Coherent spectroscopy of atomic hydrogen in nebulae: I Superradiance.

Low pressure Strömgren spheres.

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May 31, 2014

Abstract

Pressure in gas lasers is low to avoid collisions which produce detrimental incoherent scatterings. Thus, the assumption made for lower pressure gas in nebulae, that interactions are strictly incoherent (photons-atoms interactions "on the spot"), must be rejected in favor of coherent interactions. Using superradiance and multiphoton interactions to study Strömgren's model explains many astronomical observations.

1 Introduction.

Strömgren [1] showed that a star immersed in a hydrogen cloud generates a transparent sphere of plasma consisting of electrons and protons. This sphere is surrounded by a spherical shell of plasma in which excited atoms radiate very intensely, producing a rapid drop in temperature. As following authors, Strömgren assumed that coherent radiation of atoms is negligible because theory of coherent light amplification due to Einstein was and is generally ignored by astrophysicists [2, 3, 4]. Some still refer an old paper in which Menzel [5] confounds radiance and irradiance. Origin of this error is probably a bad use of concept of photon [6]

Einstein's theory of coherent light-matter interactions [7] is illustrated by study of gas lasers: coherence of interactions between molecules and an electromagnetic wave requires the following conditions:

- 1 Molecules must have the same chemical composition;

- 2 They must undergo transitions between the same states;

- 3 Projection of molecular velocity on light beam, therefore Doppler shift must be equal.

- 4 Other conditions may be added, eg anisotropy of molecules.

It should especially be noted that a system consisting of two colliding molecules depends on many collision parameters, so that this system is single, therefore its radiation is incoherent. This incoherent interaction may dissipate a lot of energy because it may be quasi-resonant. Thus, as experiments, theory shows that gas lasers which require no incoherent scattering of light, can only work at low pressure.

The collisional origin of incoherent radiation is illustrated by observation of blue sky. This interaction depends on altitude, sky darkens much faster than reduction of column density of diffusing gas. Contrary, in coherent Rayleigh

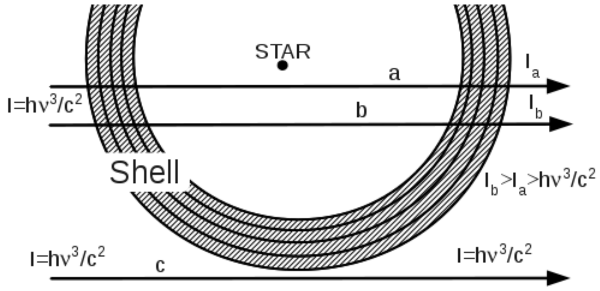

Figure 1: Amplification of absolute, unpolarized radiance of a ray crossing a Strömgren system.

scattering, that is refraction of index n, $(n-1)$ remains proportional to (low) pressure.

Most astrophysicists hypothesize intense local interactions,"on the spot", of light with hydrogen atoms of nebulae. Assuming coherence, this hypothesis becomes: Einstein coefficient $B(\nu)$ is large, excited hydrogen is a true laser medium, so that it can create intense superradiances. As interaction is coherent, light rays propagate as in a transparent medium, images remain sharp.

Our model of Strömgren's system assumes a very hot source is immersed in a *pure* hydrogen cloud under very low pressure. Superradiances and high radiance of some stars may allow multiphoton interactions.

2 Superradiance of Strömgren spheres.

Strömgren based the fast cooling of plasma in a relatively thin shell on a catastrophic non-linear process: An excited atom appearing in a region where the sphere is already considerably cooled, shines intensely, is fast de-excited, then re-excited by collisions. Through a complex process this combines a proton and an electron. Thus the density of atoms increases exponentially.

The appearance of superradiance acce.lerates radiation, increases cooling, so that the "Strömgren's shell" of excited gas becomes thinner and $B(\nu)$ larger, that is superradiance becomes more intense.

3 Geometry of superradiants rays without external source.

3.1 Theory.

Split Strömgren's shell of excited gas into infinitesimal sub-layers limited by spheres centered on star (fig. 1).

Let r distance of a polarized beam to star.

If r is small, the beam crosses each sub-layer, in an increasing incidence with r, so that path and amplification increase. Consequently, amplification of radiance of a polarized ray, from the absolute zero point radiance $h\nu^3/(2c^2)$ is an increasing function of r.

When r becomes large, beam no longer crosses all sublayers, amplification decreases, finally disappears.

Let $R = r$, where amplification is maximum. R defines radius of Strömgren's sphere.

If superradiance is intense, by competition of modes, only the strongest rays remain bright: nearly all available energy amplifies rays tangent to sphere. An observer sees only the limb of sphere.

If superradiance is very intense competition of modes tangent to sphere breaks their degeneracy, so that the limb is punctuated.

3.2 Applications to astrophysics.

Soap Bubble nebula (PN G75.51.7) shows a non punctuated limb.

The origin of certain sets of points, such as the Einstein Cross (G3237 + G0305) is generally attributed to gravitational lensing, although number of needed proper alignment of two heavy stars seems incredibly large. If the figure corresponds to a Strömgren sphere, central point corresponds to star, other dots represent the limb.

A simple test could distinguish between both interpretations: If two neighboring outer points represent modes, they have correlated phases detected by interference of images superimposed by putting a small angle bi-prism in a plane conjugate of telescope mirror.

Supernova 1987A [8] shows the three punctuated limbs of an hourglass that was observed by optical echoes before lighting the rings. The hourglass is a Strömgren shell strangled by absorption of star light by planets rotating in an equatorial plane.

4 Amplification of rays emitted by an external source.

4.1 Theory.

If the amplification by a Strömgren shell is low, the limb of sphere is no longer visible. Suppose many faint, far stars are in background. Radiances of rays emitted behind the invisible ring are increased, so that bright stars appear on a circle.

Far stars, light of which is amplified, lose their redshifts because superradiance amplifies light only at local frequencies of hydrogen atoms: they get the redshift of central star.

4.2 Applications to astrophysics.

Arp & Fulton [9] observed this centered ring of bright stars (SDSS 122524.87 09230 , fig. 2) and found close redshifts.

5 Parametric effects.

Superradiant rays from SNR 1987A appeared months after explosion of SN1987A, and, simultaneously, star disappeared. Standard theory of colliding clouds does

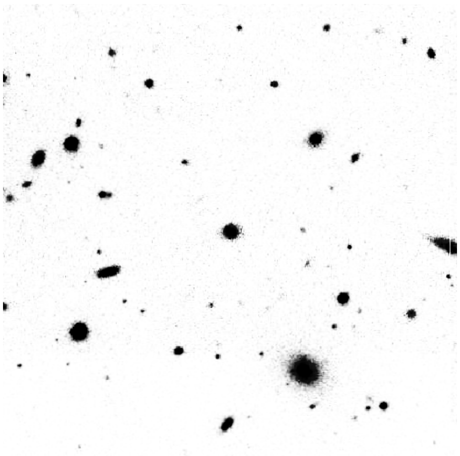

Figure 2: Amplification of faint stars by a centered invisible ring (SDSS 122524.87+092307.1.).

not explain sudden disappearance of star when rings light, nor persistence of their illumination.

As spectral radiance of the star is very high across all spectrum, a multiphoton pumping of hydrogen is possible: Whole spectrum can be absorbed by combinations of frequencies. Superradiance causes de-excitation of atoms. In fact, these processes are simultaneous, forming a parametric scattering of continuous spectrum of star into superradiant spectral lines of hydrogen. Thermodynamics authorizes it because temperature of starlight (defined by Planck's law using spectral radiance and frequency) is much larger than temperature of superradiant rays. The shell works as a laser ruby pumped by flash-tubes.

If superradiance is weak, Strömgren's shell is thick: while it absorbs the continuous, hot spectrum of central star, it amplifies rays of side modes at resonance frequencies, enabling the appearance of these close modes, so that central star gets the appearance of a nearby, compact galaxy. Structure of central star of SDSS 122524.87 09230 appears better on original photographs than on fig. 2.

6 Conclusion.

Our model takes into account only hydrogen, it must be improved by addition of other atoms. But coherence in Strömgren's systems seems already explain many observations using only laboratory verified theories. Astrophysicists should not ignore Einstein's coherence theory, widely popularized after discovery of lasers.

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