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Concerning the Time Dilation of the Supernovae

Claudio Marchesan

Education: Chemical Engineering graduate – Retired

e-mail: clmarchesan@gmail.com

ABSTRACT

This brief analysis builds upon the work presented in [viXra:2207.0051]. The observations discussed aim to substantiate the rationale behind an alternative cosmological model to the standard one. The project, named "4-Sphere" and currently under development, operates within the framework of Special Relativity.

Astronomers posit that Type Ia Supernovae serve as a cosmic clock. Their observational efforts focus on correlating the time dilation of this clock with the redshift (z) of the supernova, thereby seeking to identify the cosmological model that best aligns with the observed data.

The measured time dilation is also utilized in the distance calculations of Type Ia supernovae, as demonstrated in my work [viXra:2208.0152].

The Friedmann-Lemaître-Robertson-Walker (*FLRW*) metric, a cornerstone of the ΛCDM model—currently the most advanced model with significant predictive and empirical successes—attributes its dominance over alternative models primarily to the time dilation analysis of supernovae. Its prediction yields a value of ($1+z$), where z represents the redshift.

In this concise discussion, we aim to delineate the core issues at stake, articulating our perspective and comparing the standard model with alternative models, using time dilation in Special Relativity (*SR*) as a benchmark.

To ensure transparency, I have outlined the method for verifying my application of the mean squares estimation: Both the instructions for installing the necessary software, and the supernova data, can be found in my OSF Project Wiki Pages. You can access it in: Supernova validation m.s. extimation. This involves using Python, and the small initial effort to configure its working environment is amply rewarded by the powerful functionalities that this platform offers in the scientific field (Visual Studio offers to developers the "Python Development Tool for Windows").

INTRODUCTION

To set the terms of the problem we need to clarify the concepts and quantities involved. In the first place, to compare a distant Supernova with a sample one, chosen near us, we need to speak of a Photometry Rest Frame [*].

To simplify, we refer to the Supernova Ia *(SN)*, as a monochromatic light source, and we will treat the absolute magnitude M_B in the color B band as the bolometric absolute magnitude M. Where necessary, however, we will refer to the brightness, and other quantities, in the various color bands: *U, B, V, I, ...* [1]

That simplification brings us back to the previous exposition [viXra:2207.0051], regarding the Apparent magnitude, to reach our synthesis on the K correction.

There we emphasized the difference between *FLRW* and *SR* in the rest frame concept. While for SR a star can be stationary and far away from us, for *FLRW* the stationary star must be placed close to us, at a chosen conventional distance of 10 Parsec *(Pc)*. So, while with *SR* we can define the K correction, in my opinion clearly, as the difference between the observed and the "intrinsic" Apparent Magnitude, in *FLRW* the K_{corr} relationship concerns the Apparent magnitude, the Absolute one and the Luminosity distance [*].

[*] - But this passage does not define completely the concept and, even in *FLRW* one speaks of an intrinsic Spectral Energy Distribution *(SED)*: [arXiv:astro-ph/0307149] - The Rest-Frame Optical Luminosity Density, Color, and Stellar Mass Density of the Universe from z=0 to z=3

HOW THE TIME DILATION OF THE SUPERNOVAE HAS BEEN VERIFIED

Regression analysis is employed by astronomers to analyze the evolution of a supernova explosion and construct its light curve from observational series, to fit the shape of the decay following the bump. From the resulting curve, quantities as t^B_{Max}, the time relative to the maximum of *B,* are derived.

Over time the procedures have refined becoming more and more sophisticated and complex but, to understand what the measurements are, underlying that regression analysis, we can refer to how the problem was addressed in [*].

Type Ia supernovae are known for their homogeneous nature. From this consideration arises the idea of studying a sample of nearby Type Ia SN to find a relationship between absolute magnitude and decay curve. In the study, the supernovae of the sample are all close to us, with their redshift in the range $0.0027 < z < 0.03$ and their absolute magnitude calculation not significantly affected by K-correction

The article highlights a very important relationship found between the absolute magnitude M_B of the *SN* and the quantity $\Delta m_{15}(B)$ that measures the amount of magnitude that the B light curve drops during the first *15* days following maximum:

$M_{band} = a + b \cdot \Delta m_{15}(B)$ where the parameters a and b, found by regression on the sample are given.

For the bandpass:

1. *B:* $M_B = -21.726 \; + 2.698 \cdot \Delta m_{15}(B)$
2. *V*: $M_V = -20.883 \; + 1.949 \cdot \Delta m_{15}(B)$
3. *I*: $M_I \; = -19.591 + 1.076 \cdot \Delta m_{15}(B)$

Hence, given the redshift z of the *SN* and with two measurements of the Apparent magnitude m_{Bo}, one at the peak and the other after 15 days, it is possible to deduce all the rest.

It is now a question of establishing the way to operate.

Seen from the *SR* context, a light source at rest and far away from us is a perfectly defined physical state to which it is possible to associate its Apparent magnitude m. Are given the relations:

$m - M = \mu$ and $m = m_o - K_{SR\ corr}$ where the relations are valid in a color Band too.

The equipped procedures used by *FLRW* allow to recalculate K_{corr} at each point of the decay curve, managing in this way even strong deviations of the light spectrum after the bump. However when K_{corr} is constant, its value disappears in the differences in magnitude.

In the absence of known K_{corr}, being constant μ and with it $K_{SR\ corr}$, we can also refer to the moving light source with $\Delta m_{B0} = \Delta M_B$.

The problem, then, comes back to the measurement of some Apparent magnitudes observed at a distance of time that we know to be dilated by the γ Lorentz factor. By having more observations in the decay curve for the first *15-20* days, we can use a polynomial interpolation to estimate the second observation. Having some data before the explosion would be ideal!

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

SN CHECK IN THE SPECIAL RELATIVITY CONTEXT

Coming to the point, we choose [*] that studies the Time dilation for the distant ($z = 0.479$) supernova *SN 1995K*. To check the homogeneity properties, its similarity with two sample elements, *SN 1990N* and *SN 1991T,* has been searched for this faraway *SN:*

for *SN 1990N* $M_B = -18.74$ for *SN 1991T* $M_B = -18.96$

Our count is rough and adequate skills are lacking, so we will choose the simplest way. We will also clarify all the logical steps, using the data from [*], but without relying on its calculations.

To get Δm_{15}, the data are from Table 3 "PHOTOMETRIC DATA FOR SN 1995K" and the "bump" it is estimated [see *] on April 1 (our calculation agrees). Then:

$$m(B) = m_0(B45) - K_{corr}$$

By assuming extinction A_B to be constant throughout the entire decay curve, as it is $K_{SR\ corr}$ [*], we can ignore both in all subsequent computations, translating the entire curve without any effect on the magnitude difference between the two points separated by 15 days.

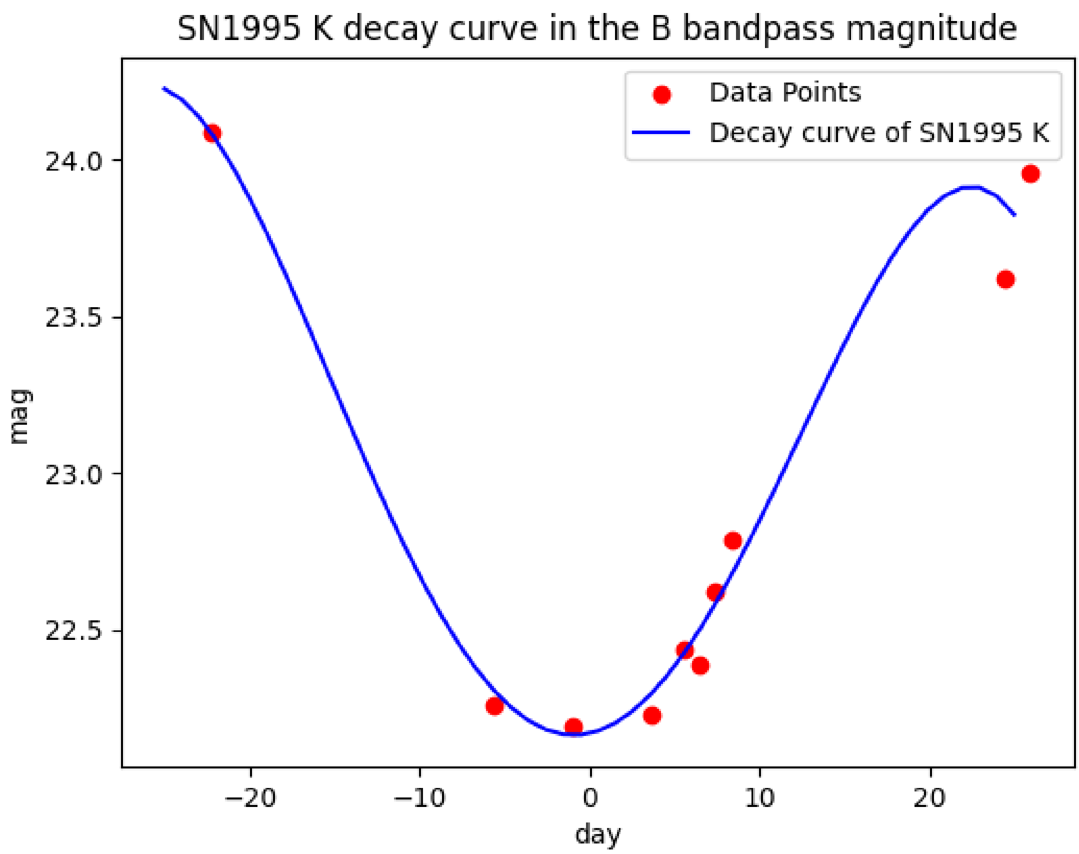
Conversely, $K_{SR\ corr}$ and Extinction will be essential for the verification of the Luminosity Distance to come from the Distance Modulus.

For $z = 0.479$ we have $\gamma = 1.078$ and the Time dilation is given by $\delta t_o = \gamma \delta t_e$. This means that the observation of April 5 does not refer to a value $m_0(B45) = 22.23$ found after 4 days from the maximum, but after 3.71 days.

Following this schema, we used a fourth-degree polynomial regression [***] in which each point was weighted according to the inverse of its uncertainty intervals. For example:

to the day April 5	$m_0(B45) = 22.23\ (09)$	was assigned $weight = 1/9$.
$day\_t_e = 3.71$	$magnitude = 22.23$	$weight = 1/9$

The relationship between Δm_{15} and magnitude for the B, V, and I bands was derived from a sample of nearby supernovae. Therefore, we must apply this 15-day interval in the supernova's rest frame.



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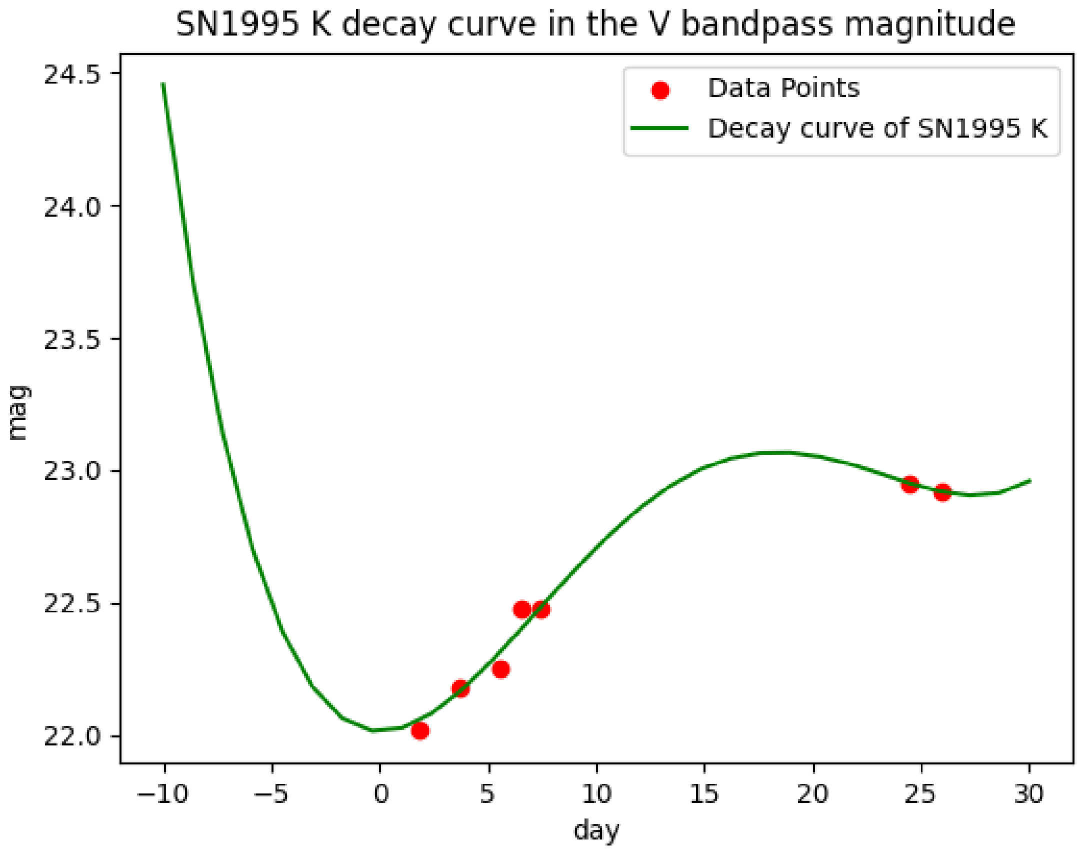
With the explosion estimated on April 1 $day_{\_t_e} = -0.91$ $with$ $m_0(B45) = 22.16$ and extrapolating the value on $day\_t_e = 14{,}09$ with $m_0(B45) = 23.31$ we get $\Delta m_{15} = 1.148$ with an Absolute magnitude: $M_B = 2.698 \cdot \Delta m_{15} - 21.726 = -18.63$

In terms of similarity, *SN 1995K* can be considered intermediate between *SN 1980N* and *SN 1990N*. The absolute magnitude of a Type Ia Supernova has a well-defined range of values, and this similarity assures us that our value is consistent.



Extrapolating the value on April 1 $day_{-t_e} = -0.91$ *with* $m_0(V45) = 22.03$ we get an Absolute magnitude of : $M_v = 1{,}949 \cdot \Delta m_{15} - 20{,}883 = -18.65$.

As previously stated, the time dilation value is utilized to calculate the distance of a Type Ia supernova. Furthermore, stellar distances are crucial for the validation or falsification of a cosmological model. With these observations together with those in [viXra:2207.0051] and in [viXra:2208.0152] I believe we should not yet rule out a model based on *SR*.

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

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

[***] – NumPy: The Polinomial class: Copyright (c) 2005-2022, NumPy Developers. All rights reserved.

THE USE OF QUARTIC FOR CURVE FITTING HAS PROVEN TO BE QUITE CONVINCING

Regarding the following: Remember that maxima and minima have inverse meaning between magnitude and brightness.

I: From the analysis of SN1995 K, I noticed that a quartic function fits well near the peak but introduces incorrect maxima beyond 20-30 days. Based on the observations, I still have the impression that any potential replacement for this curve should nevertheless account for a sudden flattening after the first 20 days. How could this be justified?

AI: Possible explanations for a sudden flattening after 20 days:

1. Transition between decay processes

   - In the first days, luminosity is mainly driven by the radioactive decay of nickel-56 $^{56}Ni \rightarrow {}^{56}Co$ this shift might not be gradual but could instead cause a sharp change in the slope of the light curve.
   - After 15-20 days, cobalt-56 $^{56}Ni \rightarrow {}^{56}Fe$ becomes dominant, altering the luminosity curve. An additional term might be needed to model this transition.

2. Opacity of the ejected material

   - In the first days, the supernova is dense and opaque, but as it expands, opacity decreases rapidly. If this transition happens abruptly, the luminosity may stop declining as fast, leading to a flattening of the curve.

3. Interaction with the surrounding medium

   - If the supernova interacts with circumstellar material, additional emission contributions could alter the expected decay.

   - Depending on the structure of the supernova and the composition of the expelled material, part of the energy could be temporarily trapped and then released more gradually. This effect might reduce the apparent rate of decline in luminosity.

References from Wikipedia:

[1] – [Photometric system]