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The Lambert-Beer law

History

The Bouguer-Lambert law was formulated by Pierre Bouguer (1698 to 1758) before 1729 and describes the attenuation of the radiation intensity with the path length when passing through an absorbent substance. It is also attributed to Johann Heinrich Lambert (1728 to 1777), sometimes even referred to as Lambert's Law, although Lambert himself refers to Bouguer's work "Essai d'optique sur la gradation de la lumière" in his "Photometria" (1760) and even does quoted from it.

In 1852 August Beer (1825 to 1863) expanded the Bouguer-Lambert's law by setting the concentration of the absorbent as a function of the transmitted light. This relationship is referred to as Lambert-Beer law (more rarely Bouguer-Lambert-Beer law).

The law

The Lambert-Beer law describes the attenuation of the intensity of a radiation in relation to its initial intensity when passing through a medium with an absorbing substance depending on the concentration of the absorbing substance and the layer thickness.

Components: the radiation transport equation
https://de.wikipedia.org/wiki/Strahlungstransport
the absorption law
https://de.wikipedia.org/wiki/Absorptionsgesetz_(Physik)

A measure of the attenuation of radiation after passing through a medium is the extinction *E*. Extinction is the absorbance of the material for light of wavelength *λ*. It depends on the wavelength *λ* of the radiation and has the form

$$E_\lambda = \log_{10}\left(\frac{I_0}{I_I}\right) = \varepsilon_\lambda \cdot c \cdot d \qquad (1)$$

with

- I_0 : Intensity of the incident (irradiated) light (unit $W{\cdot}m^{-2}$)
- I_I : Intensity of the transmitted light (unit $W{\cdot}m^{-2}$)
- *c* : Mole concentration of the absorbent substance in the liquid (Unit $mol{\cdot}m^{-3}$)
- ε_λ : decadic extinction coefficient (also called spectral absorption coefficient) at the wavelength *λ*. This one is for the absorbent Substance specific value and can, among other things, from the pH or depend on the solvent. If the concentration is given in moles, ε_λ given as decadic molar extinction coefficient, for example, in the unit $m^2{\cdot}mol^{-1}$
- *d* : layer thickness of the irradiated body (unit *m*)

The transport equation of radiation

The starting point for calculating the transport of radiation is the transport equation of radiation. It links the radiation density *L* with the absorption coefficient *κ*, the scatter coefficient *σ* and the emission power *j* of the material to be passed. The absorption and scattering coefficients as well as the emission power depend, among other things, on the density and temperature of the material. In astrophysics as well as in the following equations, the radiation density L is referred to as the specific intensity I. In a simple one-dimensional, time-independent form it reads:

$$\frac{dI}{dz} = -(k + \sigma)I + j \tag{2}$$

Radiation transport (also known as radiation transfer) is the description of the propagation of radiation through a medium. Radiation transport plays an essential role in astrophysics. The theory of stellar atmospheres, the formation of star spectra or the formation of interstellar line spectra are based on radiation transport.

The process

If electromagnetic radiation spreads in a medium, regardless of whether it is in photon or field observation, it is absorbed or scattered by the medium, in particular by its atoms and ions, or it can leave the medium. These processes are called radiation transport. In such a process, the radiation of different wavelengths is influenced differently depending on the properties of the medium, in particular its atoms and ions. The aim of a radiation transport calculation is to calculate the radiation either as a whole spectrum or as individual spectral lines or the radiation field inside the medium, either to obtain a spectrum or to draw conclusions about the composition of the medium.

The absorption law

The absorption law states that in a homogeneous medium the amount dI of the photons absorbed in a layer of thickness *dr* at a distance *r* is proportional to the particle current density $I(r)$ of the radiation there:

$$\frac{dI}{dr} = -\mu \cdot I(r) \tag{3}$$

μ - absorption coefficient of the medium.

The solution of this differential equation is

$$I(r) = I(0) \cdot e^{-\mu r} \tag{4}$$

$I(0)$ is the radiation intensity at the point of radiation.
$I(r)$ is the radiation intensity at the distance r from the radiation point.

In principle:

Any spread of radiation subjects to the Lambert-Beer law and thus also to the absorption law.

Conclusions and Criticisms

The ignoring the absorption law when calculating the radiation spread in space, which can be found at various points in theoretical physics, has serious consequences for various theoretical models. These consequences are shown below using two examples.

1st example: The accelerated expansion of the universe

In 1929 the American astronomer Edwin Hubble (1889 to 1953) discovered the redshift of the radiation spectra of distant cosmic objects. He had found that the size of the redshift depends directly on the distance of the object.

In the subsequent assessment of this spectral shift into the red range and the search for the causes for it, however, the absorption law was not taken into account. The explanation of the redshift was instead made exclusively with the Doppler effect of the frequency shift of radiating objects that move away from the observer.

The Doppler effect is the time compression or expansion of a signal when the distance between transmitter and receiver changes during the duration of the signal. The effect was mathematically recorded in 1842 by the Austrian mathematician and physicist Christian Doppler (1803 to 1853).

As stated above, however, it must be assumed that any radiation spreading in a medium subjects to the absorption law. Failure to calculate radiation spreading on the basis of the absorption law leads to incorrect or unusable results.

In theoretical physics currently practiced, the loss of energy due to the absorption of radiation

$$\Delta E = h \cdot \Delta f \tag{5}$$

with h – Planck's constant of action
Δf – frequency shift equivalent to the energy loss ΔE

is not included in the calculation of the redshift on the routes through the medium. The direct dependence of the radiation intensity on the distance of the objects, which exists through the absorption law, is not taken into account. Instead, the redshift is interpreted exclusively as a Doppler effect based on the speed of movement of the radiation source, to which it is assigned that it increases with increasing distance. However, this is an unprovable, speculatively determined assumption. From this assumption the conclusion of an accelerated expansion of the universe was derived.

In fact, there is a scientifically verifiable connection between the redshift and the distance of the object, which is given by the law of absorption (4), but not between the redshift and the speed of the object with the consequence of a Doppler shift of the frequency. Hubble himself had initially opined the thesis of the Doppler effect, but rejected it as early as 1930 with reference to "other influences". Nevertheless, today's physics invariably adheres to the Doppler explanation. From the explanations above it must be assumed that the Doppler explanation of the redshift of the spectra of distant objects is wrong. This leads directly to the conclusion that there is no accelerated expansion of the universe.

2nd example: The Olbers Paradox

The so-called Olbers paradox describes a pretended contradiction between the perception of the dark night sky and the irradiation of starlight. Heinrich Olbers (1758 to 1840) looks at a large spherical shell placed around the earth with the radius r and the thickness dr. The volume of this spherical shell and, based on it, the number Z of stars contains in it is then proportional to r^2:

$$Z \sim r^2. \tag{6}$$

The intensity $\boldsymbol{I}$ of the light from each star is inversely proportional to r^2 (surface dispersion):

$$\boldsymbol{I} \sim 1/r^2. \tag{7}$$

According to Olbers, the intensity of the light from a spherical shell $\boldsymbol{I_s} = Z \cdot \boldsymbol{I}$ is proportional to r^2/r^2:

$$\boldsymbol{I_s} = Z \cdot \boldsymbol{I} \sim r^2/r^2 = 1, \tag{8}$$

so that both distance dependencies cancel each other out and the total intensity of all starlight from this spherical shell is independent of r. The total intensity of the light from the universe It is therefore proportional to the sum of the intensities of all spherical shells:

$$I_t \sim \int_0^\infty I_s \cdot dr \sim \int_0^\infty \frac{r^2}{r^2} \cdot dr \longrightarrow \infty \tag{9}$$

From this, Olbers concluded that under these conditions, after a correspondingly long time, the light of a star would have reached the earth from every direction and therefore, the sky must appear at least as bright as the star's surface. But this would contradict the observation of a dark night sky. The term Olbersian Paradox was coined in 1952 by Hermann Bondi (1919 to 2005). He was referring to this statement by Olbers.

The Olbers paradox should serve in the cosmology as an argument against infinite isotropic and homogeneous models of the universe. It has been argued that in order to avoid this paradox it must be assumed that there cannot be an infinitely extensive universe. In truth, the so-called paradox is just a calculation error that consists in the failure to observe the absorption law.

If one takes into account the energy loss of the radiation when crossing the distances in space according to the law of absorption (4), the integral expression in the integral for the total radiation intensity of all spherical shells and subsequently the solution of the integral changes as follows:

$$I_t \sim \int_0^\infty \frac{r^2}{r^2} \cdot e^{-\mu r} dr = -\frac{1}{\mu} \cdot e^{-\mu r}\Big]_0^\infty = +\frac{1}{\mu} \tag{10}$$

This means, there is no such paradox because the assumption of proportionality $\boldsymbol{I} \sim 1/r^2$ for the radiation intensity is wrong. Instead of $r^2/r^2 = 1$, the integral contains the convergent function $f(r) = e^{-\mu r}$, with which the integral from 0 to ∞ cannot approach ∞. Therefore, the dark night sky is not in contradiction to the radiation of the starlight.

See also on this topic
http://hauptplatz.unipohl.de/Wissenschaft/Assis/AssisRotverschiebung.pdf

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