S09 N° 443 -The interstellar medium as a window onto galaxy evolution. - Poster EWASS 2018: Spatially coherent spectroscopy of interstellar gas

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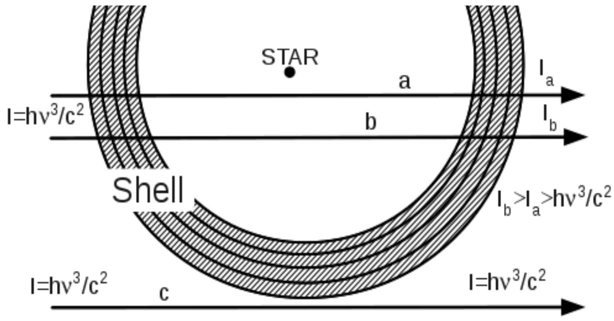
1- Introduction.

Except where close to heavy objects (stars), pressure of interstellar gases is much lower than in gas lasers. Thus interactions of light with these gases are spatially coherent. We only use consequences of this coherence, verified in laser laboratories.

These interactions may involve molecular dipoles amplifying or absorbing light (possibly amplifying the zero point field). Laser theory, derived from Einstein's 1917 paper based on thermodynamics, shows that coherent variation dI of radiance I of a *single* light beam along a path dx in a collision-less gas is dI = BIdx where amplification Einstein's coefficient B depends on the nature and state of gas. Multiplication of B by initial radiance I corresponds to a correlation through incident beam of close molecular dipoles phases, so that resulting quadratic energy interaction with stronger resulting dipoles produces a powerful, coherent increase of field. For other directions, large dipoles generated by superradiance have generally mainly incoherent couplings with light, so that super-absorptions "by competition of modes" appear. Super-radiance and super-absorption are observed in light-pumped lasers (ruby, neodyme-YAG, dye, …).



Coherent quadrupole interactions (Raman) shift frequencies of exciting light, but are intense only if incident and scattered light wavelengths are equal (avoiding a variable *phase shift* for an efficient addition of scattered amplitudes), which requires propagation in bi-axial crystals. However, if Lamb's conditions are fulfilled, that is with light pulses "shorter than all involved time constants"[1], phase shifts during pulses are negligible, so frequency shifts are produced by "Impulsive Stimulated Raman scatterings" (ISRS) [2].

2-Strömgren's systems:

Expansion of a stellar wind made mainly of protons and electrons cools it, producing much excited hydrogen atoms in a shell surrounding a "Strömgren's sphere". Amplification of light in shell may be weak, or superradiant for rays having a maximal path in this shell, that is tangentially to the sphere. De-excited by super-radiance, then involved in super-absorption, atoms intensely absorb energy received from the star. This energy can not be stored notably in gas which works as medium of a "light pumped laser". HST picture

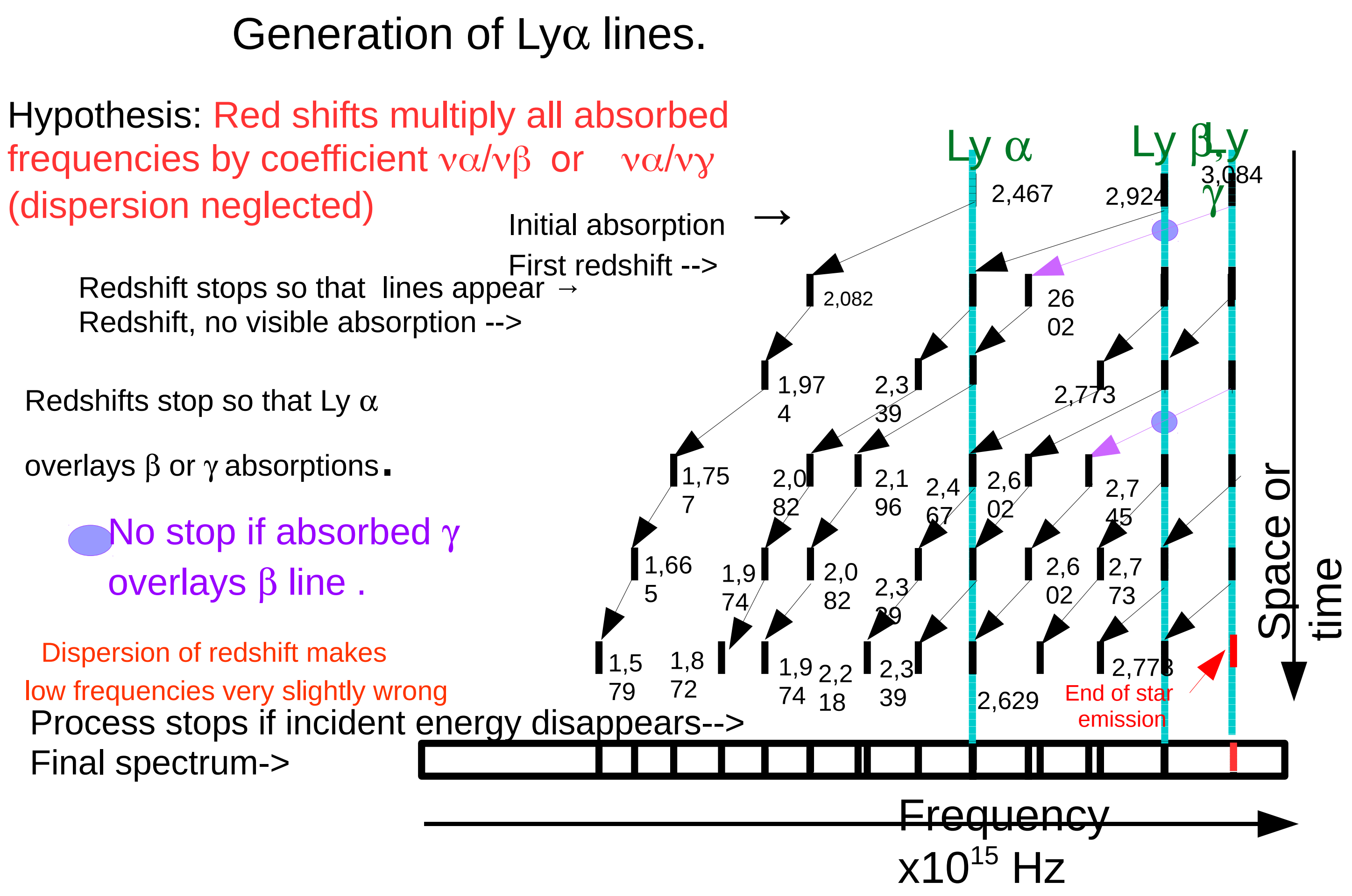
shows initial limbs of SNR 1987A in which absorption or scattering of light by equatorial planets or rings strangled Strömgren's sphere into a three limbs (to Earth) hourglass. Now, the star has eaten its planets.
Remark that probability does not allow that two background stars to be much brighter than a lot of other background stars, while they are on rings: their light is much more amplified than light only generated in Strömgren's shell.

SNR1987A shell is an *optical black hole*.

Spectroscopy of light-pumped lasers or optical black holes is complex, involving highly excited energy levels, super-emission and super-absorption. Thermodynamics is the main rule, temperature of a beam being deduced from its frequency and radiance by Planck's formula.
Astronomers observe many limbs, (circles or arcs), that competition of modes may punctuate.

3- Absorption of Lyman lines of H atoms in quasar spectra.

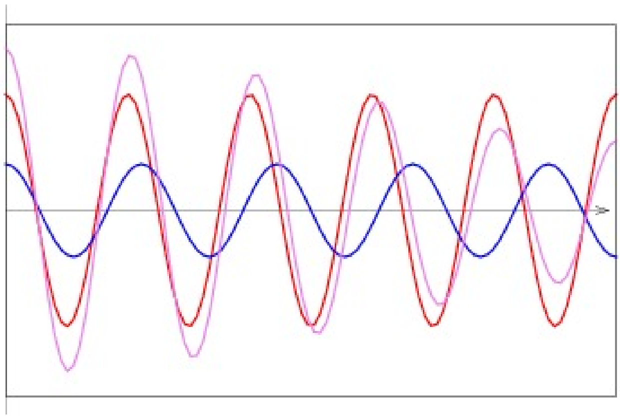
In a quasar spectrum, Patrick Petitjean [3] found absorptions attributed to Lyman alpha line of H atom, with several redshifts, but no shifted beta or gamma lines. We searched for them by applying Rydberg and Doppler formulas to redshifted alpha lines and found that they are mixed with alpha ones. This superposition explains Petitjean's observation and shows a quantization of redshifts according to Karlsson's formula because we notice that 3K (or 4K) [where K is empirical Karlsson's constant] is redshift that brings an absorbed beta (or gamma) line to alpha frequency. Why does an absorbed line at alpha frequency stop redshift, allowing strong, sharp absorption of gas lines ? The simplest explanation is that redshift requires alpha absorption, thus creation of atoms in an excited 2P state. A weak redshift resulting from a beta absorption may restart the process. **Redshifts stop so that Ly$_\alpha$ overlays β or γ absorptions.**



4- Impulsive Stimulated Raman Scattering (ISRS): Coherent Raman in space.

Spectrum of monochromatic, incoherent light scattered by a gas shows generally new, Raman lines.

Assume that, on next figure, the red line represents time variation of amplitude of an exciting coherent light, the blue one amplitude of a Raman scattered line, and purple one their sum. As long as beats do not appear (here ~ 3 periods), purple seems to be a monochromatic wave of intermediate period. ISRS uses this result , precision of which is evaluated by computations.



ISRS is generally performed in laboratories [3] using 10 femtosecond laser pulses. Usual light, of thermal origin, temporally-incoherent, formed of roughly 1 nanosecond pulses, requires that all involved time constants, that is collisional time in gas and Raman resonance period are shorter than light pulses [1], each divided by 10^5 for a comparison with laboratory experiments. Reduction of collisional time by 10^5 divides the acceptable gas pressure, thus the shift by this factor. Reduction of Raman resonance period divides ISRS twice: directly by reduction of Raman quantum, and by Boltzman factor for difference of hyperfine levels populations at equilibrium. Thus, an equal frequency shift requires a path whose order of magnitude is 10^{15} times larger than in laboratory, an astronomical path.

Hyperfine resonance at 1420 MHz of non-excited H atoms corresponds to a period less than 1 nanosecond, Lamb's conditions are not fulfilled. On the contrary, in excited states, hyperfine frequencies below 1 GHz produce an ISRS. Hyperfine levels may be de-excited by another ISRS heating a thermal frequency without perturbation of isotropy. Such sets of ISRS are named "spatially Coherent Raman Effects on temporally Incoherent Lights" (CREIL). Thus, an equal frequency shift requires a path whose order of magnitude is 10^{15} times larger than in laboratory, an astronomical path.

5- Lyman forests of quasars.

Presence or absence of Ly_α absorption structures space into probably variable shells in which H atoms are excited or not. Previously described process provides a spectrum of so-called Lyman alpha lines. But quasar spectrum shows many other absorbed, sharper, saturated lines which make "Lyman forests": Lyman alpha absorption excites H atoms to 2P state, density of which increases in gas, that becomes able to amplify Lyman alpha H line. Start of coherent "emission" which is an amplification requires an initial ray possibly provided by zero point field, but rays refracted from observed ray by fluctuations of gas density may be stronger. Thus, a close superradiant ray bursts as an observable flare. Energy is provided by de-excitation of atoms and also by a competition of flare and star modes. Thus, a "Lyman forest" line is absorbed in observed spectrum. A flare is observed close to star while a sharp, saturated line of "Lyman forest" is absorbed. It seems difficult to compute frequencies in this relaxation process.

6- Correction of Hubble's law.

Hubble did not appreciate the common interpretation of his law. Thus we propose the following corrected interpretation:

Redshifts of stars provide column densities (from stars to Earth) of atomic hydrogen in state 2P.

This sentence is not precise because most excited states of H atoms, other atoms, may shift weakly frequencies of light, but it seems a good enough approximation for most uses.

6-1 Redshifts of spiral galaxies.

Celestial mechanics provides a relation for stability of orbits of stars making spiral galaxies. With evaluation of distances by Hubble's law, that is the present evaluation of sizes of spiral galaxies, their masses must be increased by "dark matter". But it appears that search of "dark matter" inside laboratories buried under big mountains is negative. Thus it seems good to take into account an over-estimation of distances of these galaxies by an abundance of excited hydrogen around hot objects, so that dark matter and energy are not needed.

6-2 Dispersion of multiplets in spectra of far stars: AS CREIL results from an interaction with matter as refraction, it depends on frequency. There is no need to modify fine structure constant.

6-3 Very simplified descriptions of other applications:

Model of quasar: Previous description of lines formation leads to a model of quasars:
- A kernel of neutrons is surrounded by a decreasing temperature pseudo crystal (stabilized by pressure) made mainly of H atoms. A CREIL is possible which increases entropy by exchange of energy during propagation of X rays emitted at increasing distances from center, thus have decreasing thermal emission frequencies. Such spectra are observed in X emissions of Sun.
- An atmosphere of hydrogen has similar properties than Earth atmosphere, stratosphere, Heaviside noisy regions ....
- Generation of spectra in low pressure regions (sections 3 and 5).

Anomalous accelerations of space probes: Radius of Strömgren's sphere of Sun is around 10 AU. Just outside, microwaves frequencies needed to compute distances and accelerations of probes may be increased by a CREIL transfer of energy from sunlight to colder microwaves, excited H atoms playing a role of catalyst.

Maps of galaxies: Distances are exaggerated close to hot stars. Thus bubbles are inflated on maps, universe seems spongy.

Isotropy of microwave background. Frequencies of these radiations are close to hyperfine frequencies: A strong CREIL inside background radiations increases entropy.

Conclusion:

- Spatially coherent spectroscopy must be used in study of low pressure interstellar gas.

- Hubble's law does not evaluate distances, but column densities of excited atomic hydrogen.

- Dark matter and energy, big bang, … are tales.

References:

[1] G. L. Lamb Jr. "Analytical description of ultra-short optical pulse propagation in a resonant medium" Rev. Mod. Phys. **43**, 99–124, 1971.

[2] Y. X. Yan , E. B. Gamble Jr., and K. A. Nelson, "Impulsive Stimulated Scattering: General Importance in Femto-second Laser Pulse Interactions with Matter and Spectroscopic Applications" J. Chem. Phys., **83**, 3591--5399, 1985.

[3] P. Petitjean, "Le contenu baryonique de l'univers révélé par les raies d'absorption dans le spectre des quasars", Ann. Physique, **24**, 1-126, 1999.