Investigation of Luminance-and B-Band Width-Luminosity Relationship, and Further Observations of Type Ia Supernovae at the BSU Observatory

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Abstract

When observing Type Ia Supernovae, a large portion of observational astronomers utilize the blue (B) pass-band filter because there is a well-studied relationship between the 15-day decline rate and the peak magnitude in B. Unfortunately, the B-band also tends to have a low signal to noise ratio compared to other bands. The Luminance pass-band filter can achieve a much higher signal to noise ratio than the B-band. However, very few observations of Type Ia supernovae in the Luminance band have been made; as a result, there is no established relationship between the decline rate and peak luminosity. Understanding how the Luminance band relates to the B-band has the potential to allow more observatories to study Type Ia supernovae.

Introduction

Astronomers use Type Ia supernovae as "standardizable candles" to measure distances in the universe due to a mathematical consistency between the absolute magnitude and the 15-day decline rate shown by equation 1.

$$M_{Bmax} = -21.726 + 2.698\Delta m_{B15} \quad (1)$$

Because Type Ia supernovae are dim and require at least a month of continuous observation, they tend not to be studied by small observatories or those in less-than-ideal viewing locations. Many of these targets are discovered, but not followed up on – when this occurs, we miss the chance to measure the distance to the supernova's host galaxy[1]. Decreasing the observational difficulty by using the L-band could allow many more observatories to have a practical way to study them, and therefore lead to fewer missed chances.

During spring 2015, two BSU honors students (Ben Lombard and Sarah Peck) observed supernova J081659.74+511233.7 in the L-band in order to maximize signal-to-noise despite BSU's high light-pollution location and the telescope's small aperture. They produced a preliminary light-curve, confirming our capability to observe these dim targets. Three subsequent observations in B, V, R, and Luminance were conducted on Type Ia Supernova targets by Shane Johnson during summer 2015, and three more subsequently by members of the BEAR Team.

Methods and Materials

Observations:

Using the BSU observatory, we successfully imaged three Type Ia supernovae over approximately a one month period for each target with our primary focus in the B and Luminance bands. We took 60 data images for 30s per filter for a total exposure of 30min per filter. Data images were typically calibrated with 12 flat images, 12 dark images of 30s exposure, and 50 bias images.

Software:

- Maxim DL 6 - image processing and photometry
- TheSky6 - navigation
- Microsoft excel - calculations and fitting

Hardware:

- 14'' Celestron Edge HD telescope
- Paramount ME
- Apogee Alta U47 CCD
- Apogee FW50 filter wheel

Data and Analysis

Photometry:

Using Maxim DL 6's photometry feature, we measure a supernova's brightness repeatedly over a period of approximately one month relative to a stable reference star. Check stars determine the reference star's stability. Figure 1 shows how a typical data image would appear. Stars near the edges are not used because differences in chip sensitivity interfere with photometry. This effect is evident in Figure 1 as a change in background level toward the edges.

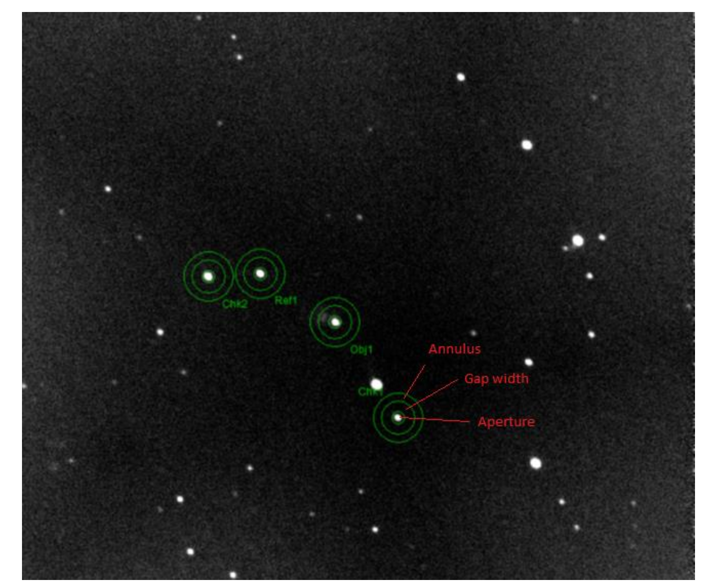

Fig. 1: Shows the object, the reference star, and two check stars.

ASASSN15li proved to be a Type II supernova[2] and ASASSN15ln's exact redshift was not determined – these data are therefore omitted. Two recent supernovae, SN 2017bgp and ASASSN16em, are not yet fully analyzed.

Modeling:

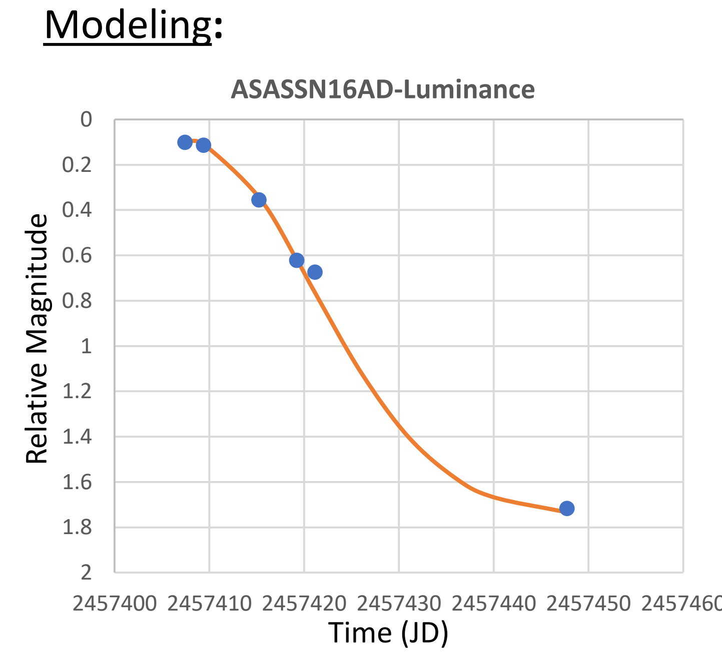

Fig. 2: ASASSN16AD- L light curve. Δm_{15}= 0.78

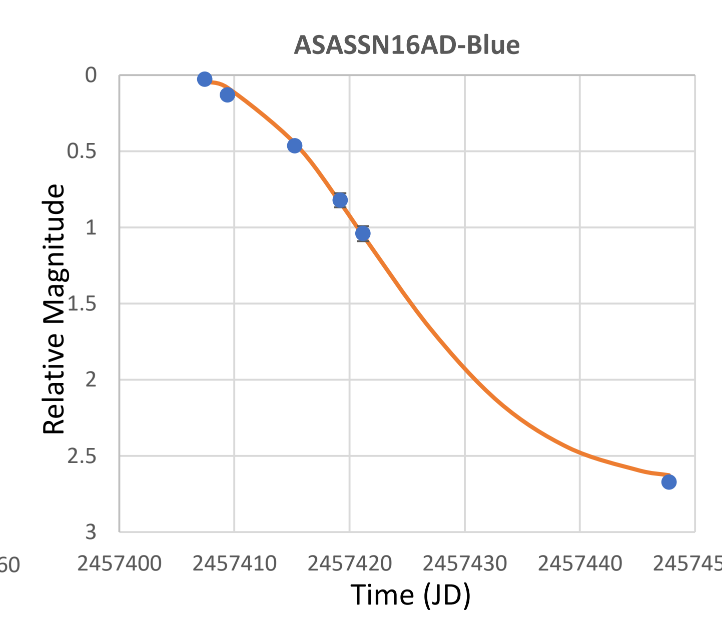

Fig. 3: ASASSN16AD- B light curve. Δm_{15}= 1.076

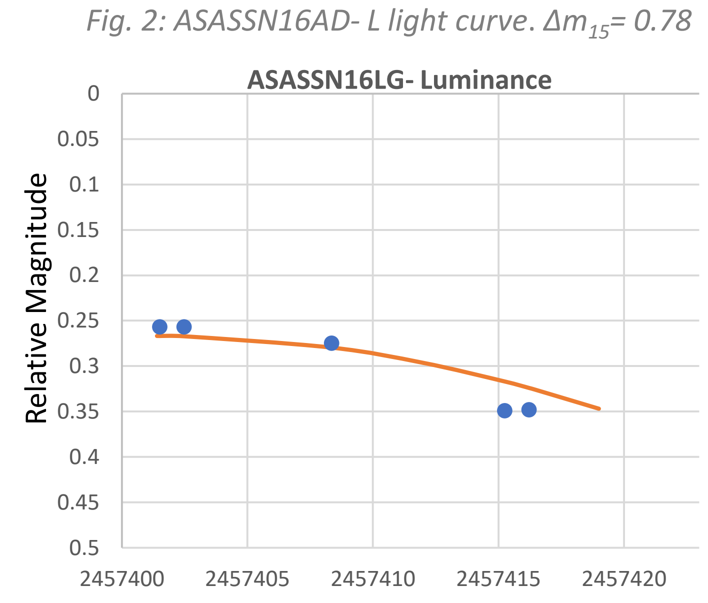

Fig. 3: ASASSN16LG- L light curve Δm_{15} = 0.058

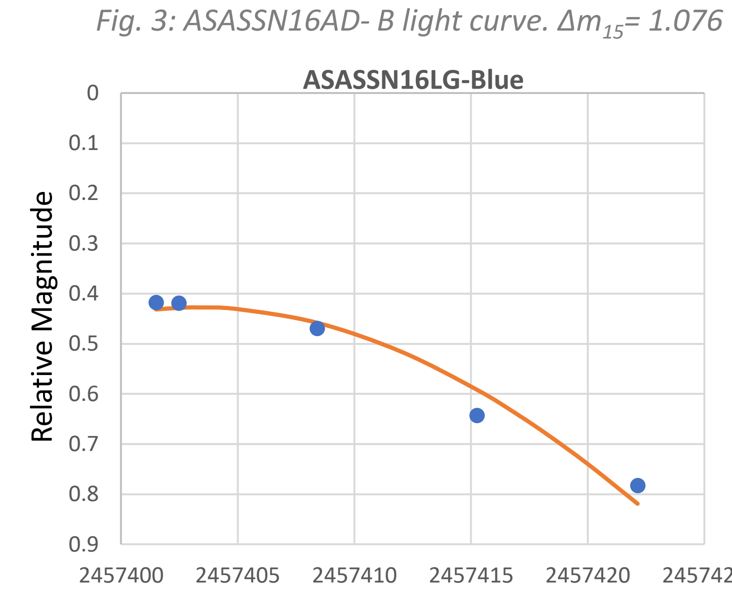

Fig. 4: ASASSN16LG- B light curve. Δm_{15} = 0.254

Other Δm_{15} Measurements		
ASASSN16AD-G: .546	ASASSN16AD-R: .755	ASASSN15la- B: .1

The lightcurves above have been corrected for time-dilation (due to relativistic recession velocities) based on reported redshifts from ASRAS and other large observatories[7]. Using the redshift of the supernova's host galaxy, z, we can calculate the true time in JD by using equation 2.

$$t' = \frac{t - t_0}{1 + z} + t'_0 \quad (2)$$

Plugging t' for t in the Gaussian fit will give us the true time at that point.

We used a simple Gaussian fit to model the early decline (after peak brightness, m_{max}).

$$\boldsymbol{m = m_{max} e^{\left(\frac{-(t-t_0)^2}{2\sigma^2}\right)}} \quad (3)$$

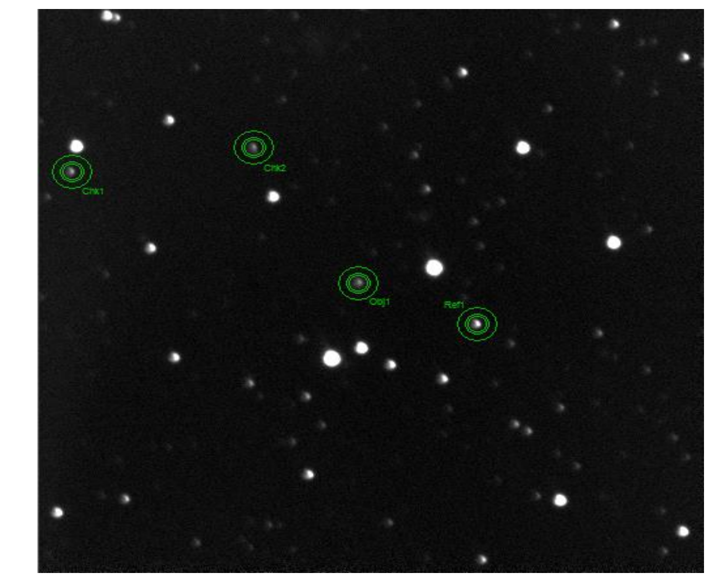

Fig. 5 shows ASASSN16lg has poor focus which may contribute to the poor fit, however does not explain the small error.

Conclusions

We are continuing to accumulate Type Ia supernova data at the BSU Observatory. We obtained good R squared values for our ASASSN16ad (.99 in L, and .98 in B) but poor R squared values for ASASSN16lg (.96 in B and .45 in L). In order to determine if there is a mathematical relationship between L and B, at least two more Type Ia supernovae must be observed and the fit to ASASSN16lg improved.

Future Work

- Determine if there exists a mathematical relationship between the Luminance and Blue filters
    - -Observe more supernovae
    - -Plot the 15-day decline rate of each supernova in B and Luminance to determine if there is a trend
- Correct for dust reddening due to interstellar dust within our galaxy and the host galaxy
- Apply standard magnitudes of reference stars to standardize apparent magnitude measurements for each supernova using equation 3.

$$m\text{-}M = 5\log(d) - 5 \quad (4)$$

- Add two more terms to the Gaussian fit program.

Acknowledgements

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References

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