

Cosmological Redshift. An Information Mechanics Perspective

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A photon's observed wavelength tells an astronomical detector about the amount of position information obtained by observing that photon. This amount of position information may depend on time in a way which, to first order over distances small compared to the size of the universe, might account for the cosmological redshift.

Interpretation of cosmological redshift as due to rapid recession of distant light sources has relied on a classical-mechanical picture (Hubble, 1936a, b). Here, we ask about information received in detecting a photon emitted long ago and far away. Specifically, the photon's observed wavelength tells the detector about the amount of position information accessed by such detection. This amount of position information may depend on time in a way which, to first order over distances small compared to the size of the universe, might account for the cosmological redshift.

In Kantor's information mechanics (**IM**) (Kantor, 1977; hereinafter cited as **IM**) total accessibility of information I_U (**IM**, p. 155) in universe U is finite; there is a constant longest possible length λ_1 (**IM**, p. 188); "radius" R_U of U is defined as $\lambda_1/(2\pi)$ (**IM**, p. 212). The amount of information indicated by a photon's wavelength is λ_1 divided by the photon's wavelength (**IM**; Kantor, 1997).

Quantum mechanics (**QM**) appears in restricted form as a special case in **IM**. The picture discussed here was reached via **IM**; it is expressed here using terms which may be more familiar from **QM**.

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POSITION

Consider an object in finite universe U , with mass much less than the total mass in U , designating a position much smaller than U , with de Broglie wavelength $h/(mv)$ (Planck's constant h , mass m , velocity v). For that object to exist in U , its de Broglie wavelength would fit in at least once; v would not be zero, although least motion so implied might not have any definite direction.

If a photon were emitted substantially isotropically from a source substantially at rest compared to the average position of distant matter in the universe, one might say in QM terms that the concept of its having a direction of propagation would not take on meaning until after an observation was made. That photon's initial wavelength λ_0 would represent a sufficient amount of position information to designate a region of size $\lambda_0/(2\pi)$ in U . While the spherical shell where the photon could be detected would rapidly expand, the photon's focal spot would remain at the shell's center, very nearly at rest.

From outside such an expanding not-yet-detected photon shell, consider such a shell as an object in U : because R_U is finite, it would seem that, unless an extra assumption were added saying that the center of an expanding photon shell could be exactly stationary, for the shell to exist in U the center of that object—the expanding shell—would have nonzero motion. With such (tiny) motion spreading the initially designatable region in U , absent significant electromagnetic interaction between the expanding shell and interstellar matter, the photon's amount of position information accessible by an astronomical detector would decrease after the photon was emitted and before it was detected.

During expansion of the not-yet-detected photon shell, the photon would not be detected within the part of U through which the shell had already expanded. For this reason, one might make a causality argument that the de Broglie wavelength for that expanding shell fit into the portion of U outside the shell; this would give rise to an increasing rate of spread of the focal spot before the photon was detected at larger distance.

Also, re increased rate of focal spot spread with larger distance before photon detection, one might consider whether a reduction of position information might in effect appear as a reduction of the mass of the photon shell object, requiring more rapid motion of the shell's center for the shell's de Broglie wavelength to fit in.

Although consideration of increased rate of motion of the center of a not-yet-detected photon shell would support relatively large redshift for photon detection at sufficiently large distance, such contribution(s) would be relatively small for distances sufficiently small compared to the size of U . That

lets us consider the behavior at sufficiently small distances to obtain an approximate value to “first order” for the magnitude of this redshift effect.

REDSHIFT

Consider a visible photon (e.g., ~ 500 nm wavelength) emitted, with initial wavelength λ_0 , substantially isotropically from a source substantially at rest compared to the average position of distant matter in the universe. The initial energy of the photon, expressed in units of mass m , would be $h/(\lambda_0 c)$, where c denotes speed of light. The initial de Broglie wavelength, $h/(mv)$, of the not-yet-detected photon shell would thus be $\lambda_0 c/v$. Let $\lambda_0 \ll d \ll R_U$, where d is the distance from source to detector. Requiring that the de Broglie wavelength fit once into $2\pi R_U$, and solving for least motion speed v_1 , the first-order term for the least possible rate of motion of the center of the not-yet-detected photon shell would be

$$v_1 \approx \frac{\lambda_0 c}{2\pi R_U} + \dots \quad (\lambda_0 \ll d \ll R_U) \quad (1)$$

During the time $t \approx d/c$ between when the photon was emitted and when it was detected, the original size of the region which the photon was able to designate, $\lambda_0/(2\pi)$, would have grown (least first-order term) by an amount $\approx v_1 t$. The new wavelength $\lambda(d)$ seen at distance d , corresponding to representation of the amount of position information associated with designating this slightly larger region, would then be given to first order by

$$\frac{\lambda(d)}{2\pi} \approx \frac{\lambda_0}{2\pi} + \frac{\lambda_0 c}{2\pi R_U} \frac{d}{c} + \dots \quad (\lambda_0 \ll d \ll R_U) \quad (2)$$

Canceling, and collecting terms, this would give as a least first-order effect of distance on wavelength

$$\lambda(d) \approx \lambda_0(1 + d/R_U + \dots) \quad (\lambda_0 \ll d \ll R_U) \quad (3)$$

For distances much smaller than the size of the universe, this first-order approximation for cosmological redshift with distance appears similar in size to that of the older picture, here writing redshift directly in terms of distance.

APPARENT TIME DILATION OF REMOTELY OBSERVED EVENT

For an event occurring in much less time than it takes for light from there to reach the observer, consider the above photon redshift with regard to frequency components of the event’s detected signature. Noting that the

wavelength appears outside the parentheses in (3), observation of the combined result would thus appear stretched in time by about the same ratio as the increase in photon wavelengths.

DISCUSSION

What does this mean? In physics, a theory is only required to deal with information accessible to an observer. Here, consideration of the amount of position information accessed by an observer might seem able to account to first order for the redshift due to distance seen in light received from nearby sources. From this point of view it would seem that, without having to specify a particular value for R_U , the assumption that the cosmological redshift be caused by rapid recession of the light source, might not be unique.

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