Conditions for Doppler-like redshifts by matter and application.

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1 General conditions

- 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: "Space coherence" means that, for all involved molecules, the relation between the phases of all involved electromagnetic fields, and the phases of all molecular oscillators is the same. Consequently, Huygens' construction shows that the radiated fields generate wave surfaces related with 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 of $n-m$; it is an increase of 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 and a parameter measuring this incoherence must appear in the theory.

- The energy absorbed by the redshifting process must not be quantised to avoid a blur of the spectra: If a molecule gives a quantum to a light beam, a fraction of the intensity of the beam gets a finite shift. A collective exchange of energy requires the space coherence.

Two weak conditions may be added:

- In a Doppler effect, the relative frequency shifts are constant. The frequency shifts observed in astrophysics show that the relative shifts of the lines of the multiplets are not strictly equal.

- The energy provided by the redshifts must be dissipated. An efficient dissipative process must exist even at low pressure.

Often, "Parametric" is used for interactions in which the matter is a catalyst, returning to its initial stationary state after the interaction; thus, a laser amplification is not parametric. Else, it is synonymous of "coherent". Here, we suppose that there is no permanent exchange of energy with the molecules.

2 Reminding the semi-classical theory of refraction.

2.1 Macroscopic theory.

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

A sheet of matter between two close wave surfaces distant of ϵ radiates a Rayleigh coherent wave late of $\pi/2$ whose amplitude is a fraction $K\epsilon$ of the exciting amplitude A. From Huygens' construction it generates the same wave surfaces, so that the amplitudes add into

$B = A[\sin(\Omega t) + K\epsilon\cos(\Omega t)]$

$\approx A[\sin(\Omega t)\cos(K\epsilon) + \sin(K\epsilon)\cos(\Omega t)] = A\sin(\Omega t - K\epsilon)$.

This result defines the index of refraction n by the identification

$K = 2\pi n/\lambda$

2.2 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 $\Phi = C_0\phi_0 + \Sigma_i C_i\phi_i$, 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 $\Psi_0 = \Pi_k \phi_0^k$. Its degeneracy is the number of molecules.

Excited by an external field, the molecular state ψ^m which radiates the coherent field late of $\pi/4$ is an excited state extracted from the degenerate states; named "dressed state", or state of polarisation, it is characterised by an index m referring the exciting mode.

Considering other refracted modes, Ψ splits as $\Psi = \Pi_m \psi^m$.

Remark that the coherent interactions are much stronger than the incoherent: A refraction by .3 μm of water delays the light of $\pi/2$, that is the light is fully scattered by the coherent Rayleigh scattering. In a pool, we see well through 25 metres of water, only a fraction if the light is scattered by the incoherent Rayleigh scattering; the factor is 10^8.

3 The Coherent Raman effect on Incoherent Light (CREIL).

The CREIL results from an interaction between dressed states; as these states have the same parity, it is 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

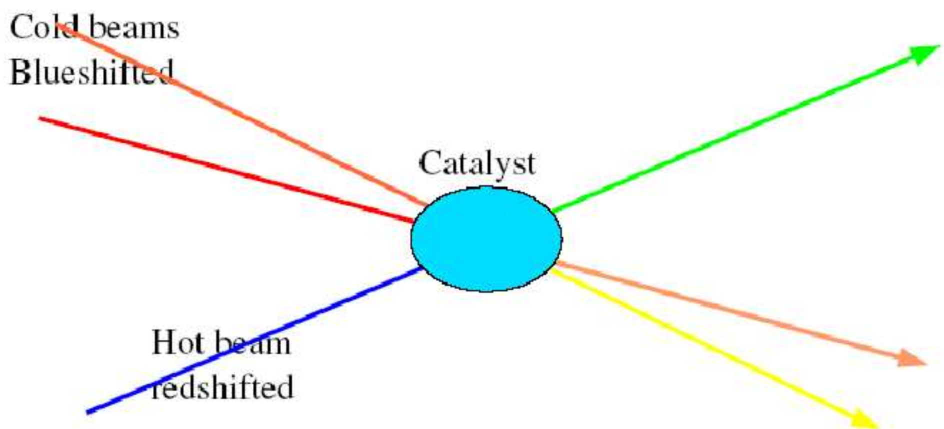

Figure 1: The CREIL effect does not blur the images.

to the colder ones. For an astrophysical application we suppose that the matter, a low pressure gas in low fields, returns to its initial state after an interaction.

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. The scattered beams have the same wave surfaces than the exciting beams, so that these beams may interfere, as in the coherent Rayleigh scattering making the refraction; the Raman beams are, however, at Raman-shifted frequencies, 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:

$$B = A[\sin(\Omega t) + K'\epsilon \sin((\Omega + \omega)t)] \quad (\text{with } (K' > 0)$$

$$= A[\sin(\Omega t) + K'\epsilon[\sin(\Omega t)\cos(\omega t) + \sin(\omega t)\cos(\Omega t)]]$$

Supposing that ωt and $K'\epsilon$ are small:

$B \approx A[(1+K'\epsilon)\sin\Omega t + \sin(K'\epsilon\omega t)\cos(\Omega t)]$

$B \approx A[\sin(\Omega t)\cos(K'\epsilon\omega t) + \sin(K'\epsilon\omega t)\cos(\Omega t) = A\sin[(\Omega + K'\epsilon\omega)t]$

$K'\epsilon$ 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.

This condition was set by G. L. Lamb Jr. for the definition of "ultrashort pulses" : "shorter than all relevant time constants". With ordinary light, the time coherence plays the role of length of the pulses: thus, the time-coherence 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. $K' + K''$ 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 polarisation the formula equivalent to $K = 2\pi n/\lambda = \Omega n/c$, $K' + K$" appears nearly proportional to $\Omega\omega/T$, and the frequency shift is :

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

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

All properties required 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.

4 The CREIL in astrophysics.

We must find a gas having, in a sufficiently populated state, a resonance at about 100 Mhz. Several solutions may be tried, using molecular, atomic or plasma resonances. Hydrogen, from far the most abundant gas, has too complicated a spectrum in its molecular states. In its ground atomic state, the spin recoupling transition at 1420 Mhz has too high a frequency.

In atomic hydrogen, the electric quadrupole allowed transitions ($\Delta F = 1$) have the following frequencies: 178 MHz in the $2S_{1/2}$ state, 59 MHz in $2P_{1/2}$ state, and 24 MHz in $2P_{3/2}$. These frequencies are very convenient; In these states, the gas will be named H*.

H* may appear mainly in the following conditions:

- Thermal excitation at $\approx$ 100 000 K, if the pressure is large enough to avoid a dissociation.
- Atomic hydrogen, at $\approx$ 20 000 K, and a Lyman alpha pumping.
- Combination of protons and electrons in a cooling plasma.

5 Proof of a CREIL in atomic hydrogen of quasars and galaxies.

This proof will result from the computation of an observed constant from spectroscopy.

Suppose that an UV rich light produced by a very hot object crosses atomic hydrogen. Supposing that there is a redshift during the absorption of the Lyman lines, the remaining intensity has the shape of a stair (figure 2, top).The permanent redshift is due to a constant Lyman alpha absorption ΔI.

By a new redshift, the top figure becomes the lower figure. To show the new absorption, the ancient red lines are dotted, the new intensities are represented by blue lines. The strongly previously absorbed line coming at the Ly_α frequency, the intensity ΔI is not any more available, so that the redshift stops; without CREIL, all lines of the gas are strongly absorbed, in particular the Ly_β and Ly_γ.

However, the decay of the states pumped by the Ly_β and Ly_γ produces some H* which shifts slowly the light restarting the regular redshift until the Ly_β then Ly_γ absorptions are reached.

The redshifts from the Ly_β and Ly_γ to the Ly_α are deduced from the Rydberg formula :

$$z_{(\beta \mathrm{resp.}\gamma,\alpha)} = \frac{\nu_{(\beta,\mathrm{resp.}\gamma)}-\nu_\alpha}{\nu_\alpha} \approx \frac{1-1/(3^2\mathrm{resp.}4^2)-(1-1/2^2)}{1-1/2^2}$$

$z_{(\beta,\alpha)} \approx 5/27 \approx 0.1852 \approx 3 * 0.0617;$
$z_{(\gamma,\alpha)} = 1/4 = 0.025 = 4 * 0.0625.$

If special conditions allow the β line play the same rôle than the α:

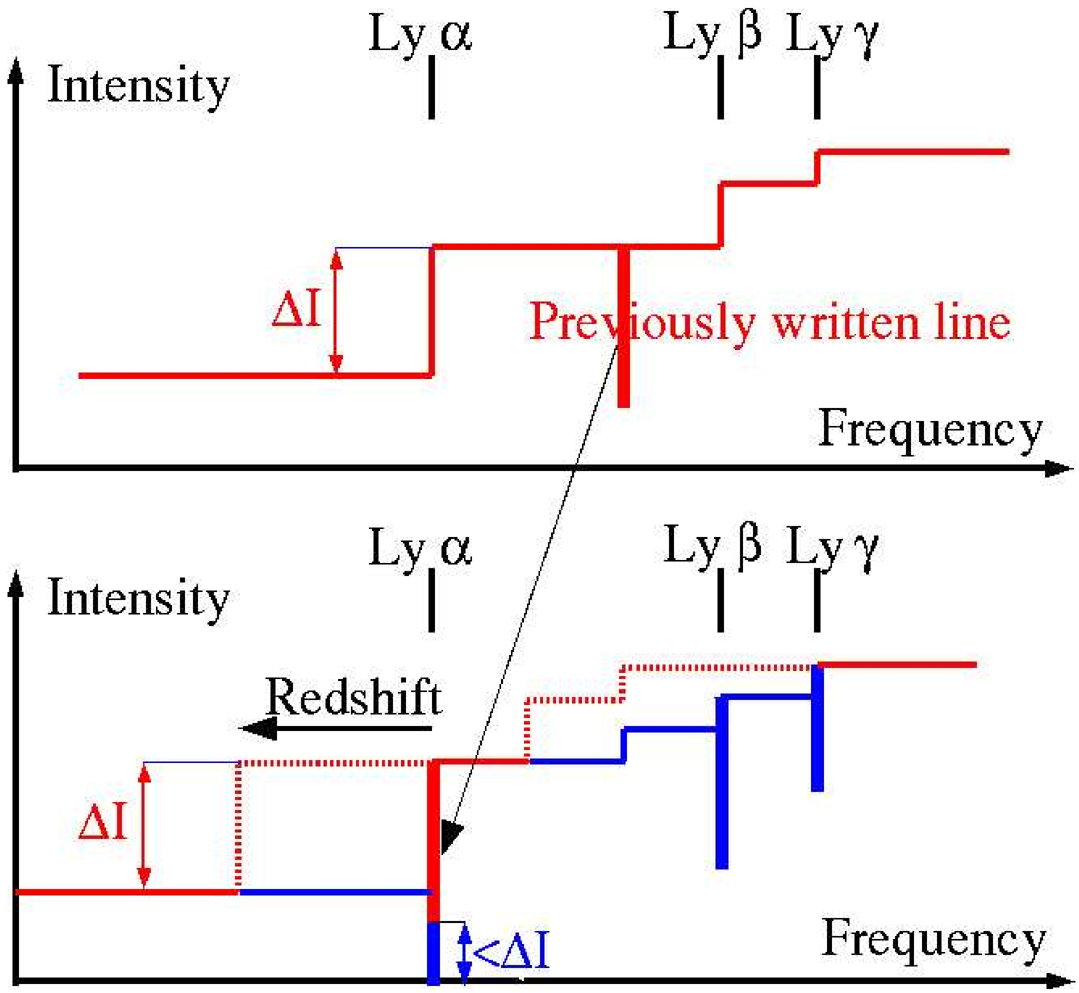

Figure 2: Multiplication of the Lyman spectral lines.

$z_{(\gamma,\beta)} \approx 7/108 \approx 0.065$.

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

If the pressure of the gas decreases, the decay of H* slows down, so that the intensity ΔI needed for a redshift between two absorption lines, decreases, that is the required column density of atomic hydrogen decreases.

On the contrary, at the coincidence with an absorbed line, the required decay from the upper states to H* becomes slow too, 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 stopped redshift when the light leaves a low density gas, so that the lines are observed with a redshift multiple of 0.062.

The observation of periodicity $z = 0.062$ by Burbidge, Tifft and others is a QUANTITATIVE PROOF that the large redshifts result mainly from CREIL in atomic hydrogen.

6 Conclusion:Verify the following CREIL/Big Bang comparison.

Transferring energy from beams having a high temperature deduced from Planck's law to cooler beams, the CREIL effect in atomic hydrogen excited to states 2S and 2P (H*) redshifts the hot (generally high frequency) beams, blueshifts the cool, generally thermal radiation which is heated.

The rule to use the CREIL is simply: Look for H* !

Use this rule to verify the following table (or listen the oral paper, or see description and references at http://arxiv.org/ps/physics/0503070).

Comparison of the standard theory (big bang) and a theory taking into account the light-matter coherent interactions (CREIL in excited atomic hydrogen H*)

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<tr><td colspan="2">Origin of the CMB</td><td>Expansion of initial radiation</td></tr>
<tr><td rowspan="8">Q
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S</td><td>Gap of redshifts between sharp and broad emission lines</td><td></td><td>Thermal ionisation of hydrogen</td></tr>
<tr><td>Multiple redshifts</td><td>Jets or clouds</td><td rowspan="2">Propagation in H*</td></tr>
<tr><td>Periodicities of these redshifts</td><td>Denied</td></tr>
<tr><td>Same redshifts of the broad lines in radio-loud quasars</td><td></td><td>Radio ionisation of hydrogen</td></tr>
<tr><td>Unique composition of the gas</td><td></td><td>Unique atmosphere</td></tr>
<tr><td>Abundance of iron</td><td>Special generation</td><td>Old object</td></tr>
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