Coherent spectroscopy of atomic hydrogen in nebulae: II ISRS.

Absorption spectrum of very low pressure, relatively cold atomic hydrogen: Lyman forest and Karlsson's formula.

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Abstract

Light of a very hot blackbody crosses assumed pure, very low pressure, relatively cold (20 000K) atomic hydrogen. Absorption of Lyman alpha line generates 2P states in which periods of quadrupolar resonances are longer than lengths (1 ns) of pulses which make incoherent light. Assuming that collisional time is also longer than 1 ns, an "impulsive stimulated Raman scattering" (ISRS) decreases frequencies of light until a strongly absorbed line gets Lyman alpha frequency. All lines of gas are absorbed. As long as fall of radiance resulting from Planck's law does not reach Lyman beta frequency, states of principal quantum number n larger than 1 provide a weak frequency shift or feed n=2 states, so that fast redshift restarts. Thus, between visible absorptions there are relative frequency shifts putting absorbed Lyman beta and gamma lines to Lyman alpha frequency. Lyman forest and Karlsson's formula are obtained.

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1 Introduction

Raman (quadrupolar) scattered light, is made space-coherent by use of pulses shorter than all involved time constants (G. L. Lamb [1]). It interferes with

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exciting light. An elementary Fourier computation shows that, before appearance of flapping, the main resulting frequency is intermediate between frequencies of both components, in proportion of their amplitudes. The other components cancel by interferences. Thus, if Lamb's conditions are fulfilled, Raman scattering shifts frequencies of light during its propagation, without blurring of images. It is the "Impulsive Stimulated Raman Scattering" (ISRS) [2].

Assuming, in a first approximation, that polarizability is independent on exciting frequency ν, relative frequency shift $\Delta\nu/\nu$ does not depend on ν.

We, generally do not need to take into account action of probe beam on studied medium. Here, we show that this action may produce atoms which, playing a catalytic role, cannot be neglected.

2 Evaluation of variation of Impulsive Stimulated Raman Scattering (ISRS), according to length of light pulses.

Suppose that femtosecond pulses used in an ISRS experiment are replaced by k times longer nanosecond pulses making time-incoherent light. How do path needed for an observation of this ISRS is increased by the necessary increase by a factor k of time constants ? To get only a coarse order of magnitude, we assume that pressure and resonance frequencies can remain optimal and other parameters constant.

- To multiply collisional time by k, pressure, thus ISRS shift, are divided by factor k.

- Decreasing quadrupolar frequency by factor k, Raman, thus ISRS frequency shift are divided by k.

- We have always a Stokes and an anti-Stokes scattering, whose results have opposite directions. Assuming thermal equilibrium, difference of populations of quadrupolar levels, assumed weak, is proportional to quadrupolar frequency: ISRS frequency shift is divided by k.

Thus, order of magnitude of ISRS is reduced by a factor k^3, of order of 10^{15} : an observation of ISRS, done in a laboratory with 10 femtoseconds laser pulses, requires, with incoherent light, an astronomical path.

An ISRS tends to saturate a quadrupolar level, so that ISRS becomes weaker. Suppose that several ISRS are associated so that populations of quadrupolar levels remain constant: gas becomes a catalyst, interaction is "parametric", it exchanges energy between several light beams in accordance with thermodynamics. The parametric effect includes always a contribution of thermal radiation, which redshifts light. We name it Coherent Raman Effect acting on Incoherent Light (CREIL).

3 ISRS resulting from Lyman alpha absorption by 1S atomic hydrogen.

Condition of coherence for an ISRS of incoherent light requires a quadrupolar resonance frequency lower than 1 GHz.

In its ground state, atomic hydrogen has the well known 1420 MHz quadrupolar resonance frequency, too high for an ISRS of incoherent light.

The 178 MHz in state $2S_{1/2}$, 59 Mhz in $2P_{1/2}$ and 24 MHz in $2P_{3/2}$ are convenient. In more excited levels, quadrupolar resonance frequencies work, but ISRS is much weaker because frequencies are too low.

3.1 Lyman forest.

Assume, for a simple theory, that a very hot source, emitting a *continuous spectrum* in UV-X region is surrounded by an a huge region of decreasing pressure and temperature pure hydrogen.

All involved distances are much larger than size of source, so that the source may be considered as a point.

Close to source, high density and temperature decrease free paths of atoms, they are assumed too large for an ISRS, so that Lyman spectrum is strongly absorbed, written into light.

At a larger distance, collisional time of atoms becomes larger than 1 nanosecond. 1S atoms cannot be pumped to 2P because Lyman lines were already absorbed. But assume that temperature remains high enough to generate a few excited atoms, so that an ISRS redshifts slightly light. Frequencies slightly higher than Lyman α which were not absorbed, get Lyman alpha frequency. Their absorption creates 2P atoms, redshift increases, becomes fast; redshift dilutes absorption which becomes invisible, until Lyman β absorbed line gets Lyman α frequency ν_α: Assuming that absorption of Lyman β line was strong, production of 2P hydrogen stops, redshift stops.

As redshift stops, all lines of gas, mainly Lyman absorption lines are strongly written into spectrum. Thus, in spectrum, we have two Lyman spectra, one shifted so that its absorbed β line got Lyman α frequency.

If it remains in light, energy at frequencies high enough to excite 1S atoms to levels higher than 2P, a weak redshift is produced by atoms excited to high levels, and by 2S or 2P atoms resulting from a cascade from high levels.

The weak redshifting brings unabsorbed frequencies at Ly_α frequency, a fast redshift works until *any* absorbed line gets Lyman alpha frequency. Each absorbed line generates new absorbed lines, complexity of spectrum increases from low frequencies to higher.

Thus we obtain sets of Lyman absorptions shifted several times by fundamental shifts which bring frequencies ν_β or ν_γ to ν_α frequency (assuming that Ly_δ absorption is negligible). This spectrum is a "Lyman absorption forest" observed in spectra of quasars [3].

Having assumed that the source is relatively small, space is divided into regions (shells) which redshift light, separated by regions which do not.

The cycles of shifts and absorptions have a large probability to stop during an absorption phase because an exit from this phase requires pumping at high frequencies while Planck's formula shows, at high frequencies, a fast decrease of radiance of a thermal source by increase of frequency: The irradiance was high enough to shift spectrum to the stop, a much larger irradiance at higher frequency would be necessary to restart.

3.2 Karlsson's formula.

Set $Z_{(\nu_0,\nu_1)} = (\nu_0 - \nu_1)/\nu_1)$ a redshift which brings an initial frequency ν_0 to frequency ν_1.

As cycle of redshifts and absorptions starts and stops generally during an absorption, the largest observed redshift is generally close to $bZ_{(\beta,\alpha)} + cZ_{(\gamma,\alpha)}$, where b and c are non-negative integers and $Z_{(\beta,\alpha)}$ (resp.$Z_{(\gamma,\alpha)}$) is redshift which transforms Ly_β (resp. Ly_γ) frequency into Ly_α frequency. By Rydberg's formula:

$Z_{(\beta,\alpha)} = (\nu_\beta - \nu_\alpha)/\nu_\alpha = [(1 - 1/3^2 - (1 - 1/2^2)]/(1 - 1/2^2)] \approx 5/27 \approx 0.1852 \approx 3 * 0.0617;$ (1)

$Z_{(\gamma,\alpha)} = (\nu_\gamma - \nu_\alpha)/\nu_\alpha = [(1 - 1/4^2 - (1 - 1/2^2)]/(1 - 1/2^2)] = 1/4 = 0,25 = 4 * 0.0625;$ (2)

The largest redshift (redshift of star) is generally close to product of Karlsson's constant $K = 0.061$ [4] by an integer q sum of integers 3 and 4. There is an overlap of lines, so we build a tree whose branches may merge. Certain values of q are remarkable, eg $q = 10$ corresponds to different combinations of redshifts (10 = 3+3+4 = 3+4+3 = 4+3+3), it corresponds to a large probability of an observed largest redshift.

Absorption and redshifts occur in well defined regions because source of light is small. If source of light is large (galaxy), these regions cannot be defined, Karlsson's formula does not work.

4 Conclusion.

We study by theory propagation of light emitted by an extremely hot thermal source, in very low pressure, relatively cold atomic hydrogen. We take into account formation of 2P hydrogen which catalyzes a parametric exchange of energy between beams of time-incoherent electromagnetic fields, in accordance with thermodynamics. Thus high frequencies (light) are red-shifted during propagation of electromagnetic field, without any blurring of images.

Redshifts of quasars and nearby, compact galaxies are generally close to prevalent values obtained by statistics [4, 5]. This result and empirical Karlsson's formula which gives prevalent values do not have any standard explanation. Our elementary spectroscopy explains existence of prevalent frequency shifts, provides both parameters of Karlsson's formula and explains why it does not apply to genuine galaxies.

The computation which provides Karlsson's formula provides also a simplified spectrum of "Lyman forest" of quasars because it uses only the three most intense lines of H atom.

References

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