Appendix 1: The observed magnitudes of supernovas

Predictions for luminosity

Since the late 1990s, Supernova Ia observations have been used as a primary test for the prediction of luminosity of standard candles in expanding space. In Standard Cosmology (SC), the prediction for the observed bolometric luminosity is based on Tolman's[i] equation

$$l_{SC} = \frac{L}{4\pi d_c^2 (1+z)^2} \tag{1}$$

where the areal dilution of the flux is based on the comoving distance d_c, and the $(1+z)^2$ redshift dilution on a combined effect of Doppler shift and decreased energy of the light quanta received.

In the DU framework, the corresponding prediction is

$$l_{DU} = \frac{L}{4\pi d_{opt}^2 (1+z)} \tag{2}$$

where the areal dilution is based on the optical distance, d_{opt}, corresponding to SC's light travel distance d_{LT} which is shorter than the comoving distance d_c. In the DU framework, Planck's equation is interpreted as the energy conversion at the emitter, the energy emitted into a cycle of radiation[ii,iii]. Such an interpretation conserves the energy carried by a cycle but dilutes the energy density of the redshifted radiation. Accordingly, in DU, the predicted redshift dilution is (1+z) instead of $(1+z)^2$ of the SC prediction.

In the redshift range $0 < z < 3$, relevant to supernova observations, the DU optical distance d_{opt} is essentially equal to the light travel distance d_{LT} of SC, which, in this redshift range, compares to the comoving distance d_c as $d_{LT} \approx d_c / \sqrt{1+z} \approx d_{opt}$. This allows writing the SC luminosity equation (1) as

$$l_{SC} \approx \frac{L}{4\pi \left(d_{opt}\sqrt{1+z}\right)^2 (1+z)^2} = \frac{L}{4\pi d_{opt}^2 (1+z)^3} = l_{DU} / (1+z)^2 \tag{3}$$

This means that the observed bolometric luminosity predicted by DU is by the factor $(1+z)^2$ higher than the observed bolometric luminosity predicted by SC. The luminosity predictions of (1) and (2) convert into predictions for apparent magnitudes in SC and DU as,

$$m_{SC} = M + 5\log\frac{R_H}{10\text{pc}} + 5\log\left[(1+z)\int_0^z \frac{1}{\sqrt{(1+z)^2(1+\Omega_m z) - z(2+z)\Omega_\Lambda}}\, dz\right] \tag{4}$$

for magnitudes *K*-corrected to "emitter's rest frame", and

---

i R.C. Tolman, PNAS 16, 511, 1930

ii Tarja Kallio-Tamminen, Unveiling the contents of Planck's quantum: mass-waves provide a basis for physics and metaphysics, this proceedings

iii Tuomo Suntola, Photon - the minimum dose of electromagnetic radiation, SPIE Optics & Photonics 2005 Conferences, Special Program SP200 "The Nature of Light: What is a Photon?", San Diego, July 31 – August 4, 2005

$$m_{DU} = M + 5\log\left(\frac{R_H}{10\text{pc}}\right) + 5\log(z) - 2.5\log(1+z), \tag{5}$$

for direct bolometric magnitudes, respectively.

With reference to equation (3), the predicted apparent magnitude in the SC framework is by the factor 5 log(1+z) higher than the apparent magnitude in the DU framework,

$$m_{SC} = m_{DU} + 5\log(1+z), \tag{6}$$

Bolometric magnitude in multi-bandpass detection

In multi-bandpass detection, a straightforward way of obtaining the bolometric magnitude of redshifted radiation is to follow the envelope curve of magnitudes observed in different filters. Such an analysis is made in[iv] for the data given in[v], Figure A1.

TABLE 7

PEAK MAGNITUDES OF NORMAL SNe Ia

z	B	V	R	I	Z	J
0.05......	17.37	17.41	17.36	17.82	17.72	(17.70)
0.10......	18.94	18.88	18.80	19.20	19.24	(19.30)
0.20......	(20.70)	20.29	20.27	20.36	20.75	(20.96)
0.30......	(21.94)	21.08	21.07	20.97	21.28	(21.63)
0.40......	(23.07)	21.89	21.62	21.55	21.67	21.97
0.50......	(24.06)	(22.59)	22.10	22.01	21.96	22.35
0.60......	(24.90)	(23.26)	22.59	22.41	22.37	22.79
0.70......	(25.53)	(23.97)	23.06	22.70	22.70	23.06
0.80......	(26.00)	(24.75)	(23.54)	22.91	23.01	23.11
0.90......	(26.39)	(25.46)	(24.06)	23.12	23.17	23.20
1.00......	(26.75)	(26.03)	(24.61)	23.48	23.39	23.25
1.10......	(27.08)	(26.45)	(25.14)	23.78	23.50	23.38
1.20......	(27.39)	(26.78)	(25.66)	(24.19)	23.72	23.59
1.30......	(27.67)	(27.07)	(26.13)	(24.59)	24.11	23.72
1.40......	(27.95)	(27.35)	(26.55)	(24.91)	(24.39)	23.94
1.50......	(28.20)	(27.60)	(26.93)	(25.36)	(24.70)	24.08
1.60......	(28.45)	(27.85)	(27.24)	(25.85)	(25.04)	24.18
1.70......	(28.68)	(28.08)	(27.51)	(26.30)	(25.32)	24.32
1.80......	(28.90)	(28.30)	(27.75)	(26.77)	(25.72)	24.38

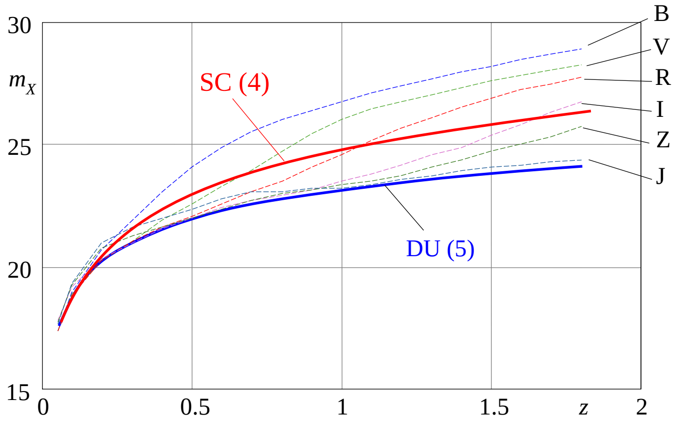

Figure A1. The magnitude data[v] in the table is converted to the set of magnitude curves describing the observed magnitudes as the function of the redshift in each filter B, V, R, I, Z, and J (dashed narrow curves). Each curve touches on the bolometric magnitude prediction at the best fit of the redshifted magnitude to the corresponding filter confirming a perfect fit of the DU prediction (5) to the observed bolometric magnitudes, the blue curve. The SC prediction (4) does not meet the bolometric curve but follows the observed magnitudes converted to "emitter's rest frame", the red curve.

The DU prediction of equation (5) shows a perfect fit to the bolometric magnitudes obtained from the envelope curve of the data set in Figure A1.

In the observation praxis in the SC framework, direct observations of magnitudes in the bandpass filters are treated with the *K-correction*, which converts the observed magnitudes to the "emitter's rest frame" presented by observations in a bandpass matched to a low redshift reference of the objects studied. The *K-correction* for observations in the X_j band relative to the rest frame reference in the X_i band is defined[vi] as

---

[iv] T. Suntola, The Dynamic Universe: Toward a Unified Picture of Physical Reality, 4th ed. (Physics Foundations Society, Espoo, 2018); https://physicsfoundations.org/data/documents/DU_EN_978-952-68101-3-3.pdf

[v] J.T. Tonry et al., ApJ, **594**, 1 (2003)

[vi] A. Kim, A. Goobar, & S. Perlmutter, PASP, 190–201 (1996)

$$K_{i,j}(z) = 2.5\log(1+z) + 2.5\log\left\{\frac{\int_0^\infty F(\lambda)S_i(\lambda)d\lambda}{\int_0^\infty F(\lambda/(1+z))S_j\,d\lambda}\,\frac{\int_0^\infty Z(\lambda)S_j(\lambda)d\lambda}{\int_0^\infty Z(\lambda)S_i(\lambda)d\lambda}\right\}, \tag{7}$$

Figure A2 illustrates the K_{BX}-corrections calculated for radiation from a hypothetical blackbody source with λ_T = 440 nm equivalent to 6600 °K blackbody temperature with redshifts $0 < z < 2$. An optimal choice of filters, matching the central wavelength of the filter to the wavelength of the maximum of redshifted radiation, leads to the K-correction

$$K(z) \approx 5\log(1+z) \tag{8}$$

shown as the solid red curve in Figure A2. The black squares in the figure show the average K_{BX} corrections collected from the K_{BX} data in Table 2 used by Riess et al.[vii]

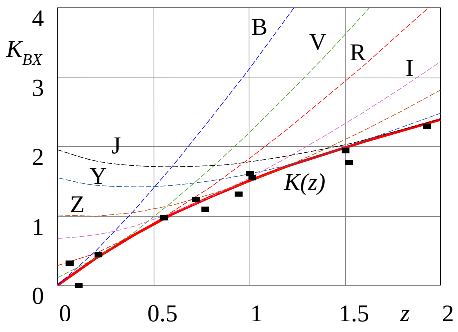

Figure A2. K_{BX}-corrections (in magnitude units) for the B band as the reference frame, calculated in the redshift range z = 0…2 for radiation from a blackbody source with λ_T =440 nm equivalent to 6600 °K blackbody temperature. All the K_{BX}-correction curves touch the solid red $K(z)$ curve, which shows the $K(z) = 5\cdot\log(1+z)$ function. The black squares are the average K_{BX} corrections collected from the K_{BX} data in Table 2 used by Riess et al.[vii] follow closely the $K(z)$ curve.

Conclusions

The SC prediction (1) does not apply to bolometric observations but to observations converted to the emitter's rest frame. Such a conversion results in a 5 log(1+z) magnitude unit's addition to the magnitudes observed in relevant band-pass filters.

The DU prediction (2) applies to observed bolometric magnitudes. The DU prediction for SC's converted magnitudes is obtained by adding an extra 5 log(1+z) magnitude units to the prediction (5) thus resulting in

$$m_{DU(\mathrm{SC\_converted})} = M + 5\log\left(\frac{R_H}{10\mathrm{pc}}\right) + 5\log(z) + 2.5\log(1+z). \tag{9}$$

The difference in the predictions results from the use of the distance for areal dilution and the interpreted effect of the redshift. DU relies on the optical distance corresponding to light travel distance in SC, whereas SC relies on the comoving distance. In the DU framework, Planck's equation is interpreted as the energy conversion at the emitter, not as an intrinsic property of radiation like in the SC framework which leads to $(1+z)^2$ redshift dilution. Combined with the areal $(1+z)^2$ dilution, the SC $(1+z)^2$ redshift dilution, leads to a total $(1+z)^4$ dilution of energy density while the volume increases in proportion to $(1+z)^3$ resulting in energy loss proportional to (1+z).

[vii] A. G. Riess et al., Astrophys. J., 607, 665 (2004)