would require a long path, an expansive long multipath cell. Worse, a Raman frequency of the order of 100 MHz is generally found in complex spectra, so that the population of the levels is low. An exception, due to the simplicity of the spectrum, is excited atomic hydrogen (see next subsection), but it seems difficult to fill a cell with this gas. As the theory is well verified in the easily accessible range of frequencies, one can ask whether it is useful to try such an expansive experiment.

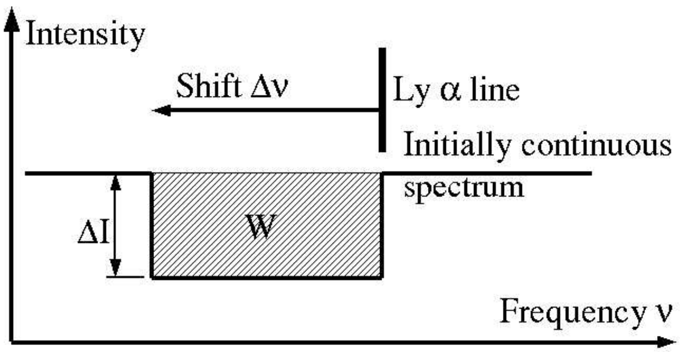

FIGURE 1. Permanent absorption by a single line uniformly redshifted of $\Delta\nu$ in atomic hydrogen. For the Lyman alpha line, the pumping proportional to $W = \Delta I \Delta\nu$ provides the population of H* needed to produce the redshift $\Delta\nu$, assuming a uniform de-excitation of the excited state.

2.3. Propagation of a far UV continuous spectrum in hydrogen

As atomic hydrogen has a simple spectrum, its levels of energy may be well populated. Its electric quadrupole spin recoupling transition ($\Delta F = 1$) in the ground state has the frequency 1420 MHz. This frequency corresponds to a period 0.7 ns, much shorter than the length of the light pulses; therefore, this frequency is too high for CREIL. But 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; in these states, the gas is named H*. It is more difficult to populate higher states, and the resonance frequencies being low, the CREIL effect is low (formula 5), so that, in these states, the CREIL effect is negligible.

2.3.1. Generation of excited atomic hydrogen H.*

Excited atomic hydrogen which redshifts the light may be generated by various processes:

Thermal excitation of hydrogen.
The ionisation energy equals kT for a temperature $T = 156000K$. Since the energy needed for pumping hydrogen to states of principal quantum number $n = 2$ (H* states) is three-fourths of the ionisation energy, it equals kT for $T = 117000K$. Using Boltzmann's law, these temperatures may be considered as indicating roughly where these particular states of hydrogen are abundant. Note, however, that by thermal excitation, the proportion of hydrogen in the H* states is much limited by the excitation to higher values of n and by the ionisation at low pressures.

Lyman α pumping of atomic hydrogen.
Above a temperature $T = 10000K$, the molecules of hydrogen are dissociated. The strong absorption of the Lyman alpha line produces H* (2P). The effective decay of H* is very slow at low pressures because this decay can only re-emit the Ly_α line which is strongly and immediately re-absorbed.

Cooling of an hydrogen plasma.
The combination of the protons and electrons of a plasma produces atomic hydrogen in various states of excitation. The 2S state is stable at a low pressure. The optical transitions from the 2P states generate a Ly_α line which may be reabsorbed.

2.3.2. Nonlinear propagation.

A Lyman α pumping in atomic hydrogen generates H*, producing a CREIL effect which shifts and renews the light at the Lyman α frequency. I show that this feed-back may produce oscillations.

Constant high UV intensity.
Set ΔI, the absorbed intensity which produces exactly the column density of H* needed to produce a frequency shift, equal to the linewidth of the Ly_α line. The absorption ΔI is constant along the redshift which may be large (fig.1). The

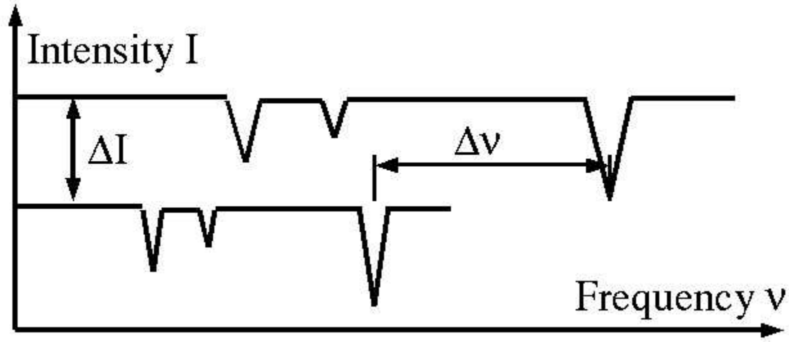

FIGURE 2. Absorption of a spectrum and redshift. The final spectrum (low) results from the subtraction of a constant intensity which increases the contrast of the spectrum, and, assuming a constant $\Delta\nu/\nu$, a change of the scale of frequencies.

resulting absorption line is so wide that it is nearly invisible. The other absorption or emission lines have the same relative frequency width, so they are not visible too.

If a line is absorbed in a region where weak lines were previously detected, the subtraction of a constant intensity increases the contrast of the weak lines (fig.2).

Constant UV intensity except an absorption lines: Generation of a spectrum.

Figure 3 top, representing a *phase of redshift* without visible absorptions, is similar to figure 1; the absorption by three Lyman lines is represented. The remaining intensity has the shape of a stair, except that it is assumed that a strong absorption line was absorbed previously. The permanent redshift is due to a constant Lyman alpha absorption of intensity ΔI.

By a new redshift, the top figure becomes the lower figure. To distinguish the new absorptions, the previous drawing is dotted. For the strong, previously absorbed line coming at the Ly_α frequency, the remaining intensity shifted at the Lyman frequency is lower than ΔI and is not sufficient to produce an amount of H* able to redshift the light out the low intensity frequency, so that the redshift process stops. Without CREIL, that is, without redshift, all lines of the gas are strongly absorbed, in particular the Ly_β and Ly_γ. The light experiences a *phase of absorption*.

However, the stoping of the redshift process is not absolute because the decay of the states pumped by the Ly_β and Ly_γ produces some H* which gradually shifts the light, restarting the regular redshift (top figure) until the strongly absorbed lines Ly_β, then the Ly_γ, play the role of "previously absorbed" line. These lines produce new stops after the redshifts which put the β or γ to the α. Thus the interaction oscillates between phases of redshift without observable absorption (figure 3 top) and phases of absorption without notable redshift figure 3 down).

The intensities of the Lyman lines are decreasing functions of the final principal quantum number n, so that the production of a pattern is better for a previously detected β line than for a γ. It seems negligible for other lines.

The positions of the final absorption lines may be measured by the redshifts from the Ly_β or Ly_γ to the Ly_α, which are deduced from the Rydberg formula :

$$z_{(\beta,\alpha)} = \frac{\nu_\beta - \nu_\alpha}{\nu_\alpha} \approx \frac{(1-1/3^2)-(1-1/2^2)}{1-1/2^2} \approx 5/27 \approx 0.1852 \approx 3*0.0617; \tag{6}$$

$$z_{(\gamma,\alpha)} = \frac{\nu_\gamma - \nu_\alpha}{\nu_\alpha} \approx \frac{(1-1/4^2)-(1-1/2^2)}{1-1/2^2} = 1/4 = 0.025 = 4*0.0625; \tag{7}$$

The resulting redshifts appear, within a good approximation, as the products of $z_b = 0.062$ and an integer q.

Iterating, the successive coincidences of the shifted β or γ line frequencies with the Lyman α frequency may be represented by a succession of numbers q, equal to 3 or 4, building branches of a "tree", the final values of q being sums of the basic used values 4, and 3. Each step is characterised by the value of q, a generation of successive lines. A branch is characterised by successive values of $q : q_1, q_2...$ So the final redshift is

$$q_F * z_b = (q_1 + q_2 + ...) * z_b, \tag{8}$$

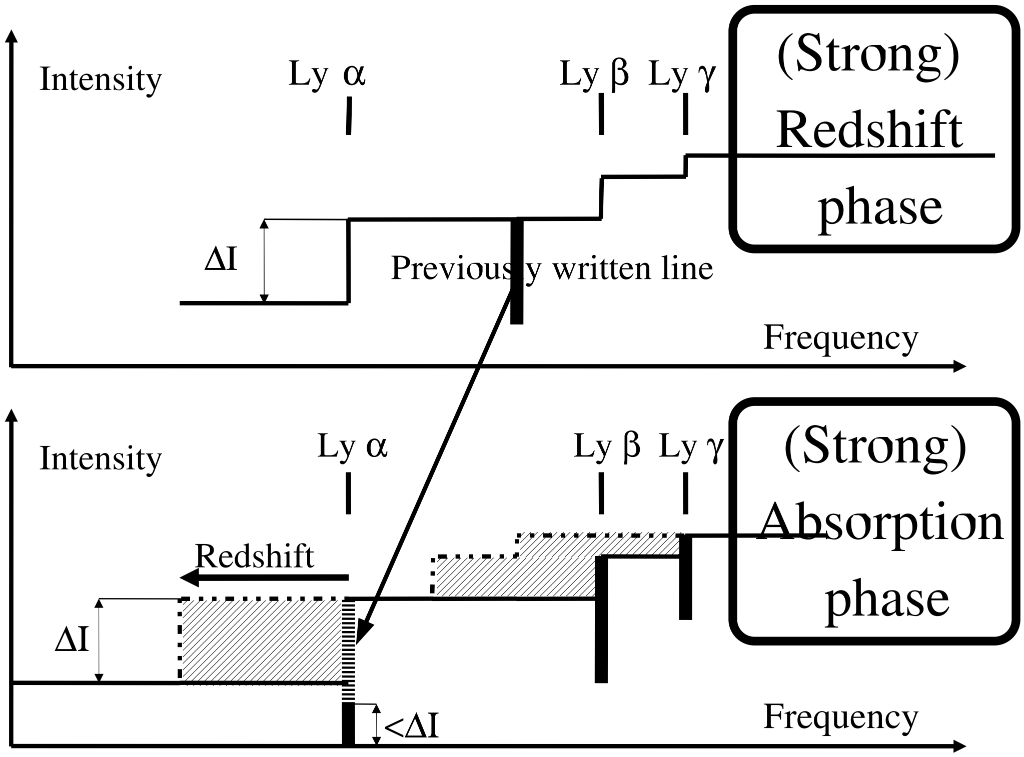

FIGURE 3. Multiplication of the Lyman spectral lines. The top graph shows a continuous spectrum after an absorption of Lyman lines and another line absorbed previously without redshift. After a redshift which absorbed the shaded regions (low graph), the intensity of the light which is shifted at the Ly_α frequency is low because we assumed that a line was previously absorbed. Therefore, the intensity ΔI cannot be absorbed to continue the redshift. All lines are visibly absorbed until an indirect creation of H* accumulates enough to restart the redshift.

the addition $q_F = q_1 + q_2 + ...$ is both a symbolic representation of the successive elementary processes and the result of these processes. The metaphor "tree" is imprecise because "branches" of the tree may be "stacked" by coincidences of frequencies. A remarkable coincidence happens for $q = 10$, this number is obtained by the effective coincidences deduced from an overlapping sequence of Lyman lines corresponding to the symbolic additions:

$$10 = 3 + 3 + 4 = 3 + 4 + 3 = 4 + 3 + 3 \qquad (9)$$

$q = 10$ is so remarkable that $z_f = 10z_b = 0.62$ may appear a value of z more fundamental than z_b.

In these computations, the levels for a value of the principal quantum number n larger than 4 are neglected, for the simple reason that the corresponding transitions are too weak.

The gas acquires a space structure, depending upon whether the light which crosses it is in a redshift phase or in an absorption phase.

2.3.3. Mean absorption.

To find how, for a given column density of H*, the CREIL decreases while the density and the temperature of the gas increase, the collisional time must be compared with the coherence of the light, some nanoseconds. Roughly, for low densities lower than about 100 Pa, the collisions are negligible during a pulse of light, so that the CREIL depends only on the column density of H*. For higher densities, leading to collisional times of the order of the coherence time of the light, for a given column density of H*, the CREIL decreases faster and faster as the pressure increases. The periodicities do not depend on this variation of the CREIL, as formula 8 does not depend on the intensity of the CREIL.

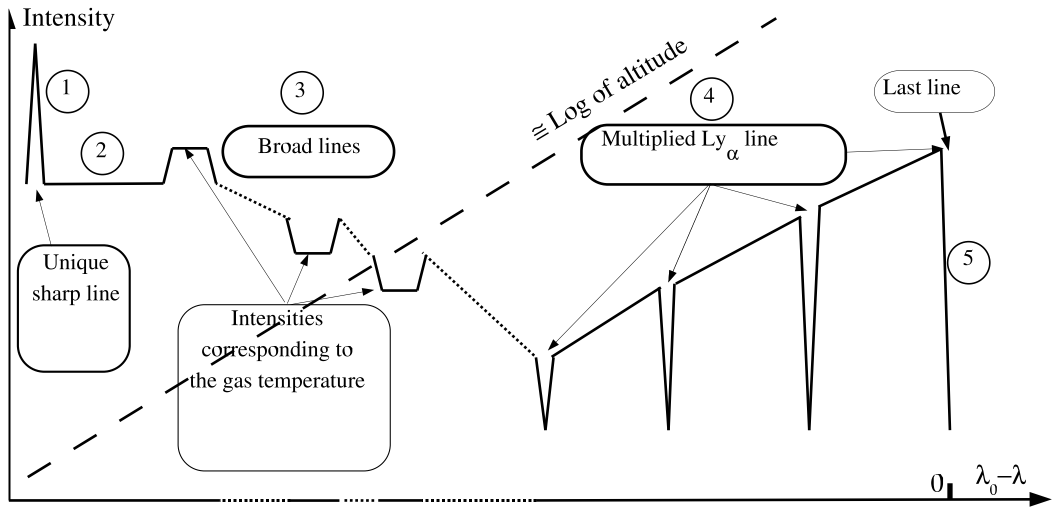

FIGURE 4. See 3.1. Qualitative schema of the spectrum of a radio-quiet accreting neutron star, transformed so that, by subtraction of the observed wavelength λ from the original wavelength λ_0, without redshift, all lines would be at 0 abscissa. The real number of lines is much larger. The very approximate log relation indicated between the altitude and the frequency shift is provided to remind one that the same frequency shift corresponds to metres at the left, to parsecs at the right.

Absolute redshift and mean remaining intensity.

If the pressure of the gas decreases, the decay of H* slows down, so that the Lyman pumping needed for a redshift between two absorption lines decreases; consequently, the column density of atomic hydrogen needed to obtain enough H* decreases.

On the contrary, at the coincidence with an absorbed line, the required decay from the upper states to H* becomes too slow, so that the absorptions (that is, the column density of atomic hydrogen) required to leave a coincidence remain large. Consequently, there is a large probability to be in a phase of absorption (stopped redshift) when the light leaves a low density gas, so that the lines are observed with an absolute redshift multiple of 0.062.

The mean intensity results mainly from the intensity remaining during the phases of redshift. At low pressures, these phases require low absorptions, so that the mean intensity is larger than at higher pressures.

For a given initial spectrum, if the available column density of atomic hydrogen is large, the process stops after a large redshift by a lack of intensity at the Ly_α frequency. On the contrary, if the process stops by a lack of atomic hydrogen, it may have retain energy at the high frequencies.

Extension to emission lines.

The explanation works for emission lines which increase the intensity of the lines available for the Ly_α absorption, increasing the CREIL and making the redshift faster, so that the absorptions are lessened, simulating emissions.

3. POSSIBLE APPLICATIONS IN ASTROPHYSICS.

3.1. Spectra of accreting neutron stars.

We will deduce, mainly from the results obtained in subsubsection 2.3.2, the spectrum of a neutron star accreting a cloud of dirty hydrogen which surrounds it. The kernel or a spot on the kernel is heated to a temperature of more than 1 000 000 K by the accretion. It emits X and gamma rays, and an UV rich spectrum close to the spectrum of a blackbody at a lower temperature.

The accretion increases the density of the gas, and we suppose that the result is an atmosphere whose dense part is thicker than the atmosphere of a bare quasar, an atmosphere which extends to the whole cloud . A knowledge of the precise movements of the gas is useless because the CREIL is not sensitive to the speed of the molecules.

We study the propagation of the light through an atmosphere supposed optically equivalent to a steady atmosphere, whose density and temperature decrease fast at the beginning, then almost stabilise. H* present in this atmosphere redshifts the light, so that the redshifts of the emitted (or absorbed) spectra decrease with an increase of the distance between the emitter (or absorber) and the surface.

3.1.1. Very hot hydrogen (T>200 000K). Figure 4 (1)

A sheet of gas close to the surface of the star has a very high temperature Its hydrogen is mainly ionised, without a spectrum, or excited to states of large principal quantum number, practically not active in CREIL. Therefore, there is no frequency shift during the emission of lines by very ionised impurities. The emitted lines are as sharp as the temperature and the pressure allow; the intensity and sharpness of a strong line may be improved by a superradiance. The high temperature of the gas, defined in a frame moving with the gas, can be maintained by conduction, convection, electronic heating or absorption of light by the impurities; hydrogen does not absorb because it is ionised. These heatings are not very efficient, so the temperature decreases quickly.

The pressure is assumed relatively high (of the order of 5000 Pa), so that the emission of the strong lines of impurities are large, possibly saturated for a path of some metres. The emitted lines may be sharper than usually allowed by the pressure and the temperature because the high density of electromagnetic energy at the frequencies of the main lines allows superradiance.

As the hydrogen is completely dissociated in spite of the pressure, there is no CREIL able to widen the lines.

3.1.2. Excited atomic hydrogen ($T \approx 100\,000$ K). Figure 4 (2)

This hydrogen is in a thicker shell than the previous one, some tens of metres. The pressure is of the order of 1000 Pa, allowing a CREIL effect reduced by the collisions. Hydrogen is atomic, so that it absorbs light and is heated to this temperature by absorption of radiation energy. Note that an excessive heating ionises the gas, reducing the absorption, so that the temperature is relatively stabilised. An important fraction of the atoms is in the H* state, so that the pressure, being not too high, allows the gas to redshift the light. The simultaneous shift and emission or absorption of lines gives to the lines (present in the spectrum) the width of the shift, so that the absorption is not large and the lines may be mixed: they cannot be observed. On the figure where the spectrum produced by a chosen transition is drawn, a gap appears at (2), between the sharp, most redshifted emission line and the lines which are described in the following subsections.

3.1.3. Atomic hydrogen in its ground state ($T \approx 20\,000$ K). Figure 4 (3,4)

The pressure decreases from about 1000 Pa to very low values, and the gas is present from the previous shell to a distance which may reach the dimension of a galaxy if the heating source is powerful enough. The thermal excitation of atomic hydrogen, being supposed low, needs a Ly_α pumping to get H* and a redshift.

A stabilisation of the temperature stronger than in 3.1.2 occurs because: if the temperature increases, the redshift, which increases the energy available for the absorptions, is reduced by an excitation of the high levels of hydrogen and some ionisation; if the temperature decreases, a dimerisation of the atoms increases the absorption.

The periodicities described in 2.3.2 appear.

If the density is relatively high (100-1000 Pa), the collisions continue to decrease the redshifts, so that the emissions, then the absorptions, appear stronger.Tthe lines are fully saturated, that is, they become wide, and the temperature of the light at the centre of the lines gets an equilibrium with the temperature of the gas. Thus, the emission lines have the shape of a hat, the absorption lines the shape of a trough. (Figure 4 (3)).

However, at these pressures, the gas is easily ionised by collisions resulting from an acceleration of ions by a low frequency electric field, so that hydrogen is transformed into protons and neutrons, and there is no local redshift. This happens if the star is "radio-loud"; the emission, then absorption of a transition produces superposed lines, a wide shape more intense at the wings than at its centre.

With a decrease of the pressure, the lines become sharper and sharper while the mean intensity increases (Figure 4 (4)), and generally the process stops while a line is being produced, as indicated in 2.3.3 (Figure 4 (5)). .

3.1.4. Can the accreting neutron stars be considered as quasars ?

It is strange that the *accretors* (accreting neutron stars) which, following the reliable theory of the evolution of the stars, should be observed, are never observed [5, 6]. The complicated spectra of the accretors, obtained in subsection 3.1 is very similar to the spectra of the quasars, in particular:

* There is a gap in the redshifts after the sharp emission lines (Rauch et al. [7], Francis et al. [8]);

* The broad lines which have the shape of troughs do no exist if there is a strong radio emission (Briggs et al. [9]), Anderson et al. [10]);

* The observed periodicities (Burbidge [11],Tifft [12], Hewitt et al. [13], Bell et al. [14, 15]) are simply produced by the propagation of the light in atomic hydrogen.

* The envelopes of the spectra are similar: In particular, the remaining mean intensity in the Lyman forest increases with the frequency up to the frequency of the Ly_α line, then it is very low if the quasar has a high redshift which corresponds to a stop if the redshifting process due to the fall of high frequency intensity and absorption by diatomic hydrogen. On the contrary, the energy over the Ly_α line remains noticeable if the CREIL and the redshift are stopped by a lack of hydrogen.

* A possible slight distortion of multiplets [2] is easily explained by a dispersion of the tensor of polarisability, a quantitative confirmation requiring both good observations and a computation of the polarisability.

Therefore, we cannot avoid the question of the identification of the accretors with some quasars.

It is commonly written that the quasars are extremely far, enormous objects (Petitjean et al. [16]). But this conclusion is founded on the pure Doppler interpretation of their redshifts while the observation of the parameter $z_b = 0.062$ characterises a CREIL effect in atomic hydrogen.

Quasars and micro-quasars have a similar name because their very high frequency spectra are very similar; they seem differ mainly by the presence of hydrogen around the quasars. Thus, the quasars could be detectors of the invisible diatomic hydrogen. The isolated quasars could be detectors of this hydrogen in a cloud surrounding our galaxy. The quasars which appear bound to other galaxies (Arp [17]) would detect the halos of these galaxies. In Arp's observation of alignments of a galaxy with quasars, the larger redshift of the quasars could correspond to a larger illumination of hydrogen by quasars, therefore a larger creation of H* on the path of the light coming from the quasars than on the the path of the light coming from the galaxy.

3.2. Possible interpretation of other observations

3.2.1. Proximity effects.

A statistical over abundance of very red objects (VROs) is observed in close proximity to quasars (Hall et al. [18], Wold et al. [19]); in particular, the galaxies which contain quasars are often severely reddened, and redshifted relative to other galaxies having similar morphologies (Boller [20]). Illuminating hydrogen in the far UV, the quasar induces a CREIL redshift, providing far ultraviolet radiation, therefore by the creation of some H* around the VROs.

The bright and much redshifted objects seem surrounded by hot dust (Omont et al. [21]), and it is difficult to explain the stability of this dust in despite of the pressure of radiation and the abrasion by ions. The blueshift, that is the heating of the thermal radiation by the CREIL, as a counterpart of the redshifts in the optical range, is a simple interpretation of the observations.

3.2.2. Kotov effect.

V. A. Kotov and V. M. Lyuty [22, 23] observed oscillations of the luminosity of stars and quasars with a period of 160,01 minutes. While the light is redshifted, this period is not. Using CREIL, it is clear that the light pulses are redshifted, but that the distances of the beginnings of the pulses are not subject to a frequency shift [24]. On the contrary, supposing a change in the scale of time by an expansion of the universe, this result cannot be explained. Therefore, thinking that the observations are reliable, there is no expansion of the universe.

3.2.3. Frequency shifts in the solar system.

Frequency shifts on the Sun.

Studying the variations of the frequency shifts on the Solar disk allows one to compute the fractions due to the Doppler effect and to the gravitation. It remains a redshift proportional to the path of the light through the photosphere, immediately explained by a generation of H* by Lyman pumping.

The frequency shifts of the high energy emission lines of the Sun was observed by the SUMER instrument during the roll of the SOHO spacecraft (Peter & Judge [25]). A fourth of a radius of the Sun, including the rim, is projected to the slit of the spectrometer. The shifts produced by the Doppler effect due to the rotation of the Sun and the relative movement of the SOHO, and the relativistic shifts being eliminated, their weakly supported interpretation of the remaining redshifts is founded on a Doppler effect produced by local vertical movements of the gas, ejected either in spicules, or in siphon flows through loops. A consequence of this interpretation is that the remaining shift must be zero at the rim. Consequently, the authors assume that the old measures or computations of the absolute frequencies are inaccurate, and they compute the redshifts relative to the frequencies they observe at the rim.

The theories using spicules, or in siphon flows explain that the hottest gas, moving upward emits blueshifted lines, while the cooler gas moving downward emits redshifted lines; but, they do not work well because, at a point of the surface of the Sun, the value of the shifts is a continuous function of the frequency without a stabilisation at the change of the sign of the shift which would be a consequence of a stop of the radial movement when it commutes from up to down. Improvements are being tried, but “still more work is needed".

The explanation by the CREIL is easy: The emission of all lines are nearly saturated, that is, their Planck temperature is nearly the temperature of the emitting gas. Where the chromosphere cools enough to produce excited atomic hydrogen, the CREIL allows a flow of energy from the hottest lines which are redshifted to the cooler ones. This result seems opposite to the observation, but it is not if the shifts are computed using the old frequencies, so that the shifts are not zero, but maximals at the rim, for which the path of the light through the chromosphere is oblique, so that the column density of H* is maximal.

Blueshift of the radio signals of the far probes.

H* may be generated by a combination of the protons and electrons making the Solar wind, where the wind cools enough, at the limits of the solar system :

Radio signals were sent from the Earth to Pioneer 10 and 11, at a well stabilised carrier frequency close to 2.11 GHz, and the Pioneers returned a signal after a multiplication of the carrier frequency by 240/221. The blueshift which remains after a standard elimination of the known frequency shifts (Doppler, gravitation) is interpreted as produced by an “anomalous acceleration”(Anderson et al. [26]).

To preserve celestial mechanics, a single, weakly supported hypothesis is now proposed: an acceleration of the probes produced by an anisotropic diffusion of the heat produced by the decay of a 2 kW plutonium source ([27, 28]). Anderson disagrees.

A key point is that there are sometimes perturbations in the received signal. Most are produced by the propagation of the waves through the corona. Others have an unknown origin, but, later, the signal recovers exactly its previous behaviour. As it seems difficult that the probes self-repair, the problem seems due to the propagation in the solar wind, perhaps perturbed temporarily by a planet, or by a solar emission. Another problem is explaining that the blueshift appears only at large distances from the Sun (over 5-10 AU).

The explanation by the CREIL seems *a priori* simple: the solar wind starts to cool at 5 AU enough to produce some variably excited atomic hydrogen (in particular hydrogen in the 2P state, whose decay is extremely slow in the vacuum); the hot radiation from the Sun transfers energy to the radio signal of Pioneer, blueshifting it. There is however a problem: the signal from the probe is continuous while the CREIL requires an incoherent signal. In fact, the signal in the mode received on the Earth (before filtering) is extremely noisy. Recall the theory of the modes: Maxwell’s equations are linear in the vacuum, or replacing the sources of field by their "advanced field"; thus their solutions build an infinite dimensional vector space whose rays are named "modes". Thus, the field in a given mode depends only on a single real parameter, the amplitude. Consequently, the noise in the received mode cannot be distinguished from the signal, that is, the received mode is incoherent enough to be blueshifted.

The CREIL allows one to preserve celestial mechanics: The signal obtained during a time constant of a receiver before filtering results from the electric field in the mode of reception of the receiving antenna for this time constant; this amplitude results from a weak amplification of the noise in the mode (2.7K radiation) by the emission antenna, so that this field is partly incoherent and may be blue-shifted by a CREIL transfer of energy from the light of the Sun.

Anisotropy of the cosmic microwave background.

Separating the cosmic microwave background into spherical harmonics, it appears that some low order harmonics are bound to the ecliptic [29].

Just as for the Pioneer radio signals, the microwave background is blueshifted, that is amplified by the solar light during a common propagation in the solar wind which contains some H* beyond 5 AU. As the solar wind is produced by the corona, it has a symmetry bound to the corona, that is to the ecliptic.

When the CMB reaches the solar system its amplification in an anisotropic density of H* may generate its anisotropy .

Experiments should be done to study H* in the solar system, in particular changing the intensities and the coherences of the radio signals.

4. CONCLUSION

The CREIL, introduced in previous papers [30, 31, 32, 33] is a parametric effect which, in excited atomic hydrogen H*, transfers energy from electromagnetic modes whose Planck temperature is high, to colder modes, a cooling process producing a redshift. Being coherent, the CREIL does not blur the images, and the relative frequency shifts $\Delta\nu/\nu$ are usually nearly constant.

A first quantitative result of the CREIL is the computation of the fundamental period $z_b = 0.062$ of the observed redshifts. Trying to explain observations by the CREIL and by the standard theory, it appears that the CREIL may explain more effects (frequency shifts of the Pioneer probes, proximity effects, ...) and does not require an extraordinary hypothesis (dark matter, ...).

The "anomalous redshifts" appear generally much larger than the Doppler and gravitational redshifts. They seem produced only by a CREIL effect in excited atomic hydrogen H*, so that these redshifts are a measure of the column density of H*, at least where the pressure is not too large. It is a simple and powerful rule.

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