Space as a Material Continuum and the Cosmological Redshift of Spectral Lines

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Abstract. The idea that space is a material continuum with standard mechanical properties such as elasticity and viscosity is applied to the propagation of shear waves (electromagnetic waves). The viscosity is shown to introduce dispersive dissipation in the governing system which affects differently the propagation of waves of different frequencies. This results in redshifting of a spectral line without the need to assume Doppler dilation of each of the frequencies constituting the packet. It is shown that the wider spectral lines experience larger redshift than the thinner one which is in very good agreement with the observation of the high-redshift objects, such as Quasi-Stellar Objects (QSOs or Quasars). The data for the spectral lines of the QSO 3C273 is analyzed in detail from the point of view of the proposed model. The conclusion is the the mere dissipation is not enough for good quantitative explanation of the redshift, and that dispersive effects should also be taken into account.

Keywords: Cosmological Redshift, metacontinuum, dissipation, dispersion, Gaussian apodization function.
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INTRODUCTION

Modern astrophysics is based on the interpretation of spectroscopy experiments in which different spectral lines are identified. A spectral line is actually a wave packet containing waves with close frequencies to the central frequency. The distribution of the power as function of the frequency is called the apodization function.

One of the most important discoveries made originally by Hubble shows that the spectral lines of distant light sources (especially the emission lines) are predominantly shifted to the lower frequencies. This effect is called the *cosmological redshift*. Doppler effect is the most natural explanation for the red or blue shifts of a monochromatic wave. In Doppler effect, shifting to the red means that the sources move away from the observer. This gave rise of the theory of inflating universe, that culminated in the so-called Big-Bang model.

Yet, until now nobody has actually measured a single frequency: the very experimental concept deals *by definition* with spectral lines because atoms never emit light as a single frequency. The distribution of energy as function of frequency (the apodization function) is usually sharply localized, but is never a Dirac delta function.

However, the theorists treated the measurements as if the apodization functions of the spectral lines are Dirac deltas. Then, the only explanation of the redshift is the "dilation" of the carrier wave. The reality, however, is rather different and the spectral lines are *always* of finite width. It is well established (see [1]) that the spectral lines of sources with larger redshifts are several times wider than the spectral lines of some

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nearby benchmark stars like the Sun, Vega and others. This suggests that the width of the spectral line can have an impact on its shifting to the red. The width of a spectral line is the result of different *thickening* mechanisms. If the cause is the Doppler shift due to the relative motion of the emitting atoms, then the distribution of the wave length around the main frequency is given by the Gaussian distribution function.

If one is to consider spectral lines of finite width, one must investigate the propagation of a wave packet, rather than the Doppler effect on a wave of a single monochromatic frequency. There can be different causes for shifting of a packet. In [2], we have showed that when dissipation is present, a wave packet of finite width behaves rather differently than a single monochromatic frequency. During a long evolution, the wave number (or frequency) of the maximal amplitude of the packet ('central wave number') can change its position making the packet appear shifted in the frequency space in comparison of its profile in the initial instant of time.

Lossless propagation of light is a useful abstraction but even the smallest amount of interstellar dust will cause dissipation and/or dispersion. A term with a small parameter in the governing equations can safely be neglected locally but it may have a cumulative effect at large distances and long times. Dispersion due to dissipation means that different wave modes are damped differently and after some time (or distance) the constitution of the wave packet can change drastically in comparison with the initial one in the context of spectroscopy measurements.

Present work deals with the effect of dissipation on the evolution of wave packets.

MATERIAL SPACE AS A VISCOELASTIC CONTINUUM

In recent works [3, 4, 5], the present author proposed that space is an absolute material continuum (called the *metacontinumm*). He showed that Maxwell equations and the Lorentz force can be derived as corollaries of the governing equation of an elastic continuum.

In the limit of small displacements/velocities of the points of the metacontinuum, we can assume the Kelvin-Voigt model of elastic medium, which stipulates that the stress tensor is a linear combination of the strain tensor and the rate of deformation tensor. For this kind of viscoelastic constitutive relation, the so-called Navier equations (see, e.g., [6, p.117] for the displacement vector $\boldsymbol{u}(\boldsymbol{x},t)$ can be generalized to incorporate the viscosity, namely

$$\mu\frac{\partial^2\boldsymbol{u}}{\partial t^2} = (\lambda+\eta)\nabla(\nabla\cdot\boldsymbol{u}) + \eta\nabla^2\boldsymbol{u} + (\zeta+\mu\delta)\nabla(\nabla\cdot\boldsymbol{v}) + \mu\delta\nabla^2\boldsymbol{v}$$
$$= -\nabla\phi - \eta\nabla\times\nabla\times\boldsymbol{u} - \mu\delta\nabla\times\nabla\times\frac{\partial\boldsymbol{u}}{\partial t}, \quad (1)$$

where λ and η are the Lamé coefficients (see, e.g., [7, 6]). Respectively, ζ is the bulk coefficient of viscosity. The shear viscosity coefficient is written as $\mu\delta$, where δ is the kinematic shear viscosity coefficient, and μ is the density of the metacontinuum identified as magnetic permeability in [3, 4, 5] . Thus we avoid the abuse of the notation μ usually used for the dynamic shear coefficient of viscosity. The notation ϕ stands for the pressure that must arise in a continuum to enforce the incompressibility condition. Note that the second line of equation (1) is valid for incompressible metacontinuum for which $\nabla \cdot \boldsymbol{v} = 0$ and $\nabla \cdot \boldsymbol{u} = const$.

One can use 'nabla' operator ∇ because the linearized equations are the same as if they are written in the current description. For a judicious distinction between the referential and current descriptions of the metacontinuum see [5].

Since the light is a shear wave, we can consider the case when we have only one component $u(x,t) = u_y(x,t)$ of the displacement vector (say y or z- transverse component) which is a function of the longitudinal coordinate x and time t. For propagation from distant sources, the fact that the one is faced actually with spherical waves can be easily accounted for by a scaling factor proportional to the inverse distance to the emitting source. Then equations (1) reduce to the following scalar equation for $u(x,t)$:

$$\frac{\partial^2 u}{\partial t^2} - \delta \frac{\partial}{\partial t} \frac{\partial^2 u}{\partial x^2} = c^2 \frac{\partial^2 u}{\partial x^2}, \tag{2}$$

where $c^2 = \eta \mu^{-1}$ is the speed of the shear waves (called 'light' when they are in the visible spectrum), and δ is the above introduced kinematic coefficient of shear viscosity.

The last equation is often called Jeffrey's equation. Equation (2) was derived by Alfven [8] for the magnetic field in the interstellar plasma when a rarefied gas of moving electrons was stipulated to exist in space. This means that even if one can neglect the viscosity of the metacontinuum, a dissipation can be present in the interstellar space because of the small impurities.

PROPAGATION OF WAVE PACKETS IN PRESENCE OF DISSIPATION

The viscosity of the metacontinuum (parameterized by δ) introduces a dissipation of dispersive type. It does not just bring about the decay of a wave in time or space (attenuation), but also acts to change the dispersion relation and causes the original wave packet to disperse and eventually dissipate (disappear as an entity).

Following [2], we consider here the propagation of harmonic waves $e^{ikx+i\hat{\omega}t}$. We will focus on the case when a wave of given spatial wave number k is excited in the initial moment of time, and then left to evolve in accordance with equation (2). The case when the wave is excited at one of the spatial boundaries as function of time can be treated in a similar fashion and is shown in the end of this section. The harmonic waves satisfy the following dispersion relation

$$-\hat{\omega}^2 + i\delta\hat{\omega}k^2 = -c^2k^2. \tag{3}$$

For a given real wave number k, the complex frequency $\hat{\omega}$ is given by

$$\hat{\omega} = \omega + is, \qquad s = \frac{\delta k^2}{2}, \quad \omega = \sqrt{c^2k^2 - \frac{\delta^2k^4}{4}}, \tag{4}$$

where ω is the actual (real-valued) frequency of the wave, and s gives the decay of the wave with time. It is interesting to note that the traveling waves exist only for $k < 2c/\delta$, which condition is easily satisfied since the dissipation is supposed to be very small, while the speed of light is a large parameter.

As already mentioned, the Doppler widening of the spectral lines usually results in a Gaussian apodization function, described by

$$E(k) = e^{-\frac{\beta}{2}(k/\tilde{k}-1)^2}, \tag{5}$$

where $\tilde{k}$ is the central wave number of the packet.

A larger β means a sharper spectral line in terms of k. Let $k = q$ be the wave number k for which the amplitude is exactly $e^{-\pi/4}$ times smaller than the maximal amplitude. Then

$$d = \sqrt{\frac{\pi}{2\beta}} \quad \text{or} \quad \beta = \frac{\pi}{2d^2}, \quad \text{where} \quad d = \frac{q-\tilde{k}}{\tilde{k}}, \tag{6}$$

and $d\tilde{k}$ gives the effective half-width of the packet.

The actual wave as function of the spatial variable in the initial moment of time is given by the following Fourier integral

$$u_0(x) = \int_{-\infty}^{\infty} e^{-\frac{\beta}{2}(k/\tilde{k}-1)^2} e^{ikx} \mathrm{d}k. \tag{7}$$

Then, the evolution of Fourier density of the wave packet according to equation (2) is given by the following simple relation

$$e^{i\omega t+ikx} e^{-\frac{1}{2}\beta(k-\tilde{k})^2} e^{-\frac{1}{2}\delta k^2 t}, \tag{8}$$

for the amplitude of a component with specific wave number k. The first term in equation (8) corresponds to a the traveling wave with phase speed

$$\frac{\omega}{k} = c\sqrt{1-\frac{\delta^2 k^2}{4c^2}}, \tag{9}$$

which means that the shorter waves travel slower than the longer waves, and are damped faster. After a time $t = T$ has passed, the amplitude in Fourier space of the wave of wave number k (the spectrum) is given by

$$E^T(k) = e^{-\frac{1}{2}\beta(k-\tilde{k})^2} e^{-\frac{1}{2}\delta k^2 T}. \tag{10}$$

SHIFTING OF CENTRAL WAVE NUMBER OF A LOCALIZED PACKET

According to equation (10), after time $t = T$ has passed, the maximum of $E^T(k)$ is not longer at $k = \tilde{k}$. Its position is defined by

$$\frac{dE^T(k)}{dk} = \left[-\frac{\beta}{\tilde{k}}\left(\frac{k}{\tilde{k}}-1\right) - \delta T k\right] e^{-\frac{\beta}{2}(k/\tilde{k}-1)^2} e^{-\frac{\delta k^2}{2}T} = 0,$$

which is a linear equation in k and its root is

$$\bar{k} = \frac{\beta \tilde{k}}{\beta + \delta \tilde{k}^2 T} = \frac{\tilde{k}}{1 + \delta \beta^{-1} \tilde{k}^2 T}, \tag{11}$$

For the shift of the central wavenumber one gets

$$\Delta k \stackrel{\text{def}}{=} \bar{k} - \tilde{k} = -\frac{\tilde{k} \delta \beta^{-1} \tilde{k}^2 T}{1 + \delta \beta^{-1} \tilde{k}^2 T} \quad \text{or} \quad \frac{\Delta k}{\tilde{k}} = -\frac{\delta \beta^{-1} \tilde{k}^2 T}{1 + \delta \beta^{-1} \tilde{k}^2 T} \tag{12}$$

which means that at time T, the new central wave number $\bar{k}$ of a packet is shifted to the smaller wavenumbers.

In terms of the wavelength we have

$$\lambda = \frac{2\pi}{k}, \quad k = \frac{2c\pi}{\lambda}, \quad \Delta k = -2c\pi \frac{\Delta \lambda}{\bar{\lambda} \tilde{\lambda}} \quad \Rightarrow \quad \frac{\Delta k}{\bar{k}} = -\frac{\Delta \lambda}{\tilde{\lambda}}.$$

Then equation (12) can be recast as the following "Time-Hubble Law"

$$\frac{\Delta \lambda}{\tilde{\lambda}} = \delta \beta^{-1} \frac{4c^2 \pi^2}{\tilde{\lambda}^2} T \stackrel{\text{def}}{=} z, \quad \text{where} \quad \Delta \lambda = \lambda - \tilde{\lambda}. \tag{13}$$

The central wave length of the packet is shifted to longer waves (*redshifted*).

Equation (9) gives that $c_g = \omega(\tilde{k})/\tilde{k}$. Then, the propagation time is $T \approx c_g^{-1} L$, where L is the length traveled by the packet. Thus,

$$\frac{\Delta \lambda}{\tilde{\lambda}} = \frac{4c^2 \pi^2 \delta}{c_g \beta \tilde{\lambda}^2} L = HL, \quad \text{where} \quad H = \frac{4c^2 \pi^2 \delta}{\beta c_g \tilde{\lambda}^2}, \tag{14}$$

and can be called "Distance-Hubble law."

The most important difference between the evolution of a wave packet (spectral line) and the redshift of a single monochromatic wave, is the fact that the redshift depends not merely on the distance travelled (time in transit), but also on the width of the initial spectral line according to equation (13). It depends also on the central wave length (central wave number) of the packet. This calls for reinterpretation of the spectral-lines observations, and reassessing the the actual redshifts.

In the view of this theory, the distance is not in one-to-one correspondence with the redshift, because of the dependence on the width of the packet, even if we choose the dissipation coefficient δ to be a universal constant. This means that two sources that are in a close proximity in cosmological sense, can have different redshifts depending on the parameter β for the spectral line under consideration. A more active (hotter) source (smaller β) will appear to the observer as much more redshifted than a quieter (cooler) source (larger β). This effect is observed experimentally, and is recently the point of a raging controversy (see, among others, [9, 10] and the literature cited therein).

Note that the Hubble constant is also a function of the central wave number $\tilde{k}$ through the possible dependence $\beta = \beta(\tilde{k})$. The latter means that parameter β can have a different value depending on the central wave number despite that in absolute units two widths of different spectral lines may appear equal. Yet, this is a smaller effect, and should be taken into account only if the respective evidence is present.

Finally, we mention that equation (10) can be rewritten as follows

$$E^T(k) = E^T_{max} e^{-\frac{(\beta+\delta T)}{2}(k/\bar{k}-1)^2}, \quad E^T_{max} = e^{-\frac{\delta T \bar{k}^2}{2(1+\delta\beta^{-1}\bar{k}^2 T)}}, \tag{15}$$

which is once again a Gaussian distribution with somewhat larger effective β, namely

$$\beta^T = \beta + \delta T = \beta(1+\delta\beta^{-1}T) = \beta(1+z), \tag{16}$$

where z is the redshift.

Before proceeding with the application to Cosmology, we reformulate the above theory for the case of spatial propagation. Consider a wave that is excited at distance L from the observer, i.e. when the wave is created from a boundary condition at $x = 0$ and the observer is situated at $x = L$. Once again we are interested in superposition of harmonic waves of type $e^{i\omega t}$ with amplitudes with a Gaussian apodization function

$$E(\omega) = e^{-\frac{\beta}{2}(\omega/\tilde{\omega}-1)^2}. \tag{17}$$

Note that in [2] a factor c^2 was introduced which results in insignificant differences of the actual outlook of the formulas. We can rewrite the dispersion equation as

$$k = \frac{\omega}{\sqrt{c^2 + i\delta\omega}}. \tag{18}$$

The sign is selected to have waves that decay at $x \to \infty$. The dispersion relation can be simplified if we also assume $\delta\omega \ll c^2$ and then

$$\Im[k] \approx -\frac{1}{2}\frac{\delta\omega^2}{c^3}, \quad \Re[k] = \frac{\omega}{c}\left[1 - \frac{3}{8}\frac{\delta^2\omega^2}{c^4}\right]. \tag{19}$$

A packet produced at $x = 0$ with a Gaussian distribution will arrive at $x = L$ as follows

$$e^{-\frac{1}{2}\beta\tilde{\omega}^{-2}(\omega/\tilde{\omega}-1)^2} e^{-\frac{1}{2}(\delta\omega^2)c^{-3}L} = e^{-\delta\bar{\omega}\tilde{\omega}c^{-3}L} e^{-\frac{1}{2}\bar{\beta}(\omega/\bar{\omega}-1)^2}, \tag{20}$$

which gives for a new central frequency of the packet:

$$\bar{\omega} = \frac{\tilde{\omega}}{1+\delta\beta^{-1}c^{-3}\tilde{\omega}^2 L}, \quad \Rightarrow \quad \frac{\Delta\omega}{\bar{\omega}} = \frac{\tilde{\omega}-\bar{\omega}}{\bar{\omega}} = \frac{\delta\tilde{\omega}^2 L}{\beta c^3} = HL = z. \tag{21}$$

Respectively, the inverse thickness of the spectral line at the site of measurement is

$$\bar{\beta} = \beta\left(1 + \frac{\delta\tilde{\omega}^2 L}{c^3}\right) = \beta(1+z). \tag{22}$$

Now the Distance-Hubble law is linear with Hubble constant $H = \delta\beta^{-1}c^{-3}\tilde{\omega}^2$. The most important feature of the above expression is the explicit dependence on the central frequency.

Apart from the shifting of the central frequency to the red, the term $e^{-\delta\bar{\omega}\bar{\omega}c^{-3}L}$ in equation (20) gives that the amplitude of the wave will also diminish, i.e., there is an attenuation that depends on the frequency. The presence of an attenuation makes the stars and galaxies appear dimmer and thus the estimated distance to be exaggerated. The attenuation can provide an alternative approach to the apparent missing mass in the Universe, without assuming the presence of dark matter (see also [4]).

Since the attenuation is frequency dependent, it will result into a different distribution of the intensity of the different colors (the so-called continuum of the spectrum). This means that the spectrum at the site of the light source will be different from the observed if the above described attenuation is taken into account.

APPLICATION TO COSMOLOGY

Many stars and galaxies emit visible electromagnetic waves predominantly in the hydrogen spectrum, called H_α, H_β, and H_γ lines (or Balmer series), because the abundance of hydrogen in the universe. Only first three Balmer lines are in the visible spectrum. Many high-temperature objects emit also in so-called Lyman series in the ultraviolet spectrum. Usually, the L_α line is the only ultraviolet hydrogen spectral line that is reliably measured. When the redshift is very large, the original L_α line can even appear in the visible spectrum.

The hydrogen lines can be broadened by the Doppler effect connected with the thermal motion of the atoms during the emission of the photons. According to the approach proposed in the present work, the magnitude of the redshift depends on the effective thickness of the respective line. For this reason, we outline in this section the way the experimental data for the spectral lines has to be treated in order to estimate the thickness of the line at the source.

Characterization of a Spectral Line

In most of the cases, the spectral line is presented as an experimentally measured apodization function of the wave length λ. After fitting, in the least-square sense, a Gaussian function, one can have the following reasonable approximation for the spectral line:

$$e^{-\frac{\beta}{2}(\lambda/\tilde{\lambda}-1)^2}, \tag{23}$$

where $\tilde{\lambda}$ is called 'central wave length' of the wave packet that represents the particular spectral line. If the process of widening of the lines is similar, the constant β is expected to be almost the same for that set of spectral lines. For instance, it is quite reasonable to expect that all of the hydrogen lines will have similar β's, because of the Doppler broadening due to the mean-square velocity of the hydrogen atoms. It is interesting to investigate this conjecture on larger selection of stars and QSO's, but it goes beyond the scope of the present paper.

The Gaussian apodization function of λ, equation (23) does not necessarily entail that the distribution for $k = 2\pi/\lambda$ will also be Gaussian, but for $|\lambda - \tilde{\lambda}| \ll \tilde{\lambda}$ both representations of a spectral line are virtually Gaussian. Thus, for $\tilde{\lambda} \ll 1$ ($\tilde{k} \gg 1$), and for very narrow packet $\beta \gg 1$, the Gaussian shape, equation (5), is virtually equivalent to equation (23), namely for the spectral line under consideration

$$\frac{\beta}{2}\left(\frac{\lambda}{\tilde{\lambda}}-1\right)^2 = \frac{\beta}{2}\left(\frac{\tilde{\omega}}{\omega}-1\right)^2 = \frac{\beta}{2}\left(\frac{\omega}{\tilde{\omega}}-1\right)^2 + \beta\cdot O\left(\frac{\omega}{\tilde{\omega}}-1\right)^3$$

when $(\omega/\tilde{\omega}-1) \ll 1$. This means that if we consider the characterization of a spectral line as

$$e^{-\frac{\beta}{2}(\omega/\tilde{\omega}-1)^2}, \tag{24}$$

then β is the same number as in equation (23)

The above formulas give us the opportunity to either fit a best approximation to the experimental data (as measured in terms of wave length λ) or to first render the spectrum as a function of the frequency and then find the best-fit Gaussian approximation. Up to terms of third asymptotic order of smallness, the two approaches give the same results.

The dependence of the redshift on the central frequency of the spectral line has another important impact on the interpretation of the observations. The superposition of different spectral lines emitted by a source give the background (called 'continuum') against which the most prominent lines can be discerned. Very often, two central frequencies of two different lines can appear very enough in the measurements. In such a case, one tries to find the possible physical mechanism responsible for the unusually looking line. The hydrogen lines (Balmer or Lyman or even Paschen lines) are supposed to always be present because the fuel of most of the stars is predominantly hydrogen. If the redshift can be a function of the width of the spectral line, then upon arrival at the site of the detecting device, different lines can appear in a juxtaposition, while they are, actually, quite different at the source. This is illustrated in Figure 1. One of the lines is the H_β

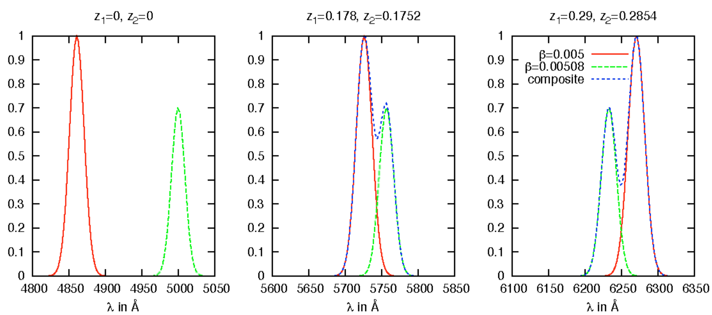

Figure 1. The comparison of two different emitted lines with their position at arrival

line which has been used by Schmidt for defining the redshift of 3C273. The other is a hypothetical line with larger initial central wavelength but with smaller initial width.

In the end of the section, we reiterate that the dependence of the redshift on the width of the spectral line, allows to have objects of different redshift situated in the vicinity of each other. The observational evidence for this is discussed in [9].

Featuring Example: QSO 3C273

The Quasi-Stellar Object (QSO or 'Quasar') #273 (called 3C273 for brevity) from the third Cambridge catalog was one of the first QSOs to be thoroughly investigated because it is the brightest QSO ever observed (see [1]). In fact, the peculiar positions of the brightest visible spectral lines of 3C273 were identified by M. Schmidt [11] as the hydrogen Balmer lines shifted with $z \approx 0.158$ and the first ever object with significant redsifit was discovered. With the advance of the spectrophotometers, much fainter objects with redshifts as large as $z > 5$ have recently been discovered. Yet, the luminosity of 3C237 and the intensity of its spectral lines makes it the most desirable benchmark for any new redshift theory. We have been able to find only three independent spectroscopy measurements of the visible and near infrared spectrum of 3C273 [12, 13, 14], and one detailed study of the ultraviolet spectrum [15]. Verifying the finding about the spectral lines is of importance of our work, because in the present approach we can make the subtle distinction between the redshifts of different spectral lines as functions of the width of the line.

Figure 2 shows the comparison between the three known experimental spectroscopic studies of 3C273. In order to make the comparison presented in Figure 2, we digitalized the respective graphs from the source papers. Despite the seeming disagreement (most

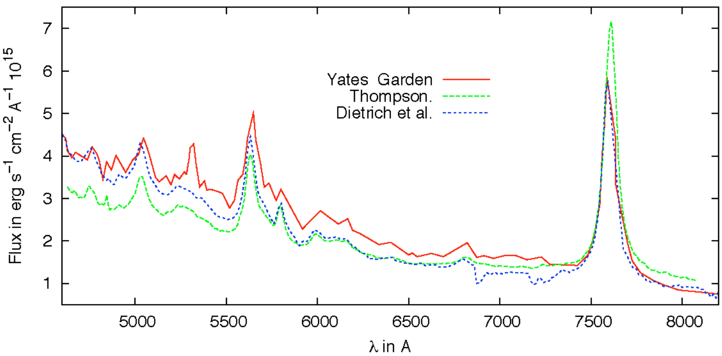

Figure 2. Comparison of three different experimental investigations of the line spectra of 3C273

probably due to some renormalizations), an important conclusion that can be reached from Figure 2, namely that the spectral lines are almost in the same positions (the redshifts of the same lines are the same) and that their widths are in good agreement with each other across the set of independent experiments. This means that the results are reliable enough for the purpose of putting the present theory to the test.

The result in Figure 2 give the first and foremost qualitative confirmation of the proposed here model: the spectral lines of the highly redshifted object, 3C273, are wider than the spectral lines of the ordinary stars. According to [1, Pg.67] this fact holds true for all observed QSOs.

Best-Fits for the major Spectral Lines of 3C273. Limitations of the Model with Dissipation only

Since the width of a spectral line plays a major role in the above presented model of the cosmological redshift, it is important to fit Gaussian function to the available major spectral lines of a QSO, in order to get an estimate for the parameter β. Figure 3 presents the best-fits of type of equation (24) for five major spectral lines of 3C273 which are believed to be (from left to right in the figure): Paschen P_α, Balmer H_α, H_β, H_γ, and Lyman L_α lines in the spectrum of 3C273. It is seen that Gaussian functions fits

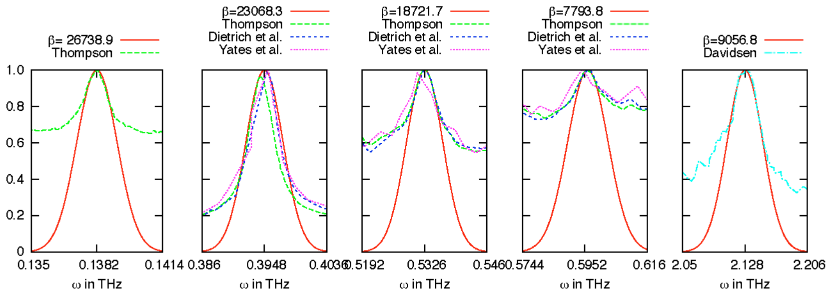

Figure 3. The best fits to the spectral lines as functions of the frequency $\exp[-\frac{\beta}{2}(\omega-\tilde{\omega})^2]$. Left to right are the supposed P_α, H_α, H_β, H_γ, and L_α lines

reasonably well the measurements, but the three experimental results do not agree very well between each other. The disagreement is not consistent, and different combinations of measurements agree for different spectral lines.

Here it should be noted that the results presented in Figure 3 are obtained after the graphs from the respective articles are digitalized. The eventual distortion of the scales during the reproduction of the graphs in the original appears, or during the digitalizing process, could also be a cause for disagreement.

The differences in estimating β from wave-length data and from frequency data show that the procedure is very sensitive. This calls for more experimental data with denser set of frequencies. Yet, the best-fit approximations clearly demonstrate that coefficient β is roughly of the same order for the different spectral line under consideration. This means that the redshift is proportional to the square of the of the original central frequency as shown in equation (21). This prediction is not supported by the observation, since all of the hydrogen lines appear with virtually the same redshift.

There are two possible explanation for this disagreement. The first is that what we identify as redshifted Balmer lines are actually some other lines that are in quite different positions originally, and only appear as a set of equally shifted Balmer lines. This explanation does not seem very likely, because involves events with very low probability: to have some disorganized array of spectral lines, each shifted with very special amount to appear as Balmer lines. The second explanation is that the model that involves solely dissipation cannot quantitatively predict the redshift. This means that along with the dissipation, another mechanism is at play in the shifting of the central frequency of a packet. This additional mechanism can be dispersion.

The Role of Dispersion

As it can be seen from equation (19), the dissipation has a dispersive effect because it changes the dependence of the spatial wave number on the frequency, i.e., the phase speed of waves with different frequencies is different. Unfortunately the dissipative dispersion does not change the redshift, but rather acts to simply increase the width of the spectral line. The only way to have a sufficiently strong dispersion is to consider dispersive terms in the equation, i.e., instead of the original equation, one has to consider the following, more general, equation

$$u_{tt} = c^2 u_{xx} - u_{txx} + \chi_1 u_{ttxx} - \chi_2 u_{xxxx}, \tag{25}$$

where $\chi_1, \chi_2 > 0$ are the two dispersion coefficients. The fourth-order spatial derivative was shown (see [5, 16] for the details) to be important for eliminating singularities when considering localized torsional waves (identified as the charges) in metacontinuum. The mixed fourth derivative is called rotational inertia and it stems from the same micro-polar models, so-called Cosserat continua, (see [17]) as the spatial fourth derivatives. The dispersion relation for he model described by equation (25) reads

$$c^2 k^2 + i\delta\omega k^2 - \chi_1 \omega^2 k^2 + \chi_2 k^4 - \omega^2 = 0. \tag{26}$$

The last equation presents a radically different relationship between ω and k which has to be investigated in depth in order to understand its quantitative effects on the redshift. This will be done in a consecutive work.

CONCLUSIONS

The present paper is devoted to the possible cosmological application of a model of space as a dissipative material continuum. The spectral lines in the spectra of distant sources (Quasi-Stellar Objects or QSOs) are considered as wave packets, and the evolution of the packets under the influence of dissipation is investigated. Only wave packets that are well-approximated by Gaussian apodization function are considered. It is shown that the redshift is given by a Hubble-type law in which the change of the frequency/wave number is proportional to the distance traveled by the wave (or the time in transit).

Physically speaking, the effect is related to the fact that dissipation damps the higher frequencies stronger and causes the maximal frequency of the packet to shift to lower frequencies (longer wave lengths). The redshifting is a property of the packet. No actual *dilation* of the different harmonics is needed as in Doppler effect. This means that even a slightest dissipation in the interstellar medium will result in a persistent (cosmological) redshift of the light propagating throughout the Universe.

The important trait of the new model is that the Hubble constant depends on the initial width of the spectral line investigated. Then, two sources, that are in a close proximity in cosmological sense, can have different redshifts depending on the width, d, of the spectral line (as represented by the parameter $\beta \propto d^{-2}$). A more active (hotter) source (smaller β or wider spectral line) will appear to the observer as much more redshifted than a more quieter (cooler) source (larger β or thinner spectral line). This conclusion is in very good qualitative agreement with the actual experimental observations.

The examination, from the point of view of the proposed theory of, the experimental data on hydrogen emission lines in the QSO 3C273, shows that dissipation alone cannot provide a satisfactory quantitative prediction and some higher-order dispersion should be taken into account in order to improve the proposed model.

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REFERENCES

1. G. Burbidge, and M. Burbidge, *Quasi-Stellar Objects*, W.H. Freedman, San Francisco, 1967.
2. C. I. Christov, *Wave Motion* **45**, 154–161 (2008).
3. C. I. Christov, *Foundations of Physics* **36**, 1701–1717 (2006).
4. C. I. Christov, *Math. Comput. Simul.* **74**, 93–103 (2007).
5. C. I. Christov, *http://arxiv.org/pdf/0804.4253* (2008).
6. L. A. Segel, *Mathematics Applied to Continuum Mechanics*, Dover, New York, 1987.
7. L. D. Landau, and M. Lifschitz, *The Classical Theory of Fields*, Reed Educational and Professional Publishing, New York, 2000, 4 edn.
8. H. Alfvén, *Cosmic Plasma*, Holland, 1981.
9. H. Arp, *Seeing Red: Redshifts, Cosmology and Academic Science*, Apeiron, 1998.
10. G. Burbidge, *Nature* **282**, 451 – 455 (1979).
11. M. Schmidt, *Nature* **197**, 1040 (1963).
12. M. Dietrich, S. J. Wagner, T.-L. Courvoisier, H. Bock, and P. North, *Astron. Astrophys.* **351**, 31–42 (1999).
13. van den Berk, and et al., *Astrophys. J.* **122**, 549– (2001).
14. M. Yates, and R. Garden, *Mon. Not. R. ast. Soc.* **241**, 167–194 (1989).
15. A. Davidsen, G. F. Hartig, and W. Fastie, *Nature* **269**, 302–206 (1977).
16. C. I. Christov, “Dynamics of Patterns on Elastic Hypersurfaces. Part I. Shear Waves in the Middle Surface,” in *“ISIS International Symposium on Interdisciplinary Science” Proceedings, Natchitoches, October 6-8, 2004*, AIP Conference Proceedings 755, Washington D.C., 2005, pp. 46–52.
17. M. Ciarletta, and D. Iesan, *Non-classical Elastic Solids*, CRC Press, 1993.