A Test of LaTeX

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1 Abstract

This analysis combined data collected from multiple photmetric and spectroscopic observations and tecniques from decades of scientific papers[?][?] to create code that estimates the distance to the SN1987a-like supernova, SN2018hna. The analysis concludes that the derived distance, between 13-15 Mpcs, is within acceptable range of other estimates and confirms the accuracy of the data and method.

2 Introduction

The distance between us and the stars above was a mystery to ancient astronomers. Not knowing the true unfathomable distance, they assumed the stars were just points of light in a cosmic dome that surrounded and rotated around the earth, the "center of the universe". It took centuries of free thinkers to finally accept that we arent the center of the universe, and that stars are in fact just like our own sun, just very far away. It took longer still to determine how far away those stars actually were. Today, we have developed many techniques to solve this very problem. The techniqe I will be using in this paper to determine the distance to a supernova is called the Expanding Photosphere Method (EPM). It involves the expanding envelope of gas around the supernova, a calculated speed of the expansion, the temperature of the gas, and various spectral and photometric data.

3 Procedure

To start off, we have to talk about what becomes of a star during a Type - IIp supernova. When the star explodes, an envelope of gas expands in all directions at a high rate of speed. The speed of the expanding gas can be determined by looking at the spectrum of the light being emitted by the gas and comparing it to another source to see how blueshifted it is. This is done using spectroscopy. For the Expanding Photosphere Method to work, we have to assume that the expanding photosphere of gas is thin and uniform, meaning that it expands

evenly in all directions away from the star.
The equation we will use to determine the distance is called the angular radius.

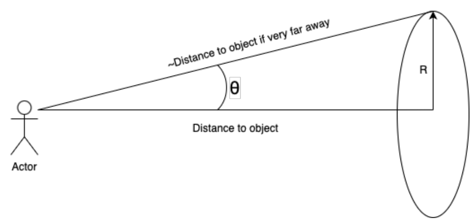

Figure 1: A diagram of angular radius.

In the above figure 3 there is a disk, a person, and a right triangle between them. Lets assume for the sake of explination that the disk is the Sun and the person is on Earth. The distance between the person and the Sun is d and the radius of the Sun is R. The angle θ created by the right triangle formed is called the angular radius. We can write this relationship as:

$$\tan\theta = \frac{\mathrm{R}}{\mathrm{d}} \tag{1}$$

The next thing we must take into account is the fact that the supernova that we are looking at is incredibly far away. This means the angular radius θ approaches 0. Using the small angle approximation, $\tan\theta$ becomes θ, and the equation 1 becomes:

$$\theta = \frac{\mathrm{R}}{\mathrm{d}} \tag{2}$$

Because the photosphere is expanding, the radius R is increasing over time with a measurable velocity. This allows us to set R to:

$$R = v(t - t_0) \tag{3}$$

Where v is the velocity of the photosphere at that time, t is the time since explosion, and t_0 is the time of explosion.
Next, since the supernova is very far away, we have to account for time dialation. This can be accomplished by using a constant in the following way:

$$d = d(1 + z) \tag{4}$$

Where d is the distance to the supernova and z is the time dialation constant.

This gives us:

$$\theta = \frac{v(t - t_0)}{d(1+z)} \tag{5}$$

We rearrange this equation to get it into slope intercept form:

$$t = \frac{\theta}{v}(1+z)d + t_0 \tag{6}$$

Where $(1+z)d$ is the slope and t_0 is the intercept. With this function 6 we can graph data points (in $(\frac{\theta}{v}, t)$ form) and find the line of best fit to determine the distance. The graphed data will look like figure 3.

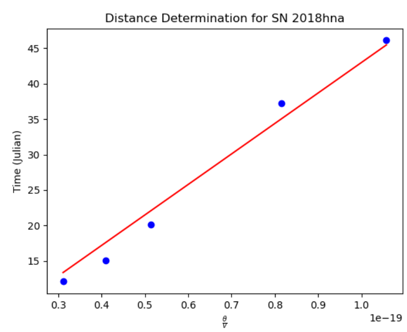

Figure 2: The graph of data points in blue and line of best fit in red.

Depending on the method of determining the angular radius θ, you may have to make multiple distances like figure 3. I will speak more about this in the data section.

4 Equations

$$\sin\theta = \frac{R}{d} \tag{7}$$

If θ is significantly smaller than 1, then $\sin\theta = \theta$

$$\theta = \frac{R}{d} \tag{8}$$

The radius is changing because of the expanding photosphere. We can calulate the velocity and starting point of expansion so $R = v(t - t_0)$.
Since the distance is many million lightyears, we have to account for time dialation. This is