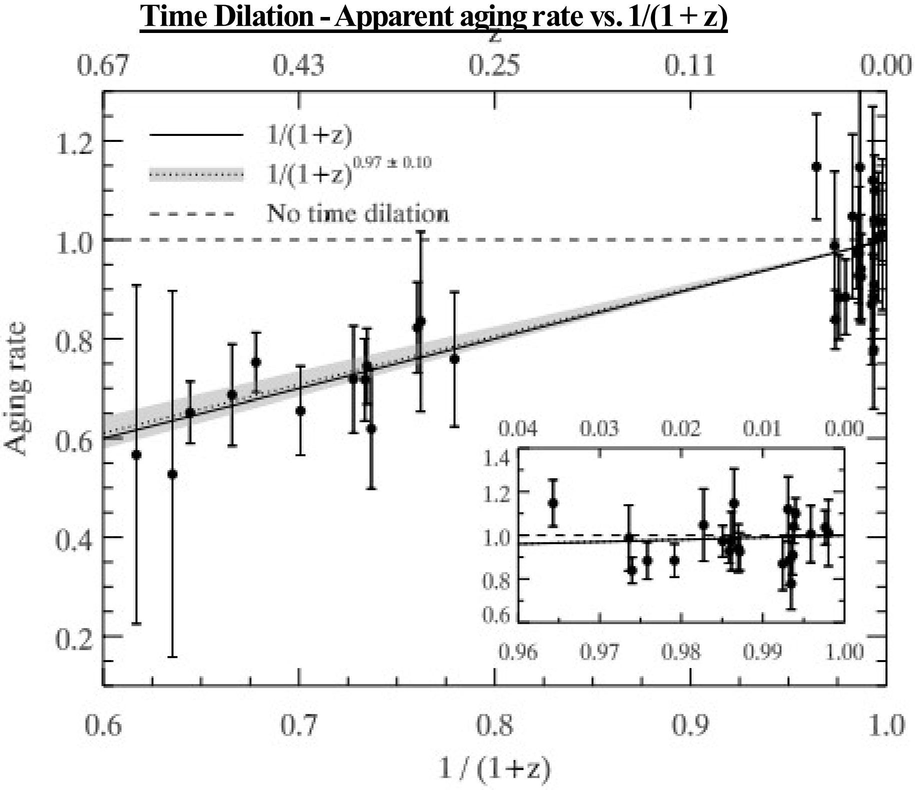
XXIB. Time Dilation in Type Ia Supernova Spectra at High Redshift - Tolman Test

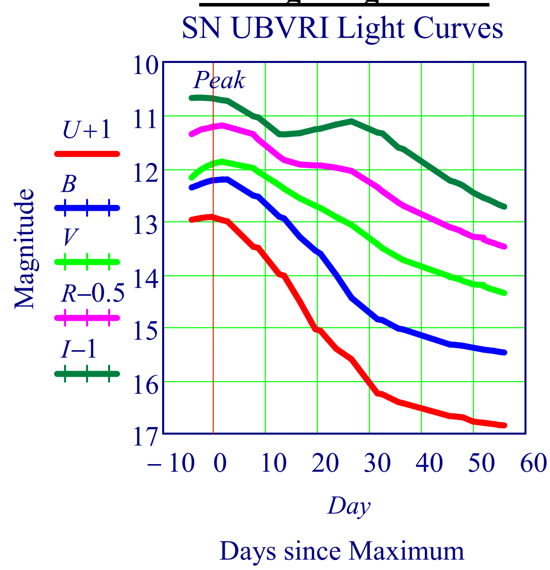
Time Dilation in Type Ia Supernova Spectra at High Reshift, S. Bondi, Am. Astronomical Society, April 19, 2008

One of the **most straightforward and direct substantiations of the ΛCDM creation model** is a phenomenon referred to as **time dilation**. The time dilation test is based on Einstein's special theory of relativity. The redshift, z, is a fundamental observational quantity in Friedman-Lemaitre-Robertson-Walker (FLRW) models of the universe. **It relates the frequency of light emitted from a distant source to that detected by a local observer by a factor of 1/(1 + z).** One important consequence is that the **observed rate of any time variation** in the intensity of emitted radiation will also be **proportional to 1/(1 + z)** (see Weinberg 1972). This phenomenon is directly related to time dilation because the stretching of the wavelength corresponds to a stretching of the time intervals between the peaks of the light wave. The further away a galaxy is, the faster it appears to be receding from us due to the expansion of the universe. (There is also a 1+z stretching of the wavelength of radiation.) Due to their large luminosities (several billion times that of the Sun) and variability on short timescales (20 days from explosion to peak luminosity; Riess et al. 1999; Conley et al. 2006), Type Ia supernovae (SNe Ia) are ideally suited to probe these time dilation effects across a large fraction of the observable universe. The suggestion to u**se supernovae as cosmic clock**s and **tested on light curves** of low-redshift SNe Ia in the mid- 1970s (Rust 1974), but only since the mid-1990s has this effect been unambiguously detected in the light curves of high-redshift objects (Leibundgut et al. 1996; Goldhaber et al. 2001). These latter studies show that the **light curves of distant SNe Ia are consistent with those of nearby SNe Ia whose time axis is dilated by a factor of 1 + z.** However, there exists an intrinsic variation in the width of SN Ia light curves that is related to their peak luminosities (Phillips 1993), such that more luminous SNe Ia have broader light curves. This width-luminosity relation is derived using low-redshift SNe Ia for which the time dilation effect.

Time Dilation - Apparent aging rate vs. 1/(1 + z)



Photometry of Supernova Ia: Peaking of Light Curve



DATA: *OPTICAL LIGHT CURVE TYPE Ia SUPERNOVA.* SUNTZEFF, ASTRONOMICAL JOURNAL, 117, 1999 March

1. UBVRI PassBand Photometric System
2. Brighter stars have smaller Magnitude.

Apparent aging rate vs. *1/(1 + z)* for the 13 high-redshift (0.28 < z < 0.62) and 22 low-redshift (***z < 0.04***) SNe Ia in our sample. Overplotted are the expected 1/(1 + z) time dilation (solid line) and the best-fit $1/(1 + z)^b$ model (with b =0.97; dotted line and gray area). The dashed line corresponds to no time dilation, as expected in the tired-light model, clearly inconsistent with the data. Inset: Close-up view of the low-redshift sample.

Using the standard definition of redshift, $z = (\lambda_0 - \lambda_1)/\lambda_1 = \nu_1/\nu_0 - 1$, we obtain a relationship between observed and rest-frame time intervals in a RW metric as a function of redshift z: $\frac{\delta t_0}{\delta t_1} = 1 + z$

<u>The prediction of time dilation proportional to *1 + z* is generic to expanding universe models</u>, whether the underlying theory be general relativity.