“Doppler De-boosting” and the Observation of “Standard Candles” in Cosmology

M. Zilberman[1]

[1]*Shiny World Corporation, Concord, ON, Canada L4K 0C0*

ABSTRACT

"Doppler boosting" is a well-known relativistic effect that alters the apparent luminosity of *approaching* radiation sources. "Doppler de-boosting" is the same relativistic effect observed but for *receding* light sources (e.g. relativistic jets of AGN and GRB). "Doppler boosting" alters the apparent luminosity of approaching light sources to appear brighter, while "Doppler de-boosting" alters the apparent luminosity of *receding* light sources to appear fainter. While "Doppler de-boosting" has been successfully accounted for and observed in relativistic jets of AGN, it was ignored in the establishment of Standard candles for cosmological distances. A Standard Candle adjustment of Z>0.1 is necessary for "Doppler de-boosting", otherwise we would incorrectly assume that Standard Candles appear dimmer, not because of "Doppler de-boosting" but because of the excessive distance, which would affect the entire Standard Candles ladder at cosmological distances. The ratio between apparent (L) and intrinsic (Lo) luminosities as a function of the redshift Z and spectral index α is given by the formula $\mathcal{M}(Z) = L/Lo=(Z+1)^{\alpha -3}$ and for Type Ia supernova appears as $\mathcal{M}(Z) = L/Lo=(Z+1)^{-2}$. "Doppler de-boosting" may also explain the anomalously low luminosity of objects with a high Z without the introduction of an accelerated expansion of the Universe and Dark Energy.

Key words: galaxies: distances and redshifts - distance scale - dark energy

1 INTRODUCTION.

"Doppler boosting" is a well-known relativistic effect that increases the apparent luminosity of *approaching* light sources. Specifically, it allows to obtain the intrinsic value of the luminosities (L_o) of relativistic jets by their apparent luminosity (L), velocities and spectral index (Kellermann, Kovalev & Lister 2007; Lister 2003; also Massi & Torricelli-Ciamponi 2014 for LS I +61^{0}303). This relationship is described by the following formulas

$$L = L_o \delta^p \qquad (1),$$

where the Doppler factor δ is

$$\delta=\gamma^{-1}(1-\beta\cos\theta)^{-1} \qquad (2),$$

the Lorentz factor γ is

$$\gamma=(1-\beta^2)^{-1/2} \qquad (3),$$

the velocity β is the speed v of a relativistic light source normalized to the speed of light c

$$\beta=v/c \qquad (4),$$

θ is the angle between line of sight and the velocity direction, α is the spectral index ($S_\nu \propto \nu^{\alpha}$), p=2-α for a continuous jet emission, and p=3-α for a discrete emitting region (Lister 2003).

"Doppler *de*-boosting" (Zhou & Su 2006; Yang 2010) is the term of the same relativistic effect calculated and observed for *receding* sources of radiation, for example for receding jets of active galactic nuclei (AGN). While "Doppler boosting" alters the apparent luminosity of approaching ($0<=\theta<=90^0$) sources to be greater, "Doppler de-boosting" alters the apparent luminosity of the receding ($90^0<\theta<=180^0$) sources to be fainter.

2 "DOPPLER DE-BOOSTING" AND "STANDARD CANDLES"

Even if "Doppler de-boosting" was successfully observed in relativistic jets of the AGN and gamma-ray bursts (GRBs), it was not accounted for in the establishment of Standard candles for cosmological distances. Although disregarding "Doppler de-boosting" for low-speed Standard candles simplifies calculations, for Standard candles with Z>0.1 the correction of "Doppler de-boosting" appears to be necessary. Otherwise, we would incorrectly assume that Standard candles appear dimmer not because of "Doppler de-boosting" but because they are located further away than in reality. This would affect the entirety of the Standard candles ladder at cosmological distances and the following cosmological models.

The following presents "Doppler de-boosting" using the redshift parameter Z used in Cosmology. As for cosmological objects with the angle $\theta=180^0$, the Doppler factor δ is shown as

$$\delta=\gamma^{-1}(1+\beta)^{-1} \equiv (1-v^2/c^2)^{1/2}\,(1+v/c)^{-1} \qquad (5).$$

And since the redshift parameter Z and velocity v are linked as

$$Z+1 = (1+v/c)\,(1-v^2/c^2)^{-1/2} \qquad (6),$$

the δ and Z are linked as

$$\delta=1/(Z+1) \qquad (7).$$

As such, for the discrete emitting region parameter p=3-α (Lister 2003), the apparent luminosities (L), redshift parameter Z, and the intrinsic luminosities (L_o) relation is shown as

$$L = L_o / (Z+1)^{3-\alpha} \equiv L_o\,(Z+1)^{\alpha-3} \qquad (8),$$

$$\text{or } \mathcal{M}(Z) \equiv L/L_o=(Z+1)^{\alpha-3} \qquad (9),$$

where $\mathcal{M}(Z)$ is the ratio between the apparent and intrinsic luminosities as a function of redshift Z and spectral index α.

Regarding spectral index α in equation (9). For Type Ia supernova (SNIa), which are considered as Standard Candles on cosmological distances, per (Deng Wang & Xin-He Meng,

2018) the spectral index α is about 1 (by "Joint Light-curve Analysis" sample containing 740 SNIa data points) and for the supernova remnant RCW 86 the spectral index is between 1.5 and 2 (Abramowski at al., 2018). In other words, for SNIa we can expect a relationship between L and L_o as

$$\mathcal{M}(Z) \equiv L/L_o=(Z+1)^{-2} \qquad (10)$$

Chart fig.1 presents the influence of Doppler de-boosting to the apparent luminosities of SNIa for spectral indices α=1 and α=2, i.e. $\mathcal{M}(Z) =(Z+1)^{-2}$ and $\mathcal{M}(Z) = (Z+1)^{-1}$.

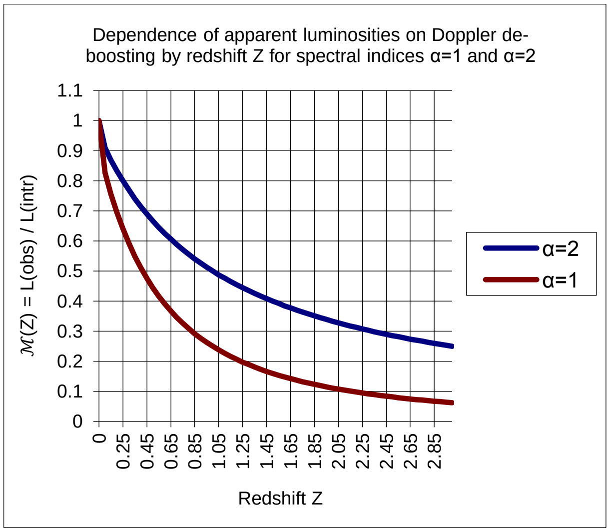

Figure 1. Influence of Doppler de-boosting to the apparent luminosities of SNIa for spectral indexes α=1 (red line) and α=2 (blue line).

As we can see, the luminosity of objects receding from the observer with a redshift of Z=3 appears 4 times fainter for spectral index α=2 and appears 16 times fainter for spectral index α=1. If we do not consider the "Doppler de-boosting" effect, we can incorrectly assume that these objects are located many times further away than they truly are.

Hence, the "Doppler de-boosting" effect (which is already confirmed in relativistic jets of GRB and AGN) may possibly explain the anomalously low luminosity of objects with a high Z without the introduction of an accelerated expansion of the Universe and furthermore the introduction of Dark energy. Instead, it can reveal and support certain new models.

3 CONCLUSIONS

A Standard Candle adjustment for Z>0.1 is necessary for "Doppler de-boosting", otherwise we would incorrectly assume that Standard Candles appear dimmer, not because of "Doppler de-boosting" but because of the excessive distance, which would affect the entire Standard Candles ladder at cosmological distances. The "Doppler de-boosting" effect may possibly explain the anomalously low luminosity of objects with a high Z without the introduction of an accelerated expansion of the Universe and furthermore the introduction of Dark energy.

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