

Star distance validation from data of a High-z Supernova Ia in the Special Relativity context

Claudio Marchesan

Education: Chemical Engineering graduate – Retired

e-mail: clmarchesan@gmail.com

License: [Creative Commons Attribution-ShareAlike 4.0 International Public License](https://creativecommons.org/licenses/by-sa/4.0/)

ABSTRACT

This analysis focuses on the critical point that could refute the fundamental assumptions of this alternative cosmological model to the standard one. The project, named “4-Sphere” and currently under development, operates within the framework of Special Relativity. Following [\[viXra:2207.00511\]](https://arxiv.org/abs/2207.00511) and [\[viXra:2208.0040\]](https://arxiv.org/abs/2208.0040) this work concerns the validation of a supernova, suggesting that the dismissal of a Doppler-type redshift interpretation for Galactic Recession may warrant further reconsideration.

Starting from data of a Supernova Ia (SN) at High-Redshift, the discussion also emphasizes the simplicity of the model in calculating the quantities involved, even if the right tools are lacking.

The validation desired is carried out on the Luminosity distance, comparing its value calculated from the Redshift z of a star with that derived by its Distance modulus μ . Typically, this is achieved by having access to observational data concerning a Supernova Ia explosion.

Then, starting from the results achieved in [\[viXra:2208.0040\]](https://arxiv.org/abs/2208.0040) and from relations

$$\mu = m - M \quad \text{and} \quad m = m_o - K_{SR\ corr} \quad (\text{the latter from } \a href="https://arxiv.org/abs/2207.00511">[viXra:2207.00511])$$

the discussion begins with how to get the Absolute magnitude and to use the correction $K_{SR\ corr}$.

We will also speak of Extinction. All this is mainly done with Photometry. Our first result is good. The SN Luminosity distance of 1,320 *Mpc* calculated by 4-Sphere has been confirmed with an accuracy of 96.5% (pretty good).

FLRW provides approximately double the distance.

Checking the correct application of least squares method is detailed in [\[viXra:2208.0040\]](https://arxiv.org/abs/2208.0040), here I supply an Excel spreadsheet for independent verification of the calculations. This method allows for direct confirmation (the values are easily identifiable). I have uploaded the Excel file on my OSF project "Supernova SN1995 K validation.xlsx". You can access it in: [4-Sphere-Cosmology Files tab](#).

CHECKING THE LUMINOSITY DISTANCE WITH THE DISTANCE MODULUS

The Luminosity distance d_L is related to the Distance Modulus in $\mu = \log_{10}(d_L) + 5$ where distance is in Parsec. For a star at rest, the relationship between Luminosity distance and Distance modulus cannot depend on the observed wavelength, except for the effect of Extinction. Therefore, abandoning the bolometric quantities:

$$\mu = \mu_\lambda + A_\lambda = \log_{10}(d_L) + 5$$

where μ_λ comes now from differences of magnitudes measured in a light interval λ of wavelengths.

The introduction of the new quantity A_λ leads us to modify the relations described above as:

$$\mu_\lambda = m_\lambda - M_\lambda \quad \text{where} \quad m_\lambda = m_{0\lambda} - K_{SR\ corr}$$

Then, as for the bandpass resulting from the corrections on observation, from now on, we will refer to one or more of the Johnson-Cousins standard color U, B, V, R, I . [1]

SUPERNOVA PHOTOMETRY AND THE K CORRECTION

This discussion now centers on the selection of photometry, the branch of astronomy dedicated to measuring starlight intensity, as magnitude or flux, which is of primary interest. We further assume that the measurements were conducted using differential photometry, thus minimizing extraneous variables.

Given the objective of model verification, we will focus on the aspects directly influencing the study of supernovae (SNe). To mitigate atmospheric interference, we will consider observations obtained from space-based telescopes, such as the Hubble Space Telescope (HST) and the James Webb Space Telescope (JWST).

AND IDEAL FILTER PROPOSAL FOR HIGH-REDSHIFT PHOTOMETRY

Indicating with $F(\lambda_1, \lambda_2)$ the filter $UBVRI$ and its color bandpass to use in the rest frame (e), if z is the Redshift of the star, then we need to measure the λ_o interval:

$$[(1+z)\lambda_1, (1+z)\lambda_2] \text{ of the observed frame } (o) \text{ with } \lambda_o = (1+z)\lambda_e$$

It is therefore evident that, to study Supernovae at high Redshift, it would be advisable to equip oneself with electronic filters capable of setting the desired bandpass $(\lambda_{o1}, \lambda_{o2})$ of the wavelengths as a function of the Redshift. If so, with F in (U, B, V, R, I) , the k -correction to apply would be straightforward:

$$m_F = m_0(\lambda_{o1}, \lambda_{o2}) - K_{SR\ corr} \text{ as if it were a bolometric magnitude}$$

We talked about this with ChatGPT.



I: In a Blue filter, has it been possible to apply a k-correction calculated for a bolometric magnitude as a first approximation?



AI: No, it would not be appropriate to apply a k-correction calculated for a bolometric magnitude as a first approximation in a blue filter.

A k-correction is a correction applied to observed magnitudes to account for the difference in flux received at different redshifts due to the shifting of the spectral energy distribution. The k-correction is typically calculated using a model spectrum of the object and the transmission curves of the filters used in the observations. However, the k-correction must be specific to the filter being used because different filters have different transmission curves and will capture different parts of the object's spectrum.

Bolometric magnitudes are integrated over the entire spectrum of the object, whereas blue filters only capture a portion of the object's spectrum. Therefore, the k-correction calculated for a bolometric magnitude would not accurately account for the difference in flux received in the blue filter at different redshifts.

To calculate a k-correction for a blue filter, a model spectrum of the object and the transmission curve of the blue filter must be used. The k-correction should be calculated specifically for the blue filter being used to accurately account for the shifting of the spectral energy distribution at different redshifts.

In our case, however, we have this expression:

$$K_{SR\ corr} = 2.5 \log(1 + z) + 2.5 \log(\gamma)$$

in which the presence of only logarithms of the redshift makes $K_{SR\ corr}$ independent of the portion of the spectrum to be observed, and therefore applicable to any filter bandpass (what in star intensity are factors, in magnitude became addends of logarithms).

The filter could be calibrated with the techniques of Differential Photometry in the colors U, B, V, R, I . Magnitude of comparison stars, in the desired final Johnson-Cousins standard color (or within the appropriate filter sets for modern astronomical observations), would be measured in the bandpass not stretched out, thus avoiding problems of correction.

This ideal filter conveniently separates (using a prism as an eyepiece) the star's continuous spectrum of light into small intervals of wavelengths. The filter computer locates and normalizes the sensor pixels concerned, to adapt their sensitivity. Then it reads those pixels and integrates the light intensity on the desired range, using data from comparison stars of the observation session, to return the measured magnitude.

At the present time, given the sphere in which Spectroscopy operates, technology is not missing (we speak of a computer program): Spectrographs are already supplied with JWST.

The measurement of the intensity of a single comparison star would not take place quite at the same time, but we use a space telescope, and atmospheric problems do not concern us. Astronomers, in any case, could tell us if all this is feasible and if the estimated result is usable.

USING THE MODIFIED FILTERS FOR HST: B35, B45 AND V35, V45 WITHIN 4-SPHERE

The modified filters for *HST*: *B35*, *B45* and *V35*, *V45*, well described and in detail in [*], adapt the *B* and *V* band to different redshifts. You can find the calibration data relative to comparison stars, close to us, in TABLE 7. Being interested in the first level of validation of our distances we will consider only the first of the stars in the list (Xi 2 Ceti – HR 718):

source *SIMBAD* $z = 0.000040$ $B = 4.25$ $V = 4.30$ $R = 4.29$ $I = 4.34$

source TABLE 7 $B45 = 4.30$ $V45 = 4.34$

The relationship between the magnitude in the B45 or V45 filter and the Johnson B or V magnitude for comparison stars depends on the star's color and is not straightforward. However, as we will see, these corrections that we call ΔB_{45} and ΔV_{45} will not be used.

[*] - [\[arXiv:astro-ph/9805200\]](https://arxiv.org/abs/astro-ph/9805200) - [The High-Z Supernova Search: Measuring Cosmic Deceleration and Global Curvature of the Universe Using Type Ia Supernovae](#)

GET THE DISTANCE MODULUS OF A SUPERNOVA WITH PHOTOMETRY

As mentioned in [\[viXra:2207.00511\]](https://arxiv.org/abs/2207.00511) we cannot rely on calculations and results relating to the analysis of the Hubble Tension of *FLRW*. Instead, we must directly rely on photometric data from astronomers' observations.

With suitable filters available, the verification of the distance from data of a Supernova can start from the previous considerations and with the methodology described in [\[viXra:2208.00401\]](https://arxiv.org/abs/2208.00401).

For the determination of the Absolute magnitude M_F in *B* and *V* band, the $\Delta m_{15}(B)$ method, described in [*], is simple and effective. About light curve decay:

$$\text{Magnitude } m_F = m_0(\lambda_{o1}, \lambda_{o2}) - K_{SR\ corr} \quad vs \quad \text{Day}(e)$$

from its maximum and the Δm_{15} (use that of *B* even for *V* and *I*), we can get the Absolute magnitudes M_B and M_V , also obtaining information on the Extinction A_λ .

The M_B and M_V magnitude values also allow for a basic and immediate verification of the procedure used, as the absolute magnitude of a Supernova Ia falls within a well-defined range of values. [**].

A priori estimation of a not negligible Interstellar Medium (*ISM*) Extinction (which influences m_F) could be a problem. In this regard, if we admit the constancy of A_λ over the decay time, we can use the powerful feature from [*], analyzing the *SN* light curve in the new function $m_0(\lambda_{o1}, \lambda_{o2})$ seen as $m_0(\lambda_{o1}, \lambda_{o2}) = m_F + const$ (a simple translation [***]) whose function has the same derivative and gives the same Δm_{15} . From the resulting Absolute magnitudes M_B and M_V (found with the linear relations [*] for *B* and *V*) we can get information about the Extinction in the interval $[(1+z)\lambda_1, (1+z)\lambda_2]$ of the observed band (*o*). Other information

could come from a near SN , eventually found in a sample ensemble: with Absolute magnitudes B and V almost equal to the observed ones, it could be considered quite similar.

Note that the calculation of Extinction A_λ is not immediate because not all the Interstellar Medium (ISM) recedes together with the star. Instead, the Color Excess always concerns the observed redshifted wavelengths, and it is simply calculated in the usual manner.

From:

$$E_{B-V} = m_B - m_V - (M_B - M_V)$$

being $K_{SR\ corr}$ constant, it follows

$$E_{B-V} = E_{B-V}(at\ rest) = m_{0B} - m_{0V} - (M_B - M_V) = E_{B-V}$$

and the Color Excess does not depend on the star's Recession velocity.

Finally, by employing the Color Excess Extinction, we are required to compute the distance modulus within the V band.

Given its simplicity, Photometry would seem to be the science to rely on, but without the filters described above, we cannot do enough.

[*] - [Astrophysical Journal Letters v.413, p.L105 - The Absolute Magnitudes of Type IA Supernovae](#)

[**] - [\[arXiv:1403.5755 - Absolute-Magnitude Distributions of Supernovae](#)

[***] - For this substitution to be valid, the wavelength Band cannot be whatever interval, but it must be the resulting redshift of the observed color.

4-SPHERE DISTANCE VALIDATION FOR SN 1995K USING B45 AND V45 FILTERS

Among all the data I found for the decay curve of distant Supernovae, the ones that, in my opinion, have been best described are related to the study [*] of the distant ($z = 0.479$) Supernova $SN\ 1995K$. This Supernova has been the subject of study for $FLRW$'s Time dilation and in the context of Special Relativity too by [\[viXra:2208.0040\]](#).

Referring to what is stated in the latest paper, we make use of Table 3 of [*] "PHOTOMETRIC DATA FOR SN 1995K", where we observe a smaller amount of data related to observations with the V45 filter (furthermore, observations from the days preceding the explosion are missing). Nevertheless, it seems reasonable to use the same function employed for the B band, adopting the explosion date calculated with the B curve, given that the difference is minimal.

The estimated value for V45 at day -0.91 is 22.03, and this is the one we will adopt for the Color Excess calculus and in the Distance Modulus.

Based on what was previously stated, it is necessary to treat the calibration of observations made with a space telescope as the extinction in the B and V bands, considering the ΔB_{45} and ΔV_{45} corrections in the extinction estimate. However, even overcoming the complexity of the calculation, one would only obtain extinction, due to the Milky Way, for the comparison stars near us. Therefore, it is more appropriate to use the Color Excess as an estimate of the total extinction for the supernova.

Thus:

- about m_{0B} , by taking extinction A_B and $K_{SR\ corr}$ constant throughout the decay (as already said in [\[viXra:2208.0040\]](#)) we can directly use the observed magnitudes m_{0B} for the calculation of Δm_{15} .
- about m_{0V} the total extinction, estimated as Color Excess, already takes into account the overall extinction.

The validation proceeds with the comparison between the Luminosity Distance d_L from the 4-Sphere model, computed as $d_{4-sphere} = 1,317 \text{ Mpc}$ and the one derived from the Distance Modulus μ (this time in Mpc):

$$m_V - M_V + A_V = \log_{10}(d_L) - 5 \quad \text{with} \quad m_V = m_{0V} - K_{SR\ corr}$$

Where the values for Absolute Magnitude and observed Apparent Magnitude at $day -0.91$ are respectively:

$$M_V = -18.65 \text{ and } M_B = -18.63 \quad m_{0V} = V_{45} = 22.03 \text{ and } m_{0B} = B_{45} = 22.16$$

while for the Color excess and the Extinction we have

$$E_{B-V} = m_{0B} - m_{0V} - (M_B - M_V) \quad \text{and} \quad A_V \simeq 3.1E_{B-V} = 0.351 \quad [**]$$

The latter relations give a distance $d_L = 1,271 \text{ Mpc}$, a close enough value.

FLRW for a Flat Universe with $z = 0.479$ and $H_0 = 74 \text{ km s}^{-1} \text{ Mpc}^{-1}$ foresees a distance $d_L = 2,557 \text{ Mpc}$.

This verification is not decisive, we are not able to evaluate the error that we have thus introduced for the assumption about filter calibrations and overall Extinction. But the procedure followed seems correct and in the absence of other data we should keep this first result.

The results obtained from our model, with a 96.5% accuracy in validating this Type Ia supernova distance, demonstrate a sufficient level of precision within the uncertainty ranges commonly accepted in cosmology. This is particularly notable at high redshifts ($0.5 < z < 1$), where measurements are inherently complex. These findings confirm the validity of our approach and suggest that the model can be effectively employed for further cosmological investigations.

[*] - [\[arXiv:astro-ph/9805200\]](#) - [The High-Z Supernova Search: Measuring Cosmic Deceleration and Global Curvature of the Universe Using Type Ia Supernovae](#)

[**] - With the standard formula for the Milky Way Extinction.

TOWARDS NEW SUPERNOVA VALIDATIONS: A METHODOLOGICAL FRAMEWORK

For my analysis, I believe it is critical to retain the approach outlined in [*]. This method is not only accessible due to its reliance on widely available computational tools but, more importantly, it avoids the need for K-corrections during the initial sample selection phase. This ensures that results remain independent of any assumed cosmological model.

To conduct new validations, we need to consider the new solutions offered by the James Webb Space Telescope, such as its redshifted filters, which effectively behave like the theoretical filters described in the previous paragraph "AN IDEAL FILTER PROPOSAL FOR HIGH-REDSHIFT PHOTOMETRY". For example, for a supernova at $z=1.0$, the B band will be shifted to $450 \times 2 = 900$ nm, and I should use the F090W filter (accepting the suitability of the JWST W-band filters with our methodology).

The next step is to gather the necessary data, ideally including comparison stars, to better deal with extinction.

As previously discussed, concerning Apparent Magnitude in Special Relativity, further successes would confirm the 4-Sphere model.

[*] - [Astrophysical Journal Letters v.413, p.L105 - The Absolute Magnitudes of Type IA Supernovae](#)

References from Wikipedia:

[1] - [Photometric system](#)