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Tired Light Broadens Supernova Light Curves

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Abstract

The observed wavelength λ_o of a spectral feature in a distant object is greater than the emission wavelength λ_e by a factor $1+z$ which is independent of of λ_e. The usual understanding is that this is the result of a cosmological or Doppler effect; if the object were receding with velocity $v = \beta c$, then $1+z = \sqrt{(1+\beta)/(1-\beta)}$. Other theories or pseudotheories attempt alternate explanations. We argue that the phenomenon itself, the shift by a factor $1+z$, also implies a broadening of any time-dependent phenomenon such as a supernova light curve width, so that one cannot use such a broadening to distinguish between alternate explanations of the redshift.

We take $\psi_1 = e^{ik_1x}$ as the wavefunction of a plane wave (a photon) at $t = 0$, where $k = 2\pi/\lambda$. Then the wavefunction for the superposition of two photons is given by

$$\psi = a_1 e^{ik_1x} + a_2 e^{ik_2x} \ ,$$

and

$$|\psi|^2 = |a_1|^2 + |a_2|^2 + 2|a_1^* a_2| \cos\left[(k_1 - k_2)\, x + \phi\right] \ ,$$

where ϕ is the phase difference between the amplitudes. Successive minima in the probability density have spacing $x = 2\pi/(k_1 - k_2)$.

Suppose that a (distant) observer measures wavenumber k_1' rather than k_1, where $k' = k/(1+z) = 2\pi/[\lambda(1+z)]$. Then the nodes have spacing $x' = (1+z)x$. Whatever mechanism redshifts the wavelength also lengthens the distance or time between nodes by the same factor.

Generalization is straightforward. If instead of the sum of two plane waves we have a Gaussian packet, then the width of the packet broadens by the factor $1+z$. The superposition of two packets whose envelope maxima are separated in space (or, equivalently, in time) must show the same feature: the distance between them "dilutes" by the factor $1+z$. The final generalization is to the superposition of many packets having random relative phase and distributed over space (time) which describes a supernova light curve: It is broadened by the factor $1+z$, no matter what the physical origin of the redshift.