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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

ABSTRACT

The arrival of the James Webb space telescope *(JWST)* opens new opportunities for verifying cosmological models, raising a debate among alternative models to ΛCDM and $FLRW$: At the time of writing nothing is certain yet, but it could also happen that, in a while, the existence of the Big Bang itself and the math expression of distances in $FLRW$ could come to be mutually exclusive.

This analysis concerns some aspects of validation of the Cosmological Model introduced in [viXra:2006.0202]. 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. In the most important case, this is possible knowing the data relative to an explosion of a Supernova Ia.

Then, following what said in [viXra:2207.0051] and from relations

$$\mu = m - M \quad \text{and} \quad m = m_o - K_{SR\ corr}$$

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 even if not decisive. The SN Luminosity distance of 1.300 Mpc calculated by 4-Sphere has been confirmed. $FLRW$ provides approximately double the distance.

CHECKING THE LUMINOSITY DISTANCE WITH THE DISTANCE MODULUS

The Luminosity distance d_L (that is provided by the cosmological model) is related to the Distance Modulus in $\mu = log_{10}(d_L) + 5$ where distance is in Parsec (independently from the cosmological model). 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 on more of the Johnson-Cousins standard color *U, B, V, R, I*. [1]

SUPERNOVA PHOTOMETRY AND THE K CORRECTION

The discussion, now, presupposes the choice of Photometry that it is the branch that is specific to measure starlight intensity, as magnitude or flux (that is what interests us). We also assume that the measurements were taken as Differential Photometry, so that other aspects are not to consider.

Given the purpose inherent the model verification, we will mention here the aspects that directly affect the study of a Supernova *(SN)*. To avoid problems due to the atmosphere, we will assume the use of a space telescope like Hubble *(HST)* and James Webb *(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:

$$[(1+z)\,\lambda_1, (1+z)\,\lambda_2] \text{ of the observed frame } (o) \text{ with } \lambda_0 = (1+z)\,\lambda_e$$

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:

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

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, 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 concerned sensor pixels, to adapt their sensitivity. Then it read 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.

Otherwise, the steps to be implemented and the tools to use, in the alternative model quoted above, are difficult even to hypothesize.

USING THE MODIFIED FILTERS FOR HST: B35, B45 AND V35, V45 WITH 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 a 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 $B45 = 4.30$ $V45 = 4.34$

Applying the stretched bandpass to a nearby star, in the absence of Redshift, with its wider integration interval for the flux, produces a magnitude plus the term $log_{10}(1 + z)$. This effect does not exist at the operating Redshift: z = 0.5.

Then, to use them in our context we just need to add these corrections to the measured magnitudes: $\Delta B_{45} \approx -0.05 + 0.42$ and $\Delta V_{45} \approx -0.04 + 0.42$

[*] - [arXiv: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:2207.0051] 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:2208.0040].

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 days indicated in the abscissas must refer to the system at rest. This then also allows a good verification, at the various Redshifts, of the Time Dilation foreseen, whatever is the model, because the Absolute magnitude of a Supernova Ia has a well-determined range of values [**].

The 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 the star. In the mentioned case $z = 0.5$, for a distance calculated in band B, Extinction A_λ, in Milky Way, must be applied on m_B as the Visible A_V while, close to the star, usually as the Blue A_B.

Instead, the Color Excess always concerns the observed redshifted wavelengths, and it is simply calculated in the usual manner: $E_{B-V} = m_{0B} - m_{0V} - (M_B - M_V)$. 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: $\mu_\lambda - A_\lambda = m_\lambda - M_\lambda$ where $m_\lambda = m_{0\lambda} - K_{SR\ corr}$

From:

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

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

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

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

Given the 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].

With reference to what is stated in this last paper, we always refer to Table 3 of [*] "PHOTOMETRIC DATA FOR SN 1995K" where we can see that the data relating to the V45 filter are not sufficient to describe the entire curve (the observations relating to the days before the explosion are missing).

We will then use a simple linear regression only to have an estimate of the filter value for magnitude at day 0. Indeed, the measured value of V45 for the nearest day, April 3, has a too high (30) margin of uncertainty. The estimated value for V45 at day 0 is 22.10, and this is the one we will adopt for the Color Excess calculus.

As stated above, the corrections to apply to the measured magnitudes are:

$$\Delta B_{45} \approx -0.05 + 0.42 \;\text{ and }\; \Delta V_{45} \approx -0.04 + 0.42$$

With the Absolute magnitude for V coming from $M_V = 1.949\,\Delta m_{15} - 20.883 = 18.72$, then for the luminosity Distance d_L we need to compare its value from the 4-Sphere model, computed as $d_{4-Sphere} = 1.317\ Mpc$ with that from the Distance modulus (this time in Mpc):

$$m_B - M_B - A_B = log_{10}(d_L) - 5 \quad \text{with} \quad m_B = m_{0B} - K_{SR\ corr} = B45 + \Delta B_{45} - K_{SR\ corr}$$

where the values for the observed Apparent magnitude m_{0B} and m_{0V} are that of $B45 = 22.19$ and $V45 = 22.10$ at *day* 0, while for the Color excess and the Extinction we have

$$E_{B-V} = m_{0B} - m_{0V} - (M_B - M_V) \quad \text{and} \quad A_B \simeq 3.1E_{B-V} = 3.1 * 0.08 = 0.25$$

The latter relations give a distance $d_L = 1.312\ Mpc$ a very good value. *FLRW* for a Flat Universe with $z = 0.479$ and $H_0 = 74\ km\ s^{-1}Mpc^{-1}$ foresees a distance $d_L = 2.557\ Mpc$.

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

[*] - [ads: DOI 10.1086/306308] -The High-Z Supernova Search: Measuring Cosmic Deceleration and Global Curvature of the Universe Using Type Ia Supernovae

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

References from Wikipedia:

[1] – Photometric system