Hubble's Law as an Inverse Square Law

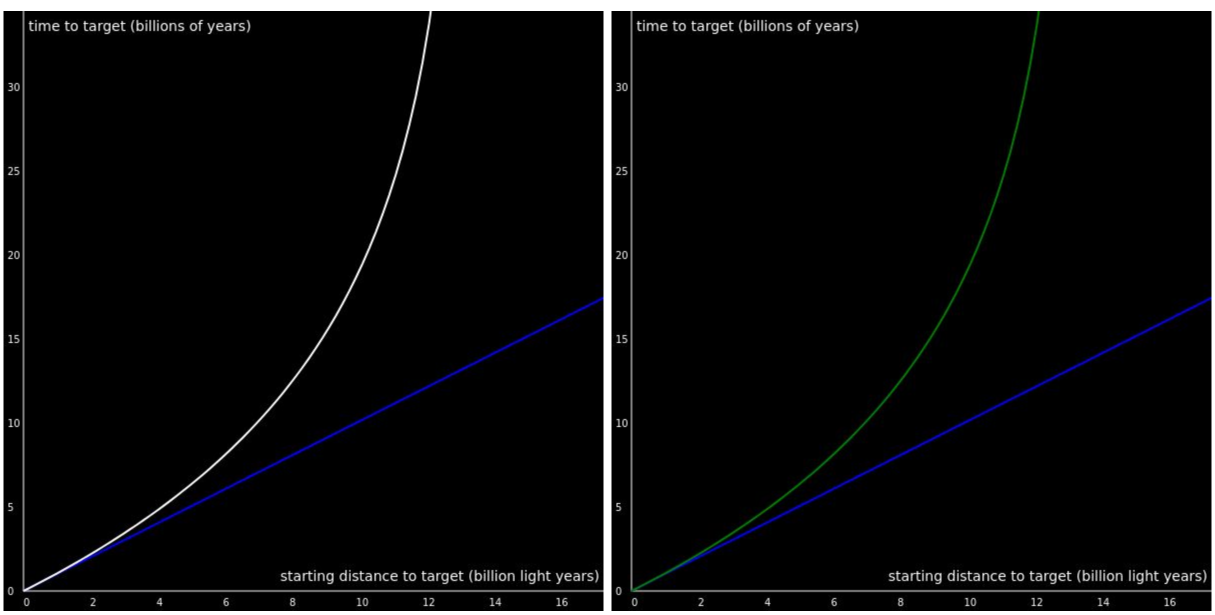
A Testable Cosmology with Practical Applications

A change to Hubble's law provides a new cosmology that fits the observed acceleration of redshifts using distance, the speed of light, and a static Hubble constant with zero other parameters. The CMB is proposed to be not of cosmological origin, but a consequence of the conservation of energy and thermodynamics applied to the redshifted energy of photons. Testing the hypothesis is presently feasible and would yield working practical technology if confirmed.

Background

Many years ago I found a simple way to mimic the expansion of space in a physics model. It's based on the fact that as space expands, the travel time to a distant galaxy increases. One consequence of the expansion of space is, loosely speaking, that time expands too: increasing distances means increasing durations.

To demonstrate this, consider targets placed in space 1 million light years apart. A photon is emitted, and in the static universe (blue) the photon reaches a new target every 1 million years, while in an expanding universe (white), the photon is lagging behind.

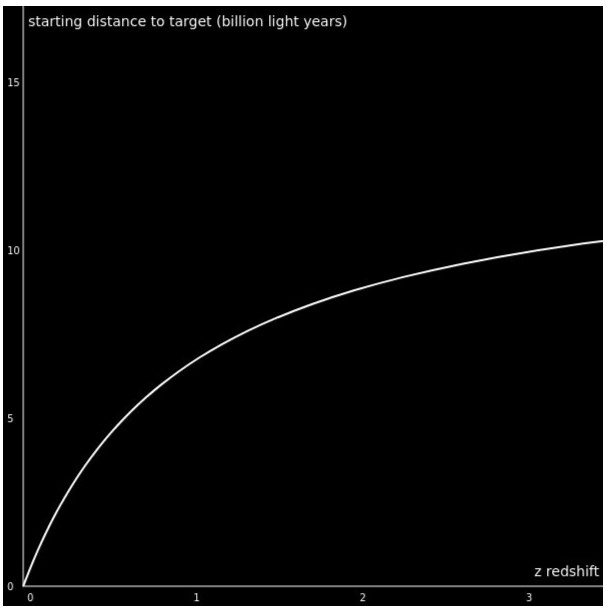


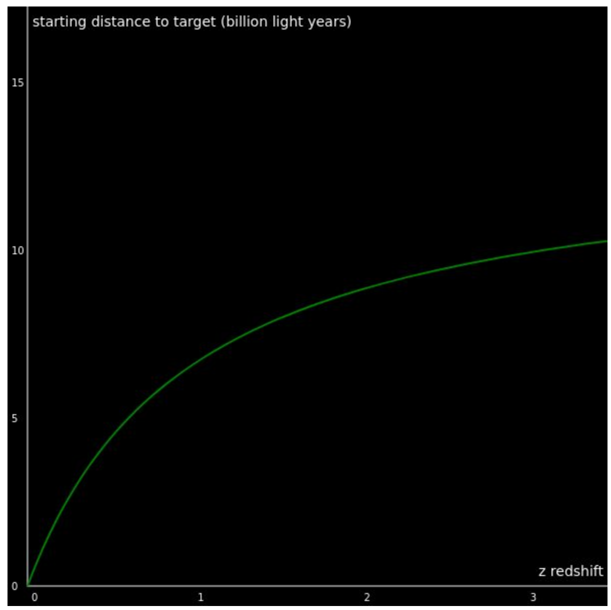
The trick is, rather than place everything in the physics model in motion away from everything else, these time delays could be exactly reproduced by just slowing down the photon (green).

In a simple expanding universe, everything moves away from the observer at v=HD. In this mock-expansion model, the photon's velocity is v=c-HD. This just moves HD from one velocity to another. The photon's original wavelength and new velocity can be used to calculate a new frequency, frequency = velocity / wavelength. The new frequency and original frequency can be used to calculate a z.

$$z = \frac{f_{\text{emit}} - f_{\text{obsv}}}{f_{\text{obsv}}}$$

These models produce the exact same redshifts as each other, for the same value of H, shown here as H=74 km/s/Mpc.





The Expansion Rate of the Universe

Recently, the question of "how fast is space expanding, exactly?" has become something of a mystery.[1][2][3][4][5] The current expansion rate seems to be faster than it was in the past.

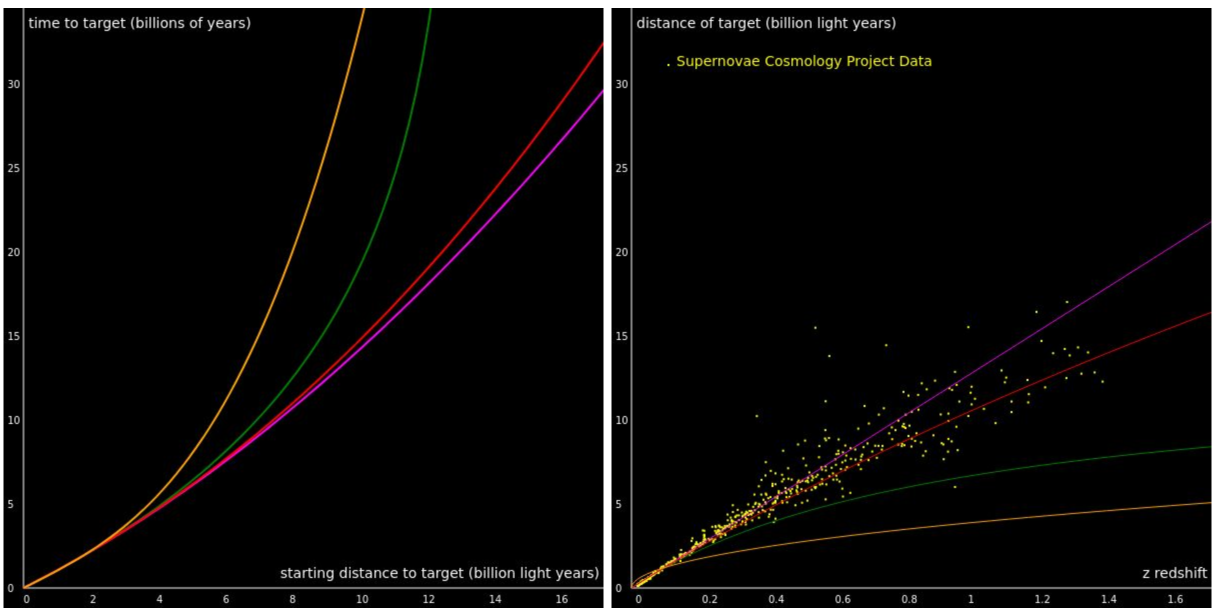
With that in mind, I considered the mock-expansion idea and different ways to change it. A photon in the mock expansion model begins with a velocity of c that decreases by HD as it travels. Something similar happens if, rather than subtract HD from c, you divide c by 1 + HD. At first, when D=0, v=c/(1+0), which is v=c. As HD gets bigger, v gets smaller.

Hubble's constant usually has units of km/s/Mpc, which works out to units of inverse time. Those units no longer work for v=c/(1+HD). This requires new units that are of inverse distance. Using the form v=c/(1+D/H) inverts the inverse distance to just plain distance, and ends up being much more intuitive.

By putting variations on a theme, I devised similar but different mathematical models to compare:

- hypothesis 1: v = c - HD
- hypothesis 2: v = c / (1 + D/H)
- hypothesis 3: v = c / (1 + D/H)^2
- hypothesis 4: v = c / (1 + (D/H)^2)

The next step was to compare these hypotheses against the observational data. For that I used the Supernovae Cosmology Project's data[6]. I converted the distance modulus to co-moving distance, and ran models for the hypotheses and showed the results against the observational data. The code for this is at the bottom of this document. The inverse square variation, hypothesis 3, is a very good fit of the data, for H=25 Gly.



Hypothesis 1, H=74 km/s/Mpc (green), Hypothesis 2, H=12.5 Gly (magenta), Hypothesis 3, H=25 Gly (red), Hypothesis 4, H=3.8 Gly (orange)

This mock-expansion idea, though, violates a fair amount of the established laws of physics. The question then became, how could this inverse square version of mock-expansion be converted into an actual expansion model? The answer to this question is that objects in the universe are moving away at velocity v = c - c / (1 + D/H)^2. Such a universe, however, cannot exist. If the expansion of space is not linear, then different observers will determine the same part of space to be expanding at different rates.

Although the inverse square variation looked promising for a moment, it appears to be a dead end. That is, unless hypothesis 3 is taken seriously and the conflicts with established physics can be resolved.

Photon Velocity

The redshifts in this hypothesis are not caused by the expansion of space, or other interactions as in tired light theories (discussed in a later section). The redshifts are interpreted as their own phenomenon that is as fundamental to nature as inertia. Light from distant galaxies is observed to be redshifted because light redshifts with distance.

The decelerating photon hypothesis is that cosmological redshifts indicate new physics for a photon:

1. A photon loses frequency as it travels cosmological distances, but with no change to wavelength, resulting in a loss of speed, according to $v=c/(1+D/H)^2$
2. The energy of a photon absorbed by matter is emitted as a new photon with D=0, and therefore v=c and an elongated wavelength.

In this interpretation of the redshifts, the frequency decreases while the photon is in flight, and the wavelength increases at the beginning of a new photon's journey. This is different from the expanding theory where frequency and wavelength change together without affecting the photon's velocity.

This poses a number of conflicts with existing physics. One of the most illustrative issues involves the Hubble Space Telescope (HST) and Snell's law.

The hypothesis says that the photon travels at less than c, and then after interacting with matter, new photons that travel at c are emitted. If decelerated photons reach a mirror and change speed, the photon's motion can be compared to that of light changing mediums.

This would result in a change to the angle at which decelerated light reflected off a mirror, which would be relevant in the case of the HST observing highly redshifted galaxies.

One would expect then, that if redshifted photons are traveling at less than c, the HST would not be able to resolve them at the expected angles with any clarity. Since the HST does resolve such galaxies, light must be reflecting normally, which means the photons have to be moving at c, invalidating the hypothesis.

To demonstrate this, I built two models of light reflecting off a mirror. The first using Fermat's least time principle. The second using Feynman path integrals. These demonstrated the problem.

Photons and Reflection

For the purpose of solving the reflection problem, imagine a non-relativistic space. In this space there are observers who experience time according to one master clock. In this space there are also photons, and each photon has its own clock. Similar to relativity, but not quite. Every photon's clock begins synchronized with the master clock, but falls off with distance, at a rate of $1/(1 + D/H)^2$ which is equal to $1/(1 + z)$. This is derived in a later section.

Previously, the code for the model of the decelerating photon looked like this:

```
photon.dx = c / Math.pow(1 + photon.x / H, 2)
```

The hypothesis was directly changing the velocity based on distance. To solve our problems, we'll approach this slightly differently. The photon needs a clock that starts at zero, and this is what the hypothesis directly changes, like so:

```
// find out the time slice for a photon at this distance
dt = 1 / Math.pow(1 + photon.x / H, 2)

// add that time slice to the photon's clock
photon.clock += dt

// move the photon at the speed of light for the time slice
photon.dx = c * dt
```

The photon will actually always be traveling at c according to its own clock. But since that clock gradually runs slower than the master clock, the photon appears to decelerate according to the observers in the model.

When the photon hits the mirror, it will be emitted as a new photon with D=0, causing dt=1, causing the v=c, and creating an elongated wavelength.

Now when we run the problem demonstration of Fermat's least time principle, rather than choose the photon that arrived first according to the master clock, we choose the photon whose clock has the lowest reading.

You can see this demonstration and source code at https://mikehelland.github.io/hubbles-law/other/reflection3.htm

When run, photons reflect at the same angle as photons moving at c in a vacuum, no longer demonstrating a problem with the hypothesis. This works because the least time principle always favored the photons that hit the mirror first when a speed increase was involved. If a photon was the first to reflect and gain a higher speed, it had a considerable advantage over the other photons traveling at the slower speed. In the updated demonstration, the time is measured by each photon's clock, which changes speed when the photon hits the mirror. For the photon that hits the mirror first, the speed boost no longer provides an advantage, because the photon's clock speed will have increased too, canceling out any advantage being first to the region once held.

A similar resolution can be added to Feynman's path integral in quantum electrodynamics. Each photon has a clock, which provides the time slice to be used. Photons that are redshifted have slow clocks dt<1, when they are reflected as fresh photons, their clock speed returns to dt=1.

Accounting for the difference in dt before and after the reflection, the problem demonstration again shows there is no problem at all.

You can view this demonstration and source code at
https://mikehelland.github.io/hubbles-law/other/reflection_nm.htm

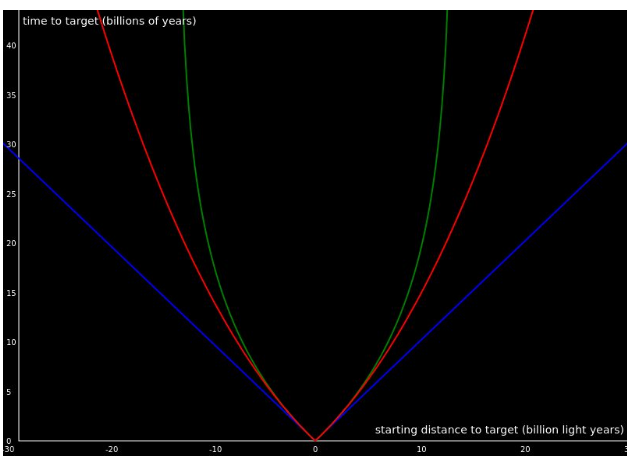
As you can see, the combination of increasing the wavelength and dt produces an interesting wave effect in the dials of the bottom simulation, before settling on the exact same phases we would expect for a photon moving at c.

This shows the hypothesis that time slowing down for a photon over cosmological distances is compatible with classical and quantum theories of light.

The Geometry of Spacetime

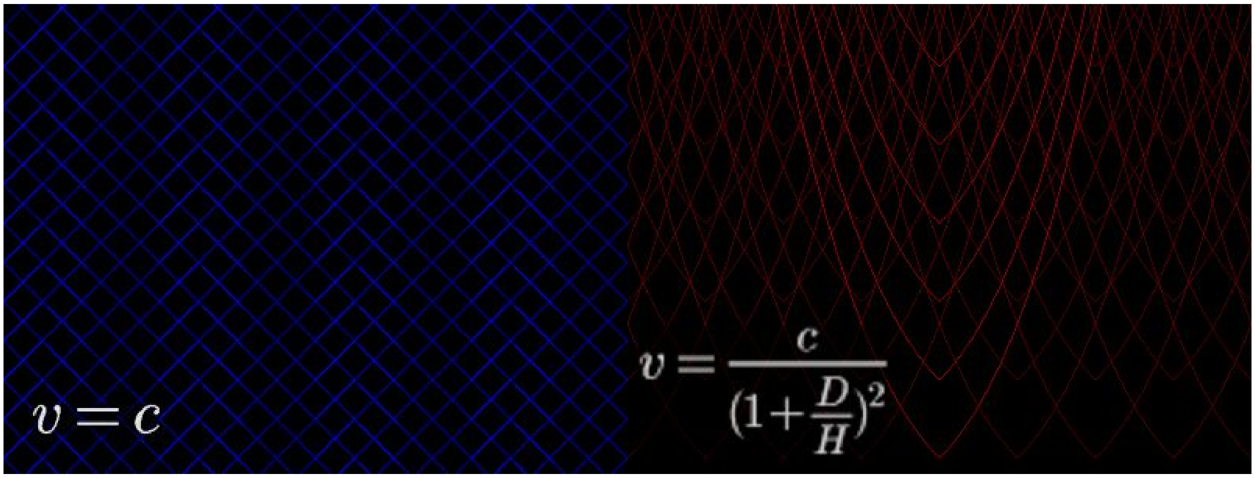
In a relativistic universe, every observer has their own clock, and so does every object. The photon has a clock in relativity, but it always reads zero. The photon is said not to experience time. In that case it would be tempting to reverse the situation from the previous solution. Instead of the photon's clock gradually slowing down, a relativistic photon's clock begins standing still, and gradually gets faster.

But the speed of light in a relativistic universe is hardcoded into the geometry of spacetime. A massless particle cannot just slow down in a vacuum; it must follow a light-like path, the null geodesic. A photon that experiences time would veer off of the null geodesic with a time-like trajectory. This can be demonstrated by looking at the lightcones made by such a photon.



Blue: basic spacetime, Green: expanding universe and v=c-HD, Red: $v=c/(1+D/H)^2$

In a basic spacetime, all the photon geodesics will be parallel or perpendicular, shown left in the image below. What's proposed here is that every point in spacetime is the beginning of a new geodesic whose trajectory depends on the distance from the starting point. As a consequence, the geometry of spacetime would change to something more like the image on the right.



If the geometry of spacetime is changed in this way, the observed accelerating redshifts are produced.

Cosmology

This standard interpretation of the redshifts as expanding space has grown into a theory that does much more than explain the redshifts. As such, accounting for all the features of the universe it claims to account for is unlikely for any alternative explanation of the redshifts. However, some key criticisms of the new hypothesis should be addressed.

This is the Tired Light Theory, which is discredited

The expanding model has been challenged by hundreds of non-expanding theories[7], and all of them have failed. These theories propose different ways light can interact with matter or other forces to reduce the light's energy, and they are known as tired light theories.

Light loses energy in the tired light theories, but it never loses speed as the theories are consistent with special relativity. Because tired light moves at c, there are no time delays in a photon's journey like there are in the expanding model or the decelerating photon hypothesis. Tired light photons match the arrival time of the simple static model (blue in the gif), while the decelerating photon hypothesis (green) has time delays that match the expanding model (white).

In this hypothesis, one could say light *does* get "tired", but it does so in a way that is conceptually and mathematically unique to the established tired light theories.

The CMB indicates a hot past

The Cosmic Microwave Background was predicted by the big bang theory as a remnant of the fiery conditions at the beginning of the universe, and its discovery is an important piece of evidence for the theory.

If the decelerating photon hypothesis is correct, the CMB must have some other explanation. Consider the following facts:

1. Photons lose energy with distance
2. There is energy coming from all directions as microwave background radiation

The energy lost through redshifting and the energy of the CMB might be more closely related than we currently think. What happens to the energy a photon loses when it redshifts? It has to go somewhere. If the energy lost by redshifting is discarded into space it would start to pile up.

If space is filling up with the energy discarded by redshifting photons, when the energy in a volume of space is greater than the energy equivalent of the temperature of its surroundings, that volume of space should start emitting radiation to cool to equilibrium.

This might take the form of a "background" field that receives the energy lost by redshifting photons and returns the energy to the EM field as photons to reach a thermal equilibrium.

Early 20th century astronomers calculated that the minimum temperature to which a black body in our galaxy would cool is about 3 K well before the CMB was discovered[8].

The CMB was discovered in 1964 at 3 K, which has been refined to around 2.7 K.

In the expanding model, the similarity between the predicted effective temperature of our galaxy and the temperature of the CMB is a coincidence.

In the decelerating photon hypothesis, the temperature of the CMB is an effect of the background field cooling to the effective temperature of the galaxy.

The farthest galaxies are younger than nearby galaxies, indicating a beginning of time

A universe that begins with a big bang should contain younger and younger galaxies as we look back in space and time. As we've been getting a better look at the universe, we are finding that the distant universe isn't meeting our expectations for when galaxies become massive[9][10][12][13][17], dusty[12][13][14], spiraled[16], barred[16], disced[10][11][16], bulged[9], and have shut down star formation[15].

In a universe that expands, there is a race against the clock for the universe to take shape, and lately the clock has been winning. A universe that doesn't expand, on the other hand, has no discernible age or hurried time schedules for galaxy formation and evolution to squeeze into.
The Tolman surface brightness test indicates an expanding universe

The Tolman Surface Brightness Test is meant to distinguish a static universe from an expanding one.

In the decelerating photon hypothesis, a photon experiences the same delays in the journey as a photon would in expanding space. But successive photons in an expanding universe would experience higher delays, whereas each successive photon in the decelerating photon hypothesis experiences the same delay as the first photon.

An expanding universe predicts an extra factor of dimming, due to the photons arriving at a lower rate due to the galaxy's motion away from us. Based on observations, it predicts one factor too many[18]:

> "The exponent found is not 4 as expected in the simplest expanding model, but 2.6 or 3.4, depending on the frequency band."

The decelerating photon hypothesis predicts one fewer factor than the expanding universe, matching observations.

Also note that the frequency of the light made a difference here. In an expanding universe, that would be impossible.

Time dilation in supernovae light curves indicate an expanding universe

Due to the expanding universe, a nearby event that lasts for 20 days, such as a supernova, would appear to last longer when the event takes place far away. That is because of the same reason that an expanding universe predicts a fourth dimming factor in the surface brightness test: the galaxy is farther away each time it emits light. This is known as time dilation, and it is observed in the light curves of distant supernovae. The more dilated the duration of the event, the farther away it must be.

In the decelerating photon hypothesis, space is not expanding, and thus it cannot stretch the time it takes for an event to occur. The only way the decelerating photon hypothesis could be true then, is if the longer supernovae observed are not time dilated, but actually much bigger supernovae than we assume they are.

This is the position argued by Jensen[19], page 5:

> On the other hand, the Delta(15) values seem to indicate the opposite trend, the light curves and therefore the supernovae themselves are actually getting smaller with increasing redshift! Why would this be true? Why would we find smaller supernova with increasing redshift? Unless the morphology of supernova are changing, and the spectra indicate that they are not, we should expect the size of the supernova we actually observe to increase slightly with distance, a predictable Malmquist type II bias of about 4%.

And page 6:

This same argument can be made with the most basic piece of statistical data: Supernovae rise times: In the local universe, the average rise time is 20 days, but in the redshifted universe; it is 17.5 days, which again, would tend to indicate more distant supernova are smaller (Li). If this time dilation factor is removed, the high redshift sample has an average rise time of about 25 days. This is too long for normal Ia, but not if the distance modulus and the corresponding attenuation factor are underestimated. In this case, the higher redshifted SNe Ia would indeed be over-represented by very high magnitude ‘peculiar’ Ia, or hypernova. Credence is given to this conjecture by the fact the number of supernova actually found in high redshift surveys represent only a small fraction (~4%) of the expected yield (Tonry).

Jensen argues that the farther we look into space and the larger our sample size becomes, the smaller the average supernova appears to be, contrary to expectations. He advocates adjusting for a Malmquist type II bias, meaning the farther into space we look, the lower the fraction of the galaxy's light will reach us, altering our measurements. These particularly long lasting supernovae are then not only larger events than we think they are, they are also farther away than we think.

A New Redshift-Distance Relation

Whether or not the interpretation of redshifts proposed here is considered possible or necessary, because it fits the acceleration of the redshifts, it can be used as an accurate predictor of z and distance given one or the other. The hypothesis is:

$$v = \frac{c}{(1+\frac{D}{H})^2}$$

When used to calculate redshifts, the standard pattern arises that at z=1, v=0.5c, and at z=2, v=0.333c, and so on, such that:

$$v = \frac{c}{1+z}$$

Therefore:

$$\frac{c}{1+z} = \frac{c}{(1+\frac{D}{H})^2}$$

$$1+z = (1+\frac{D}{H})^2$$

$$\sqrt{1+z} = 1+\frac{D}{H}$$

Solving for D we get:

$$D = H(\sqrt{1+z} - 1)$$

And solving for z we get:

$$1 + z = 1 + 2\frac{D}{H} + (\frac{D}{H})^2$$

$$z = (\frac{D}{H})^2 + 2\frac{D}{H}$$

These formulas predict the observed z and D of a galaxy in an expanding universe that is accelerating, without a cosmological constant or dark energy.

Tests and Applications

It is important to keep in mind that interacting with a cosmologically redshifted photon will, according to the hypothesis, reset it's D to zero, causing it to behave as a normal photon. With that in mind, several good tests for this hypothesis can be made where the redshifted light is not disturbed until the end of the experiment.

If ancient photons have indeed decelerated, a simple test could be devised using existing technology.

Launch a probe that scans for supernovae, and send it out past Mars. When it detects a supernova in the opposite direction of Earth, send a signal back to us with its location.

If all the photons involved are moving at c, the signal from the probe should reach Earth at the same time as the supernova.

Prediction: If the decelerating photon hypothesis is correct, the signal from the probe to Earth should travel at c and reach us sooner than the slow light from the distant supernova.

If confirmed, such a test would provide a working technology for astronomers to apply immediately to get advanced warnings on Earth about events such as supernovae.

Furthermore, using the distant probe we can calculate the speed of the supernova's light, being able to produce a distance measurement free from the influence of peculiar velocity.

Shutter Test

Consider a long tube in space with a telescope at one end and an open shutter at the other. The telescope has a nearby galaxy and a highly redshifted galaxy in its sight.

What happens when the shutter is closed?

Prediction: Because the red light is moving slower than the yellow light, first the nearby galaxy will disappear from view, then the distant one.

Extra doppler shifts from high z galaxies

Because photons from high z galaxies should be moving slower than c, their relative velocity to Earth should be detectable by the Hubble Space Telescope as Doppler effects.

Prediction: Observing a high z galaxy on Earth's horizon, when Earth is on opposite sides of the sun, should produce more redshift when the Earth is moving away from the distant galaxy than when the Earth is moving toward the galaxy, to a degree more exaggerated than for nearby galaxies.

Conclusion

The decelerating photon hypothesis changes the physics of light at cosmological distances to accommodate the redshifts. On the other hand, the expanding interpretation of redshifts has led to a change in just about everything in the universe except for light.

When interpreting the redshifts as Doppler effects in the early 20th century, astronomers did so because it was known and familiar and didn't require new laws of physics.

> We may state with some confidence that red-shifts are the familiar velocity-shifts, or else they represent some unrecognized principle of nature. We cannot assume that our knowledge of physical principles is yet complete; nevertheless, we should not replace a known, familiar principle by an ad hoc explanation unless we are forced to that step by actual observations. - Edwin Hubble

The observed acceleration of the redshifts has forced us to that step.

If dark energy is in the consideration as a possible fundamental ingredient of nature, then the observed phenomenon of cosmological redshift, the actual observations that lead to dark energy, should be considered as well.

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