Coherent spectroscopy in astrophysics: SNR1987A, quasars, galaxies ...

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Abstract: A lot of astronomical observations seem inexplicable, "anomalous", because, except refraction, the coherent interactions of light with matter are ignored. Understanding optical coherence seems difficult: Although Einstein published a fundamental paper on emission and absorption of light in 1917, most spectroscopists ignored the concept of coherence until Townes' maser worked. The necklace of SNR1987A, the spectroscopy of the quasars, the anomalous acceleration of the far Pioneer probes, the existence of voids in the maps of far galaxies, and so on are easily explained.

Introduction: the Strömgren's model.

Strömgren studied a system consisting of a large homogenous cloud of hydrogen under low pressure, cold at long distance, containing an extremely hot source as a O or B star. Near the star, at a temperature T higher than 5 .10^4K, hydrogen is fully ionized into protons and electrons. Further, for T close to 2.10^4K, it is in an atomic state and at long-distance, for T< 8.10^3K, in molecular form.

According to Strömgren, the equilibrium of the system results mainly from the absorption of the light of the star at the eigen frequencies of the spectrum of hydrogen or in the ionisation continuum, and the spontaneous emission of the lines. The plasma of protons and electrons, free in gas with low pressure, is transparent, so that all the frequencies of the rays emitted by the star (known here as radial rays) are transmitted without absorption until the temperature of plasma was cooled enough (by diffusion or by marginal optics effects, due, for example, to impurities), so that atoms appear.

Strömgren showed that the atoms excited by collisions or absorption of the radial rays lose spontaneously and quickly their energy by radiating the spectrum of atomic hydrogen; the collision of the obtained, not very excited atoms with protons and electrons, leads to the formation of new atoms, in a self-accelerated process. Strömgren thus showed that the zone of transition between the completely ionised (in protons and neutrons) plasma and atomic hydrogen is relatively thin. This zone is called “Strömgren shell ”, and the sphere of ionized gas, of radius R, “Strömgren Sphere”.

Whereas the radiation of a star is in general about isotropic, the matter which could be ejected, for example during explosions of a supernova is distributed more irregularly. The Strömgren theory remains qualitatively valid, but the sphere becomes one or more surfaces likely to be highlighted by echoes of photons if the emission of light by the star is variable [1,2]. Despite their distortion, we will talk about Strömgren sphere and shell.

Superradiance.

Photography of the supernova 1987A [3] shows that it is surrounded by rings. The density of gas in their vicinity is about 10^{10} m^{-3}, which gives, for a path about a hundredth of the diameter of the central ring, that is to say 0,01 light-year (approximately 10^{14}m), a column density of $10^{24}m^{-2}$, about the product of the the column density of active gas in a laser by the quality factor of its cavity. Under these conditions the spectrum of a superradiant line is reduced, as in a laser, to the Dicke spike, and because of competition of the modes, as in a laser, the number of brilliant rays is low. These rays correspond to a maximum path in the amplifying medium: here the rays are tangent to the Strömgren sphere defined by the starting of the superradiance (fig. 1, f). As the superradiant rays are intense, they strongly extract energy from excited atoms HI* (fig. 1, c), including electrons and protons in a collisional state (HII) (fig. 1, b). Consequently, the cooling of gas is more brutal than in the original model of Strömgren (fig1, a).

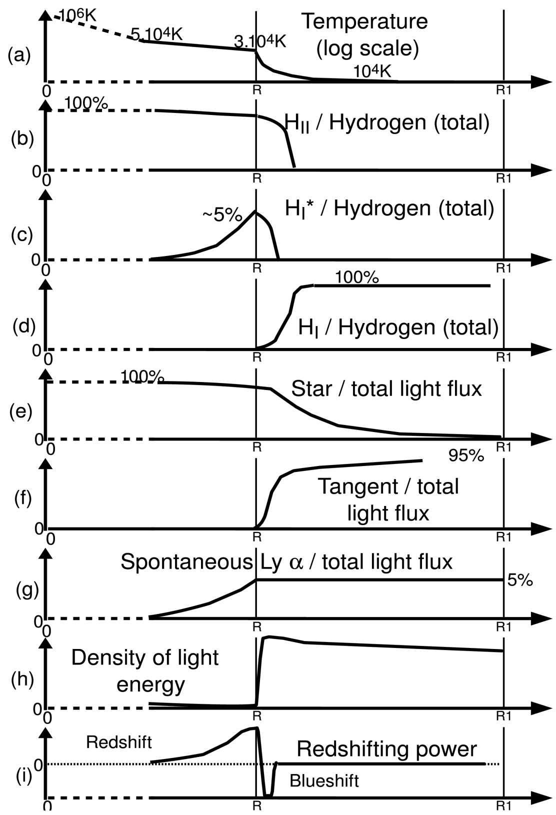

Illustration 1: Variation, of the state of gas and radiation according to the distance to star.

Let m, n, p, q four levels of increasing energy of the atom; stimulating the emission of the line of transition from p towards n depopulates p and populates n, which promotes emission from q towards p and n towards m. It is thus formed cascades which support, in particular, the emission of the whole of the transitions alpha. The nonlinearity due to the high luminance of the beams, binds the elements of the cascade into a multiphotonic, colinear emission of the set of lines. The tangentially emitted rays generate in a direction, a cylinder and are seen like a ring; this ring is discontinuous because of the competition of the modes.

As the emissions at the various frequencies of a cascade are dependent, the corresponding modes are dependent as well as allow them their various diffractions.

Induced diffusion.

The radial rays emitted by star can pump the atoms up to excited levels, including in the ionization continuum. Because of the very great brightness of these rays, these pumpings can be multiphotonic, so that, adding frequencies, absorption is not limited to the lines, but relates to all the continuous spectrum. Then, the cascades induced by the superradiances can de-energize the atoms. But the whole process involves rays of high or average energy, so that the elementary transitions are bound in a process of multiphotonic diffusion which transfers energy from the radial continuous spectrum into spectral lines of tangential rays. This process is “parametric”, i.e. it does not excite permanently the atoms, but “dresses” them, i.e. mixes transitorily the initial state of the atoms with a small proportion of excited states. The process is in conformity with the laws of thermodynamics because it transfers the energy of the radial rays whose temperature deduced from their brightness by Planck's law of is very high (10^6K) towards the less hot superradiant rays.

The temperatures of the radial and tangential rays tend to equalize; as the star is seen under a solid angle much weaker than the spots which form the rings, it is invisible.

Because of the weakening of the radial rays in the shell, the spots are more brilliant on the internal edge of the ring.

Coherent Raman Effect acting on time-Incoherent Light (CREIL).

In laser technology, one uses coherent effects (which do not modify the wave surfaces, therefore the geometry of the rays), parametric (in which the energy of matter does not change in a permanent way) to combine, to multiply, to move the frequencies of the rays, for example to obtain a blue ray starting from an infra-red laser. These interactions are intense, but it is difficult to obtain coherence because the wavelengths depend on the frequencies, besides some exceptions, like the use of two indices of refraction of a crystal. One can obtain same wave surfaces if two frequencies are rather close and lines broad enough to overlap; then the two waves interfere in a single wave having an intermediate frequency. This result is all the more easily obtained that the lines are made broader by time limit of the light pulses; under the best conditions, the obtained shift of frequency is inversely proportional to the cube of the duration of the pulses, so that easy observation with femtosecond pulses in an optic fiber, require 10^{18} times longer paths with the nanosecond pulses which form the natural light: astronomical paths are needed.

So that the effect is parametric, it is necessary to combine at least two coherent, impulsive Raman effects acting on at least two rays crossing in the active medium; there is then transfer of energy of the heat to the cold; in practice, according to Planck's the law, light is usually hot, radio waves, in particular thermal radiation, are cold. The Raman line must be close to the exiting line: frequency 1420 MHz of spins recoupling in the fundamental state is too high, whereas the similar 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 appropriate [4].

Application of CREIL to SNR1987A.

The Ly line is emitted *spontaneously* in the external area of the Strömgren sphere by the excited hydrogen atoms. The decrease of the temperature for an increase in the distance r to the star thus allows the formation of an increasing density of atoms, therefore an increase in the spontaneous emission of the line (fig. 1, g). These atoms produce also parametric transfers of the energy between the spontaneously emitted, the radial and the thermal rays, the result being a reddening of the spontaneous radiation, all the more important as the path is larger, thus the emission weaker: the Lyman line is widened, its intensity decreases when its wavelength grows. When this radiation penetrates in the Strömgren shell, there remains still a little excited hydrogen (fig. 1, c), whereas tangential flux starts to be intense (fig. 1, f). As the tangential rays move away from star much more slowly than the radial rays, the density of energy of hot rays is much larger than in the sphere. Thus, the transfer of energy towards the spontaneously emitted rays becomes positive and the line is moved overall towards the short wavelengths[5].

The lines emitted in the shell are not notably moved in spite of a long path in HI (nonexcited).

Applications to other problems of astrophysics.

Many observations of frequency shifts are now qualified "anomalous", "peculiar", "puzzling" and so on. One notices that these shifts always occur in the presence of atomic, excited hydrogen (HI*) and not in its fundamental state (HI) (fig.1,i). HI* can result from the thermal excitation of atoms in a plasma, cooling of a very hot plasma or an excitation of relatively cold atomic hydrogen by far ultra-violet.

This last case led to define several types of areas in the space containing atomic hydrogen . HI : These types depends on the luminous energy of all light beams, at and over the frequency of the Lyman α line :

- In an area "A": the absorption of a fraction of the energy at Lyman α frequency is sufficient to move by CREIL effect the spectrum of the width of the line. Thus, the energy at Lyman α frequency is renewed, the rays can pump the atoms on the levels 2p on all their path; the whole spectrum undergoes a permanent shift of frequency, so that absorptions or amplifications of any line are spread over the width of the redshift, the lines of the spectrum are weak, practically inobservable.

- In an area “B”: the intensity at the Lyman frequency, therefore the CREIL are too weak to shift the absorbed Lyman α line out of the linewidth. In the absence of notable redshift all lines of the gas are normally absorbed or amplified.

A ray crossing an area “A” undergoes a strong redshift. The application of Hubble's law, increases apparently the length of the light path. Thus areas are inflated in the direction of the observation, their stars are moved away, the area appears void.

In cold gas of an area “B”, the lines appear as usual. When the rays pass then in an area “A”, the previously absorbed lines stop redshifting, the light passes in an area “B” where the lines are again written, so that the process starts again, at intervals which depends on the distance from absorption lines to the Lyman α line. This effect is observed in the lyman forest of the quasars, where absorption due to the lines Lyman β and γ creates the periodicities of Karlsson [6].

An explanation of Hubble's law can be a CREIL effect in excited atomic hydrogen. The assumption necessary of a constant density of excited atomic hydrogen is surely not checked near the brilliant stars located in areas where there exist hydrogen clouds. Thus a representation of the sky in space, on which the lines drawn from the Earth are graduated in redshifts, is not a true chart because of the distortions due to the presence of "A" area abnormally inflated radially, so that they appear void. A periodicity of the voids was observed by W.G. Tifft [7], rediscovered and specified by B. N. R. Guthrie and W. M. Napier [8]. This periodicity corresponds to much weaker redshifts than Karlson's. It seems that its mechanism is the same, but replacing the absorption lines of atomic hydrogen by lines much closer to the Lyman α line, perhaps lines of molecular hydrogen.

Recent representations of the far galaxies, studied by space Fourier transformation [9] show that by applying Hubble law, the Earth is the center of the Universe. Indeed voids are aligned on circles whose Earth is the center. It is necessary to correct the radial scales to make disappear this illusion. It is clear to us that the voids correspond to areas rich in excited atomic hydrogen which strongly redshift the light, invalidate the Hubble law. In the directions of observation, the current representation of the galaxies appears similar to a cellulose sponge that it would be necessary to compress so that its holes disappear. A first approximation method of deflating would be to reduce some low frequency Fourier coefficients of the radial developments to get more isotropy.

The transfer of energy towards the cold, thermal rays increases their frequencies, which corresponds to an amplification observed in the vicinity of the hot stars, whose spectra are very redshifted.

The “anomalous acceleration” of Pioneer 10 and 11 probes appears where the solar wind starts to

condense into excited hydrogen atoms, beyond 5 astronomical units. In this area, the redshift of the light emitted by the Sun provides to the radio signals an energy which increases their frequency as would do it a Doppler effect. This amplification also explains why the anisotropy of the thermal radiation known as cosmological is linked to the ecliptic.
It is probable that the astonishing shifts of frequency of the emission lines of the Sun in the extreme ultra-violet result from a CREIL effect in the external dense layers of the Sun [10].

Conclusion

Except for the refraction, the coherent interactions of the light with the matter are not taken into account in astrophysics whereas the vast intergalactic gaseous mediums are favourable with these types of interactions. These well-known interactions of the specialists in the lasers give elementary interpretations, without new physics, of many effects “anomalous”, “peculiar”, “puzzling”. The current results are obviously coarse, goal a big improvement does not seem to require much work. A large problem is set by the failure of Hubble's law whose validity requires a constant density of excited atomic hydrogen, which is evidently not true everywhere.

Bibliography

1. C. L. Martin & D. Arnett, ApJ, **447**, 378 1995.
2. B. E. K. Sugerman et al. Arxiv: astro-ph/0502378.
3. http://imgsrc.hubblesite.org/hu/db/1997/03/images/a/formats/print.jpg.
4. J. Moret-Bailly, AIP Conf. Proc., **822**, 226, 2006.
5. Michael E., McCray R., Filippenko A.V., Lundqvist P. and Al, Astrophys. J., **593**, 809, 2003.
6. Karlsson K.G., Astron. Astrophys., **13**, 333, 1971.
7. W.G. Tifft, ApJ., **179**, 29, 1973.
8. B. N. R. Guthrie and W. M. Napier, MNRAS **243**, 431, 1990.
9. J. G. Hartnett & K. Hirano, Astrophys Space Sci; DOI 10.1007/s10509-008-9906-4.
10. J. Moret-Bailly, arxiv, physics, 0507141.