Demonstration, improvement and use of Karlsson's law for quasars

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Démonstration, amélioration et application de la loi de Karlsson aux quasars. // Demonstration, improvement and use of Karlsson's law for quasars.

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Abstract

Les rougissementss qui transforment les fréquences ν_β (ou ν_γ) des raies Lyman β (ou γ) de l'atome d'hydrogëne en fréquence ν_α de la raie Lyman alpha (Ly$_\alpha$), sont, avec une bonne approximation 3K (ou 4K), où K est la constante de Karlsson 0,061. Supposant que toutes les fréquences d'un spectre sont multipliées, *dans chaque rougissement successif*, comme dans un effet Doppler, par la même constante, ici le rapport de frequences ν_α/ν_β (ou ν_α/ν_γ), on obtient (comme avec la loi de Karlsson aux faibles rougissements) des fréquences très voisines de fréquences observées. Pour obtenir d'autres raies, il faut ajouter initialement aux absorptions Ly_β (ou Ly_γ) des absorptions d'autres atomes. Les absorptions ne sont visibles qu'avec arrêt des rougissements (qui diffusent les raies), lorsqu'une raie absorbée atteint la fréquence ν_α, c'est à dire lorsque l'absorption Ly_α qui produit des atomes 2P disparait. Les périodes hyperfines des atomes 2P sont plus longues que les impulsions qui forment la lumière naturelle, une des conditions de cohérence spatiale de la diffusion se trouve vérifiée, et le glissement de fréquence peut être dû à un effet Raman impulsionnel cohérent (ISRS) interdit dans 1S. La loi de Hubble ne s'applique pas aux quasars.

Abstract.

Redshifts which transform frequencies ν_β (or ν_γ) of lines Lyman β (or γ) of hydrogen atom into frequency ν_α of Ly$_\alpha$ line, are, with

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a good approximation 3K (ou 4K), where K is Karlsson's constant 0,061. Assuming that all light fequencies are multiplied in *successive* redshifts, as in a Doppler shift, by same constants, here ratio of frequencies ν_α/ν_β or ν_α/ν_γ, we obtain for pure atomic hydrogen a canvas of frequencies very close to frequencies observed in quasar spectra. Other lines result from initial absorptions by other atoms before redshift process. Absorptions during shifts are diluted, not visible: visible absorptions need a stop of redshifts when an absorbed line reaches (ν_α) frequency, that is when there is no more excitation of H atom. Excited in 2P state, H atom has hyperfine periods longer than length of pulses making thermal light, so that impulsive stimulated Raman scattered light interferes with incident light, shifting its frequency. Hubble's law does not apply to quasars.

Keywords: Line:formation. Radiative transfer. Scattering.

98.62.Ra Intergalactic matter; quasar absorption and emission-line systems; Lyman forest

290.5910 Scattering, stimulated Raman

190.2640 Nonlinear optics : Stimulated scattering, modulation, etc.

1 Introduction.

Burbidge [1], then Karlsson [2] observed that relative frequency shifts of quasars z $= [\nu_{emit} - \nu_{obsv}]/\nu_{obsv}$ are often close to remarkable values $z = 0.061$ and $z = 1.95$. This result was generalized by Karlsson's formula:

$z(n) = nK$, (1)

where n is integer 1, 3, 4, 6,... and K=0.061.

Many sharp, saturated lines making "Lyman forests" of quasar obey these rules; many authors tried to apply similar formula to galaxies, but it failed.

As his formula does not work well for large n, Karlsson proposed a periodicity of ln(1+z), additions of which multiplies sets of frequencies by parameters, as Doppler redshifts do, without good results.

The aim of this paper is extension of Karlsson's work to understand formation of "Lyman forests" of quasars. We use mainly conventions and results found in P. Petitjean's paper [3].

2 Discussion of Karlsson's formula.

In Doppler frequency shifts, emitted and received frequencies verify equation which involves, as parameters, emission and reception speeds $V_{emission}$ and $V_{reception}$:

$\nu_{reception} = \frac{c-V_{reception}}{c-V_{emission}} * \nu_{emission}$ (2)

We assume that frequency shifts at various light frequencies obey an equation similar to equation (2), so that a single parameter is needed to compute frequency shifts at all frequencies, for instance the ratio f_1/f_0 of a particular shifted frequency over initial frequency :

$\nu_{shifted} = \frac{f_1}{f_0}\nu_{initial}$ (3)

The terms of strange serie 1, 3, 4, 6, ... of Karlsson's formula may be written $3p + 4q$, where p and q are any non-negative integers. Thus redshifts $3K$ and $4K$ are remarkable, able to generate simply all Karlsson's redshifts.

Compute redshifts which put Lyman ν_β and ν_γ frequencies of H atom to ν_α frequency:

$Z_{(\beta,\alpha)} = (\nu_\beta - \nu_\alpha)/\nu_\alpha = [(1 - 1/32 - (1 - 1/22)]/(1 - 1/22)] \approx 5/27 \approx 0.1852 \approx 3 * 0.0617 \approx 3 * K$; (4)

$Z_{(\gamma,\alpha)} = (\nu_\gamma - \nu_\alpha)/\nu_\alpha$ =[(1-1/42 -(1-1/22)]/(1-1/22)] = 1/4 = 0,25 = 4*0.0625 $\approx 4K$. (5)

Assuming that use of 3 lowest Lyman frequencies of H atom is better than use of K, and that variation of shifts at various frequencies is obtained from a particular shift as in a Doppler redshift, Karlsson's formula becomes simpler: shifted frequencies $\nu(p, q)$ depend only on absolute frequency ν_0 , three well known frequencies and two any non-negative integers p and q:

$\nu(p, q) = (\nu_\alpha/\nu_\beta)^p * (\nu_\alpha/\nu_\gamma)^q * \nu_0$. (6)

Karlsson's formula (1), applied, for instance, to Lyman beta line with n=3 does not generate exactly Lyman alpha frequency, while formula (6) does. Though resolution of spectra does not allow to distinguish a doublet from a superposition of lines, we will choose formula (6) because choice of possible values of p and q seems more natural than extraction of n from a less natural serie. Is it only aesthetics ?

3 Model of a quasar surrounded exclusively by hydrogen.

3.1 Possible hypothesis.

We assume that "Lyman forest" is built by absorption of a thermal emission of an extremely hot star by *pure*, relatively cold (2000-5 000 K), low pressure, thus non-excited, atomic hydrogen.

Following properties of "Ly_α forest" are directly deduced from Petitjean's paper [3]:

-A- As lines are sharp, widening of lines by collisions must be negligible, pressure of gas must be very low.

-B- To obtain absorption of Lyman lines at several frequencies, a redshift process of electromagnetic waves is necessary. Here, we make only hypothesis of formula (3) about this redshift.

-C- A single, unshifted Ly_β is observed; no unshifted Ly_γ appears because it does not remain absorbable energy at high frequencies after redshifts of thermal emission profile.

Absence of an absorption line may result from :

-a- Absence of emitted energy around frequency of line.

-b- A permanent shift of light frequencies dilutes absorption, so that all absorbed (or emitted) lines have width of shift and lines are weak, not observable. Accordingly, absorption (or emission) of sharp lines requires a stop of frequency shifts.

-c- Accurate superposition of observed lines results from the choice of redshift equations: Absence of shifted β and γ lines while sharp α lines are observed, is due to superposition of these lines with α lines.

In standard theory, sharpness of saturated absorbed lines requires contradictory conditions:

- Column density of gas must be large for saturation;

- Absorbing gas must be thin to avoid a broadening of lines by frequency shift during absorption.

- Pressure of gas must be low to avoid collisional broadening of line.

Thus gas must be in filaments which are only detected by quasars.

Supposing that redshift is related to a physical property of gas, condition is:

- Light is redshifted except if an absorbed line is at Lyman α frequency. Thus redshift requires a lyman α absorption, that is generation of 2P hydrogen.

3.2 Building of spectrum.

Figure 1 represents a canvas of atomic hydrogen spectrum for building any absorption spectrum by addition of lines, in particular able to play the role of Ly_β or Ly_γ lines.

Rules used to build spectrum taking into account only hydrogen atoms are simple :

- i - At start, close to star, we suppose that α, β and γ lines have been absorbed.

- ii - It appears a frequency shift until an absorbed, shifted line of initial frequency ν reaches ν_α frequency. Thus all absorbed frequencies have been

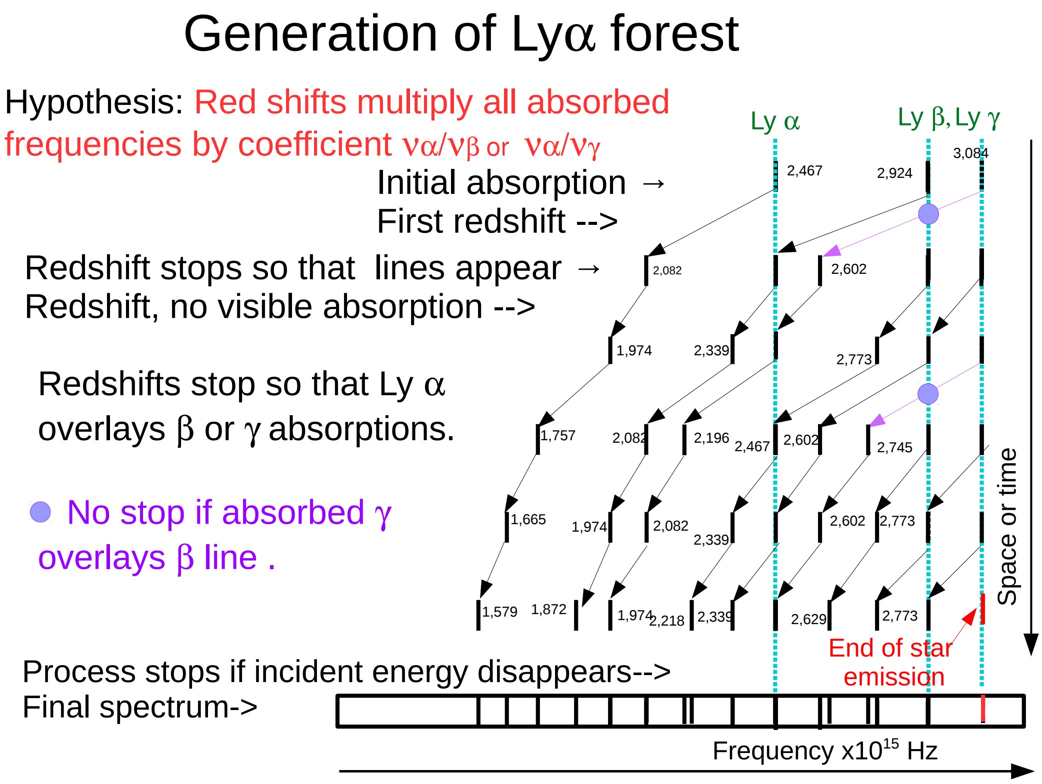

Figure 1: Lyman hydrogen forest of a quasar. During stop of redshift Ly_β and Ly_γ lines are absorbed. Lines of other local gas may be also absorbed and may later play the role of Ly_β and Ly_γ lines if their frequencies are larger than ν_α. Written frequencies do not take into account dispersion of hyperfine polarizability of H atom.

multiplied by ν_α/ν, coefficent lower than 1. In pure atomic hydrogen ν may be ν_β or ν_γ, assuming that higher frequency lines are too weak.

- iii - During stop of frequency shift, the three main lines of H could be absorbed, but there remain no energy at Ly_α frequency.

- iv - Assume that Ly_β absorption produces a very weak redshift. During this negligible redshift, gas lines are visibly absorbed. If weak redshift is able to shift absorbed frequencies off Ly_α absorption line before full absorption of light at Ly_β frequency, fast redshift restarts, go to - ii -. Else there is no more redshift, absorbed Ly_β line is visible, but Ly_γ line is probably not because its frequency is probably larger than the shifted high frequency limit of emission of star.

In pure H, total redshift results from several relative shifts $Z_{\beta,\alpha}$ and $Z_{\gamma,\alpha}$ which correspond to multiplication of light frequencies by ν_α/ν_β or ν_α/ν_γ.

Computed lower frequencies written on figure are not very good. They can be corrected by multiplication by a unique dispersion function $F(\nu)$ equal to 1 at ν_α frequency.

3.3 Comparison of optical properties of 1S and 2P hydrogen.

In 1S state, hydrogen has 1420 MHZ frequency, (21 cm wavelength,) quadrupolar resonance frequency.

In its first excited state, hydrogen atom has quadrupolar resonance frequencies 178 MHz (1,7m) in state $2S_{1/2}$, 59 Mhz (5 m) in $2P_{1/2}$ and 24 MHz (12 m) in $2P_{3/2}$.

A qualitative difference is that ordinary incoherent light is made of around 1 nanosecond (30cm) pulses which have these parameters between those of 1S and 2P states.

To shift frequencies of a spectrum, so that absorbed Lyman β (or γ) line is shifted to Lyman α frequency, we must set, in equation (3), $f0 = \nu_\beta$ (or ν_γ) and $f1 = \nu_\alpha$

A single, unshifted Ly_β is observed; no unshifted Ly_γ appears because it does not remain absorbable energy at high frequencies after redshifts of thermal emission profile.

Shift of frequencies must stop to absorb lines of a gas (assuming absorbable energy at their frequencies). Absence of observed Ly_β and Ly_γ absorption lines in forest can only be explained by an accurate superposition of these lines with Ly_α observed lines.

3.4 Introduction of other gas in spectrum building.

Lines found in figure 1 appear in real spectra, after a correction of their frequencies by the factor $F(\nu)$. But many lines have an other origin: various lines absorbed at frequencies larger than ν_α may play the role of Ly_β and Ly_γ, multiplying density of lines.

Figures much more complex than fig. 1 can be drawn.

3.5 Structuring space.

Redshifts stop if frequency of an absorbed line becomes ν_α and not if absorbed ν_γ frequency reaches ν_β frequency. This shows that redshift results (mainly ?) on generation of 2P hydrogen atoms.

Up to now, we have only supposed that it exists somewhere (sometime for light) a redshift. Thus space is divided along the path of light into regions where generated 2P atoms shift light frequencies, and regions in which there is no 2P atoms and no frequency shifts.

As quasars are not alone in space, perturbation of generation of these regions may result from pumpings of atoms by light of other stars. Thus region in which quantized redshifts appear must be small enough to avoid an important lighting by other stars.

Around the star, the shifting and normal regions must make concentric shells.

To avoid different pumpings by light coming from different regions of the surface of the star, redshift must appear only at a distance much larger than size of the star, that is in a region where pressure of gas is low.

These conditions are evidently not verified for a set of relatively close stars as a galaxy. As the star must produce very high light frequencies, if it is small it must be extremely hot. An hypothesis which seems valuable is an accreting neutron star, a type of stars which were never found in nebulae while they should be seen.

4 Physical interpretation.

4.1 Comparison of optical properties of 1S and 2P hydrogen.

In 1S state, hydrogen has 1420 MHZ frequency, (period T=0.7ns; wavelength $\lambda = 21$ cm), quadrupolar resonance frequency.

In its first excited state, hydrogen atom has quadrupolar resonance frequencies: 178 MHz (T=5.6 ns, λ =1,7 m) in state $2S_{1/2}$, 59 Mhz (T=17 ns, $\lambda = 5$ m) in $2P_{1/2}$ and 24 MHz (T=42 ns, $\lambda = 12$ m) in $2P_{3/2}$.

A qualitative difference is that ordinary incoherent light is made of around 1 nanosecond pulses: these pulses are shorter than hyperfine periods in excited states, as required by conditions of space coherence of "Impulsive Stimulated Raman Scattering" (ISRS) : *Length of pulses must be shorter than all involved time constants* [4].

Space coherence of incident and scattered light in ISRS allows an interference of exciting and scattered light, which shifts frequency of incident light and preserves the geometry of light beams.

The other condition for ISRS is: Collisional time most be longer than 1ns, that is pressure must be very low, so that pressure broadening of lines is low.

These conditions make ISRS in space very weak compared with ISRS in labs which uses around 10 nanosecond laser pulses, around $k = 10^5$ times shorter than usual light pulses:

- Division of pressure by k divides the shift by k.

- Division of Raman shift by k divides the shift by k twice:

- - Once by division of quadrupolar frequency;

- - Once by division of difference of populations of quadrupolar levels.

Thus order of magnitude of path needed to observe ISRS is 10^{15} times longer than in laboratory experiments: astronomical paths are needed for observation.

4.2 De-excitation of Raman levels.

As pressure is very low, collisions between atoms are negligible. A radiative process is necessary to de-excite hyperfine levels, thus obtain Raman frequency shift.

Happily, there are cold background electromagnetic waves. Thus, the real process is not a single ISRS, but a set of ISRS: hyperfine levels of 2P atoms are not excited. Excited atoms H catalyze an exchange of energy between light beams, it is a *parametric interaction.* Variations of energy produce frequency shifts of light beams, so that their entropy is increased. This parametric interaction is usually named "Coherent Raman Effects between Incoherent Light beams" (CREIL).

5 Conclusion.

Karlsson's relative frequency shifts 3K or 4K transform, shift, with a good approximation, absorbed Lyman frequencies ν_β or ν_γ of H atom into ν_α frequency. During corresponding frequency shifts H atoms are pumped to 2P level by permanent, diluted, invisible Ly_α absorption.

Coherently scattered Raman light interferes with incident light, shifting its frequency (As Rayleigh scattering shifts the phase, producing refraction).

Stop of redshift which allows saturated, visible absorption of lines is due to lack of 2P atoms. However, redshift may remain very weak by Ly_β absorption, until absorbed line is shifted out of Ly_α frequency, so that fast redshift restarts...

Additional absorptions by various atom may also play the role of Lyman β and γ absorptions, complicating the spectrum. Comparison of theoretical and observed spectra is not good at lowest frequencies, probably because, as refraction, ISRS has a dispersion.

Hubble's law does not apply to quasars which may be accreting neutron stars lying in close galaxies.

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