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Note on Redshift and the Principle of Conservation of Energy

Francois Danis[1]

[1] Independent Researcher, Diss, UK

Correspondence: Francois Danis, Independent Researcher, Diss, UK. E-mail: francois.jp.danis@gmail.com

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Abstract

Redshift has always been associated with the Doppler effect, but sound waves and electromagnetic waves are different; if the association is wrong, the recessional speeds observed in the universe could be wrong.

When redshift is observed, the energy of the photon is dropping; that change of energy cannot be explained by the Doppler effect. After a short history of the link Redshift-Doppler, the Ives-Stilwell experiment will be reinterpreted as a proof of special relativity, not a proof of the Doppler effect. A new proposal is presented: because of the acceleration of the expansion of the universe, there must be a potential field to explain that acceleration. A change of potential along that field could explain the change of energy corresponding to the redshift.

Keywords: relativistic Doppler effect, Transverse Doppler Effect, conservation of energy, Hubble tension, fifth force, dark energy

1. Introduction

The energy of a photon is given by Planck's relation and is dependent on the frequency. As the frequency drops when redshift is observed, the energy of the photon drops. In one of Hubble's books (1936), it is stated that: "Any plausible interpretation of redshifts must account for the loss of energy". That loss of energy is indeed confusing. In order to bypass this problem, Doppler redshift and cosmological redshift are currently regarded as separate mechanisms. The principle of conservation of energy in the expanding universe has been questioned (Peebles, 1993; Macleod, 2005; Davis, 2010). To restore the conservation of energy with cosmological redshift, the latest study involves an unknown mechanism (Ortiz, 2024).

This present work questions the interpretation of redshift as a Doppler effect and will present a proposal which explains the change of energy while maintaining the principle of conservation of energy. If the link Redshift–Doppler is wrong and the new proposal accepted, most recessional speeds in the universe will have to be revised.

1.1 Differences Between Electromagnetic and Acoustic Waves

Special relativity and corresponding observations are showing us that, whatever is its frequency, a photon and its attached wave are always traveling at the speed of light (Einstein 1905, Michelson 1887, De Sitter 1913). If an observer moves towards a source, the speed of light stays constant but the speed of an acoustic wave would change. That is one important difference.

The photon being massless shouldn't have any kinetic energy, its energy is solely in the wave with the famous equation: $E = hf$. E being the energy of the photon, f its frequency and h the Planck constant. If the frequency changes, the energy changes as well. Although the dissipation of the energy of an acoustic wave is well understood, the Doppler effect doesn't deal with the energy, only the frequency, so it cannot explain the change of energy of a photon. The link frequency – energy is another difference.

1.2 Redshift History

Redshift (and blueshift) of stars have been predicted by Fizeau in (1848) then observed as early as 1868 (Huggins). The explanation of the redshift with the Doppler effect was in place before science knew about the existence of a photon and Planck's relation. Redshift is often described as a relativistic Doppler effect. We have just seen two differences between an electromagnetic wave and an acoustic wave. Those differences should question the validity of using Doppler equations to reach the recessional speed of the source of light.

2. Relativistic Doppler Effect

A redshift is characterized by z defined as z = v/c and femit/fobs = 1+z. There is a problem when femit/fobs >2 as it would mean that v is greater than the speed of light.

Relativistic Doppler effect limits v under the speed of light. Time dilation is considered and any Doppler effect is multiplied by Lorentz factor. It works well and served its purpose, but if you scrutinize it, Lorentz factor seems to be an ad hoc adjustment.

With special relativity there is a length contraction. This length contraction means that a wavelength should be contracted, resulting in a shorter wavelength. Then there is time dilation; the frequency should be lower. Those two effects are opposites and by the same factor (Lorentz factor) the result should be nil. Why the length contraction is not considered with relativistic Doppler effect has never been justified.

3. Discussion About Ives–Stilwell Experiment

A Doppler effect with light seems to have been observed with the Ives–Stilwell experiment.

The Doppler effect is well understood when source and observer approach or recede from each other (radial or line-of-sight direction, corresponding to a radial Doppler effect). Dr J. Stark convinced Einstein (1907a) of the existence of an effect that later became known as Transverse Doppler Effect (TDE) corresponding to an observation perpendicular to the direction of the motion. TDE became one of the predictions of special relativity.

The first experiment to observe TDE is Ives–Stilwell experiment (1938). A schematic of the experiment is presented Figure 1. Some ions (H2+ and H3+) are traveling through an area visible by a detector. A molecule is moving at high speed compared to the detector and the observation of the frequency of the emission of light of that molecule is changing with its speed. The emission is in all directions; the concave mirror in Figure 1 reflects some of the backwards emission while other photons go directly to the detection system.

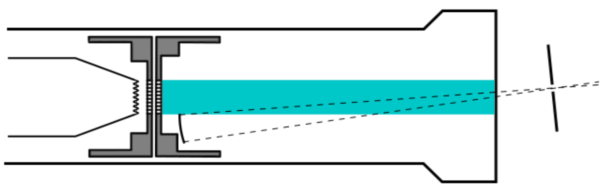

Figure 1. Schematic of Ives–Stilwell experiment

A molecular beam of H2+ and H3+ is accelerated through a multiple gap electrode (in grey), the potential varying from 7,859 to 20,755V. Light due to H2+ and H3+ is observed by a detector situated to the right of the figure. Credit: Prokaryotic Caspase Homolog via Wikipedia (CC BY-SA 4.0).

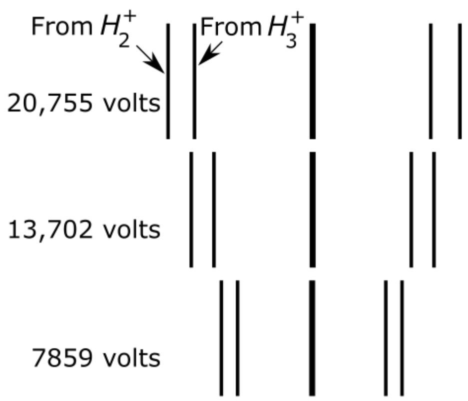

Figure 2. Observations from Ives-Stilwell experiment

Credit: Prokaryotic Caspase Homolog (CC BY-SA 4.0).

Ives and Stilwell observed 4 lines as presented in Figure 2. As I understand it, the additional central line would correspond to the frequency of a photon emitted by a molecule at rest. The four other lines correspond to the emission either forwards or backwards. Those observations indeed show a shift in frequency.

The prediction is $1+z = \gamma$ (formula found in their preliminary result). That is the prediction of TDE and the shift of frequency fits perfectly. γ is the Lorentz factor which is part of special relativity. Because there is no v/c directly involved, this is not strictly a Doppler effect but an effect of special relativity similar to a Doppler effect. So, the test shows that special relativity is correct which explains the redshift/blueshift observed.

Here are related questions which are better discussed in this section. First, as stated above, TDE would not be a real Doppler effect; is that correct? Second, I cannot understand how TDE is observed without the radial Doppler effect; the experiment would show that there is no radial Doppler effect. Is that second point correct? The lack of radial Doppler effect could then be explained by the last paragraph of section 2. Is that correct?

The Bełopolsky experiment claims to show a radial Doppler effect (1901). The description of the apparatus is not clear enough: how did Bełopolsky keep the number of reflections constant? Has the result been repeated with current technology? Is the observation explained by special relativity instead of Doppler?

4. Dark Energy, Spacetime and Potential of the Universe

In the universe, we are immobile and the universe is expanding; because of the acceleration of its expansion (Peebles, 2003), there is a fifth-force. With a force there is a potential that deforms spacetime as in Figure 3. This figure was in my mind when I suggested that “speed-force” from combined relativity could explain dark energy (Danis, 2024). But even if my previous paper is wrong, spacetime should resemble Figure 3 because of the acceleration of the expansion.

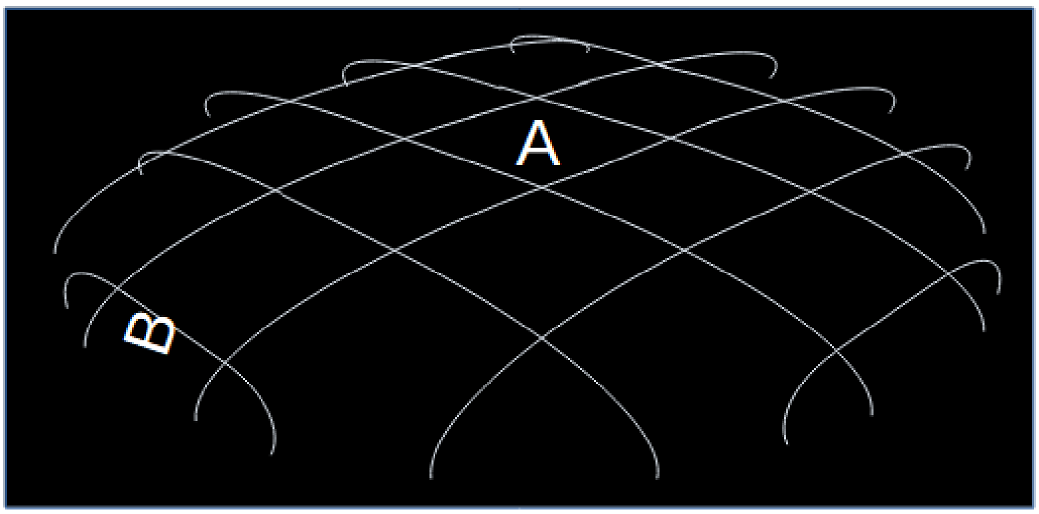

Figure 3. Spacetime/potential of the Universe

“A” represents where we are, “B” represents where red-shifted light is coming from. This figure is an image, not the result of any calculation.

One photon is leaving point B with an energy corresponding to a high frequency. Because the frequency is dropping, the energy due to the frequency is dropping as well. But to move from B to A, the potential energy is increasing. I hypothesize that the potential energy is the reason for the difference of energy/frequency. The result is that energy would be conserved.

A change of potential, leading to a redshift, was already presented in the last part of one of Einstein’s papers (1907b) which is at the origin of gravitational redshift. Gravitational redshift was first observed by Greenstein et al. (1971). What is new here is its use for the universe.

So, the difference of potential could be measured with the redshift. The difference of potential energy should be transformed into kinetic energy, so indeed the redshift gives information about the recessional speed.

Lorentz factor is interesting because it depends on the speed and varies from 1 to infinity. Figure 3 shows zero difference of potential at point A (so a factor 1) to an infinite difference just after point B. With combined relativity (Danis 2024, 2025), the redshift will correspond to Lorentz factor squared. Special relativity could give a redshift directly proportional to Lorentz factor as with the relativistic Doppler effect; but special relativity doesn't deform space so cannot justify Figure 3.

Combined relativity explains why space would be deformed as on Figure 3 and tells us that Lorentz factor squared is the difference of potential. Lorentz factor squared gives a result in speed squared, the kinetic energy is in speed squared. So, the change of potential energy would be directly transformed into kinetic energy as stated above. From the singularity of the Big Bang to now, it seems that energy is conserved and the potential energy has given the speed to the galaxies in the universe.

To calculate the difference of potential we would start with femit/fobs = γ^2 and from γ we can recover the recessional speed of the source. From the speed of the source, we can retrieve the kinetic energy therefore the difference of potential. This method may need to be developed further, but the essential should be there.

5. Inertial Field

The idea of difference of potential seems correct to describe Fig.3 but with a galaxy, we observe stars rotating around the center. Some stars will have a relative velocity towards the observer, others away from the observer. As, with our new proposal, the redshift is proportional to the velocity and the potential, the result is an asymmetric potential field.

To explain this asymmetry involves a separation between a gravitational field and an inertial field. It is a complex subject not directly related to redshift (Danis, 2025). Simply put for this paper, a gravitational field depends on the position of mass at one instant; an inertial field depends on the dynamics of those masses (similar to 'mass' versus 'acceleration of the rocket' as in the equivalence principle). Einstein predicted gravitational redshift with a gravitational field; an inertial field would also create a redshift.

Because the universe is uniform, the gravitational field is roughly flat, nothing like Figure 3. Because of the isotropy of the universe, an observer at point B would see the universe as in Figure 3, with point A falling off the edge. That Figure 3 is also representing the inertial field as suggested above. With the universe as with a galaxy, the gravitational field would be different to the inertial field.

6. Speed Differences Between Doppler Effect and Combined Relativity

With a speed of v=0.1c and combined relativity, the corresponding length contraction would be a factor 1.01 (Lorentz factor squared: γ^2). The number of waves contained in the contracted 1m at B (0.99m) remains identical in the non-contracted 1m at A, so leads to the change of frequency as follows:

femit/fobs = 1.01

With Doppler effect, z = v/c= 0.1.

femit/fobs = 1 + z = 1.1

For the same observed redshift, combined relativity would give a higher speed than Doppler. The table 1 below gives an idea of the differences in speed.

Table 1. Difference of speed between the new proposal and the current approaches

femit/fobs	Combined	Doppler	R Doppler
1.001	0.04	0.001	0.001
1.01	0.10	0.01	0.01
1.10	0.30	0.10	0.10
2.00	0.71	1.00	0.60
3.00	0.82	2.00	0.80
10.00	0.95		0.98
100.00	0.995		0.9998
	speed in c	speed in c	speed in c

Motions in this table are along the line-of sight. "femit/fobs" represents the redshift, other columns are the corresponding speed. "Combined" is for combined relativity, "Doppler" is for simple Doppler effect where the speed could reach value above 1c. "R Doppler" are for relativistic Doppler.

The direction of those speeds shown in table 1 is parallel to the direction of observation (radial direction) and corresponds to the speed of galaxies receding from us as for Figure 3. For the rotational speed of stars around a galaxy, velocity is never in the direction of the observer so an angle must be considered. Currently, there is a longitudinal Doppler effect for radial direction and the transverse Doppler effect (TDE of section3) for direction perpendicular to the observation. With combined relativity, there is no Doppler effect for the transverse direction. But there is no reason to refute TDE as it has been observed by Ives-Stilwell and shown to be a special relativistic effect; simply the name (TDE) is wrong. Only the radial effect has to be changed if the new proposal is accepted.

My biggest concern is the factor 40 difference between the old theory and the new one for small speed as the first line of table1. For example, 0.001c is 300km/s; the highest rotational speed of star in Andromeda is about 250km/s. Is it possible that this factor 40 has been missed?

7. Discussions

7.1 Trying to Save Doppler

If my analysis is correct, the lack of observation of radial Doppler effect with the Ives-Stilwell experiment requires an explanation. Einstein (1907a) was already questioning the Doppler effect whilst studying the result of the experiment of Dr J. Stark where the observation could be explained with special relativity. Einstein predicted a difference between the Doppler effect and special relativity. What was that test? Has that test ever been carried out? Is there any link with Bélopolsky's experiment (1901) which predate special relativity?

Due to the constancy of the speed of light, it is difficult to justify the Doppler analysis. The only variable is the energy of the photon. Ortiz's paper (2024) is an attempt to unify the three different redshift mechanisms (cosmological, gravitational and Doppler) while keeping Doppler's analysis, and conserving the energy. The paper explains the change of energy with the expansion of the universe. The conclusion would be that the conservation of energy is respected and Doppler analysis is still valid. But there is a twist in the next subsection.

Of the other references I checked on the conservation of energy with redshift, nobody (including Ortiz et al.) seems to have questioned the Doppler analysis to explain the change of energy.

7.2 Against Doppler Redshift

What is interesting in Ortiz et al. paper is that, by re-instating the conservation of energy and adding the unification, they link the universe expansion factor (a) with Lorentz factor (γ) via their equations (12) and (23); then, adding the gravitational potential (ΔU) with equations (17) and (20) one finds:

$$1 + z = 1/a = \gamma = 1/\sqrt{(1-\Delta U)}$$

That formula would be valid only in Newtonian limits (small ΔU) N.B. the formula is not in Ortiz's paper but is implied; in the paper, Lorentz factor is not mentioned (not recognized?) and the three kinds of redshift are kept separate.

You may notice that $1 + z = \gamma$ (their relation (12)) is identical to Ives-Stilwell prediction for TDE (this section 3). Ortiz et al. seem unaware that they have shown that TDE and radial Doppler effect are identical. They missed the conclusion that Doppler redshift is a misnomer as the redshift is a special relativistic effect independent of the velocity (direction) of the object observed.

Added to this special relativistic effect there is the expansion effect as 1/a in their work. With combined relativity (Danis, 2024) , $1/a = \gamma$. Therefore the factor becomes Lorentz factor squared (γ^2 instead of γ) in the radial direction, which would then be directly proportional to the potential difference as suggested in this work and in the formula above if all the terms are squared. In the transverse direction, combined relativity uses Lorentz factor γ (not γ^2) as Ortiz et al. suggest and as observed by Ives-Stilwell. If correct, this interpretation of the study by Ortiz et al. would confirm combined relativity.

7.3 Possible Tests

7.3.1 Seasonal Variation

Observations of low-redshift along the ecliptic plane in the direction of the velocity of the earth must exist; 6 months later the same target would be in the opposite direction. The earth's average orbital speed being nearly 30km/s, a variation in the redshift should be observable. Because of section 6, such a variation would favor this proposal or Doppler.

7.3.2 The Hubble Tension

If redshift is not a Doppler effect, then the accepted recessional speeds are wrong. If the revision of all the speeds resolves the Hubble tension/crisis (Riess, 2022) then the new proposal could be right.

To solve the Hubble tension, most current literature is suggesting a Dynamical Dark Energy. I found one study/review (Huang, 2025), with more than 60 relevant references. Huang's paper is interesting because it also suggests that there is a problem with low-redshift data. Further work is needed to check whether section 6 would solve their problem.

Again, I checked only some references, but what is clear is that nobody questioned the validity of Doppler analysis.

7.4 The New Proposal

This paper is a call to all scientists to test this new theory. There would be no Doppler effect with light and that is one novelty of this work. A transverse redshift would be a special relativistic effect which would be seen in all directions (not only transverse). The additional radial redshift would be due to a change of potential. This proposal needs further studies. Is this work coherent? Is there something missing? Is there any observation that could contradict this new theory? A more extensive bibliography search may help: what is Stark's experiment? Did Einstein accept Doppler effect? What is the difference between Doppler redshift and cosmological redshift (there is none in Ortiz's paper (2024))? Has the variation of seasonal redshift already been observed/explained? etc.

Figure 3, beyond point B there is the Cosmic Microwave Background (CMB) (Alpher, 1948). Is this new theory affecting our understanding of the CMB?

Figure 3, beyond the CMB there is the cosmic inflation (Starobinsky, 1980). I cannot see any reason why the curvature of Fig.3 would stop, so the field should be nearly vertical, like the gravitational field near a black hole. So, time would run very slowly (if at all). Is the inflationary period needed? Can it be just a "normal" expansion seen from far away, and time would flow very slowly for matter that has formed the universe?

The fifth-force gives Figure 3 and Figure 3 explains the fifth-force. It is a circular "argument" and doesn't explain anything. The reason for the fifth-force/potential has to be found if it is not in combined relativity (Danis 2024). The Hubble energy suggested by Macleod could be another alternative (2004).

If the idea of Figure 3 is accepted it would mean that the frequency of the photon would seem to increase again when the photon is moving away from us and reaches the opposite end of the visible universe. But do not conclude that a new observer at the opposite end would see no redshift. That observer would see spacetime as in Figure 3. That new potential is relative to the observer; one observer cannot judge for another observer, as already stated in the previous paper (Danis 2024).

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Data sharing statement

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