Photometric Analysis of SN 2018bgz

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ABSTRACT

Over the past few decades, Type Ia Supernovae (SNe Ia) have proven to be very useful tools in extragalactic astronomy and cosmology due to the fact that they behave as "Standardizable Candles," objects that adhere to empirical relations that allow for methods to calculate their intrinsic brightness. Knowing a Supernova's (SN's) intrinsic brightness leads to further information about the SN by conducting photometric analysis. Here, we present an example of how that analysis can be done and what can be learned from it. Specifically, we present the result of our photometry of images taken over the course of about 5 weeks with CCD detectors on the 1-m Swope telescope at the Las Campanas Observatory and various nodes of the Las Cumbres Observatory Global Telescope (LCOGT)[1] of SN 2018bgz, a SN Ia located in the outskirts of UGC 9544 with a known redshift of $z = 0.034$. The most notable results from our photometric analysis include a Burns stretch-BV value of $s_{BV} = 1.089$, an inferred distance to the SN of $d = 142.4 \pm 5.4$ Mpc, , and a Hubble constant of $H_0 = 71.4 \pm 3.4 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Evidently, our analysis indicates that SN 2018bgz is close to a normally declining SN Ia, a conclusion that is made more sound by the fact that our value for the Hubble constant is consistent with other more robust measurements.

I. INTRODUCTION

Recent work has lead to many improvements in how we standardize Type Ia Supernovae (SNe Ia), the explosion of a Carbon-Oxygen White Dwarf whose mass exceeds the Chandrasekar Mass limit of 1.4 $M_{\odot}$. Phillips et al. (1993) demonstrated the usefulness of the measurement of the number of magnitudes that a SN decreases in the B-band in the 15 days after maximum, which is now known as the Phillips Parameter and denoted Δm_{15}; SNe with higher values of Δm_{15} have a lower intrinsic brightness and vice versa. Burns et al. (2011) discovered the empirical relation between brightness and the parameter stretch-BV, s_{BV}, which is the ratio of the number of days the SN is at B-V maximum and 30 days since normally declining SN have their B-V maximum epoch occur at ~30 days; analogous to Δm_{15}, a lower value of s_{BV} means a lower intrinsic brightness and vice versa. The difference between the two is that s_{BV} does a better job of describing fast declining SN; they are related by following equation given in Burns et al. (2018):

$$\Delta m_{15} = 0.98 - 2.02(s_{BV} - 1) \qquad (1)$$

Thus, our measurements of Δm_{15} and s_{BV} allow us to determine the absolute magnitude, *M*, of a SN (see Burns et al. 2018 for equations to do so). With *M* and a measurement of how luminous the SN appears to us on Earth encapsulated in the quantity known as the apparent magnitude, *m*, a distance to the SN, *d*, can be calculated with the following well-known equation:

$$m - M = 5\log_{10}(d) - 5 \qquad (2)$$

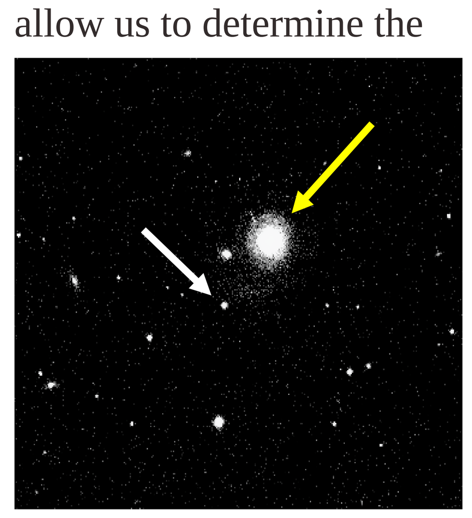

Figure 1: Field of SN 2018bgz which is indicated by the white arrow. The yellow arrow points to UGC 9544, the SN's host galaxy. Evidently, the SN is at the outskirts of the galaxy which can explain the lack of host reddening. See Fig. 4 for positional coordinates.

As a sanity check, we then used our value for *d* and a known value for UGC 9544's heliocentric velocity (given in Table 1) to determine a value for the Hubble Constant, H_0, using Hubble's Law which is:

$$v = H_0 d \qquad (3)$$

1. The nodes used are located in Sutherland, South Africa; CTIO in Chile; and Fort Davis, Texas.

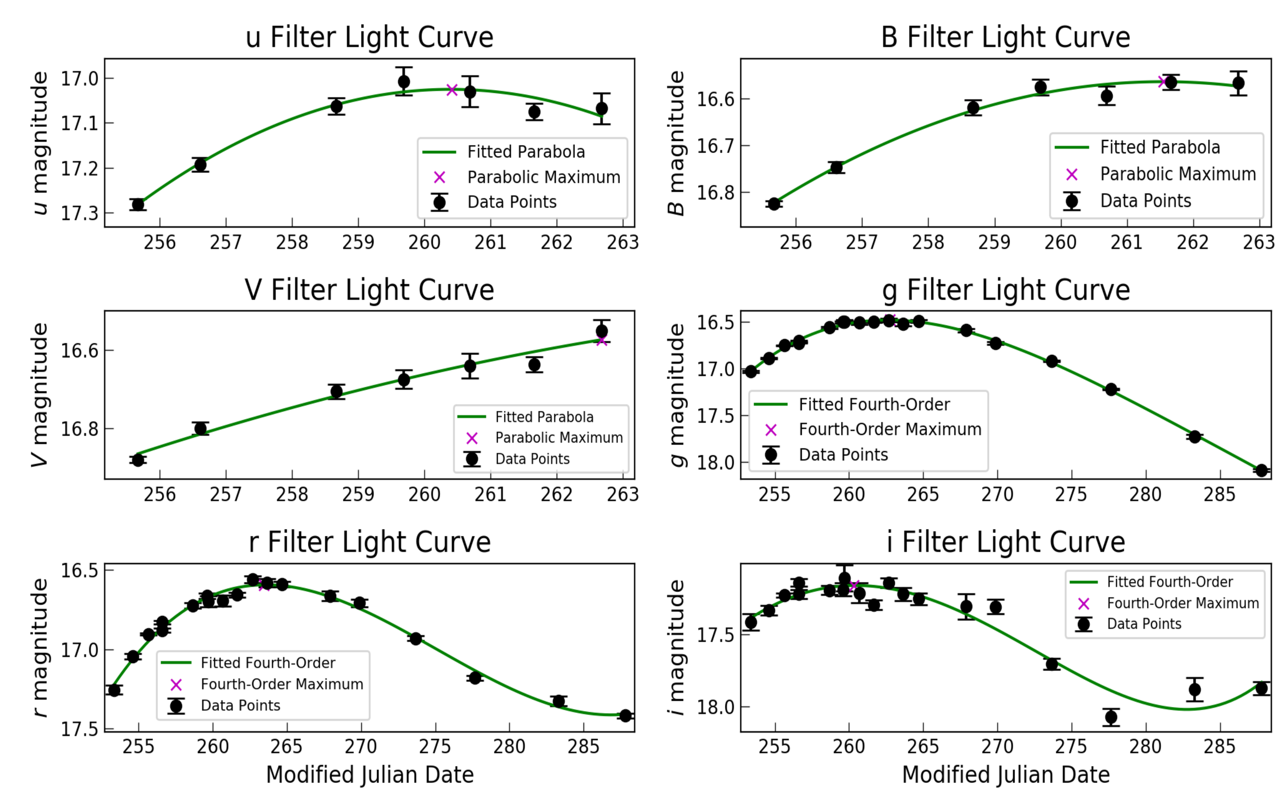

Figure 2: Polynomial light curves in 6 bands (u, B, V, g, r, and i) generated in Python using the photometric data obtained from IRAF. Each subplot shows every data point with corresponding error bars (black dots), a fitted polynomial (green curve; order indicated in legend), and the maximum of that polynomial.

This is the basis of knowledge that motivates our work that is described in the subsequent sections.

II. METHODS/DATA

In order to obtain sound photometric data, we performed the requisite bias, flat-field, and zero-point corrections and calibrations using Landolt (1992) and Sloan Digital Sky Survey (SDSS) standard field stars in the IRAF environment for every night observations were made. After this, we continued to use IRAF in order to reduce our images from the Swope Telescope (u, B, V, g , r, and i filters) and the LCOGT (g, r, and i filters) of SN 2018bgz and perform aperture photometry on them (see Fig. 1 for an example image). In addition to our photometry, we also utilized the light-curve fitting software SNooPy (Burns et al. 2015) to obtain our results. These two methods gave us the necessary information to utilize the equations in Section I and Burns et al. (2018) to calculate a value for H_0, which served as a good cross-check of our photometry and is sensible to do since SN 2018bgz is far out in the Hubble flow. To account for reddening, we utilized the NASA/IPAC Extragalactic Database (NED) to obtain a Milky Way reddening value along the line of sight to the SN and SNooPy to find the analogous value for UGC 9544.

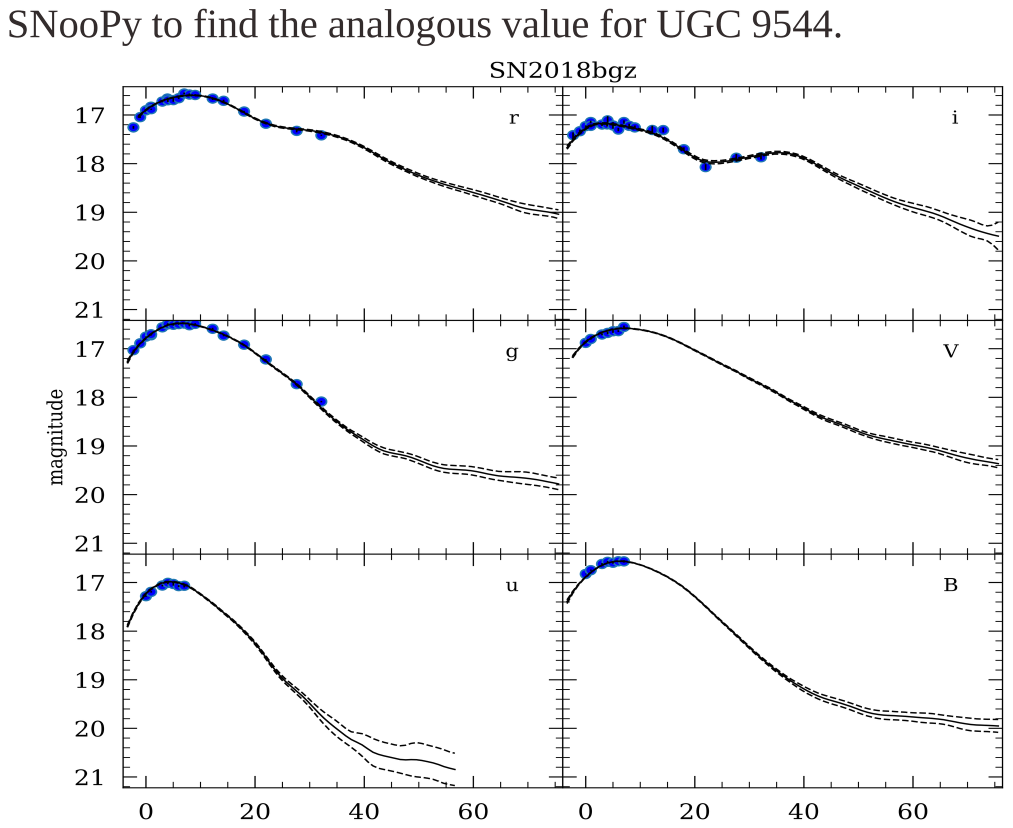

Figure 3: Similar to Figure 2 in that this is a plot of Light Curves through our six filters. This plot was generated using the software SNooPy developed by Burns et al. (2015) meaning they are more sophisticated fits; see text for further discussion.

III. RESULTS

After the data sets containing the apparent magnitudes in each filter as a function of time were obtained, we first fitted them with polynomial curves as demonstrated in Fig. 2. The u, B, and V filter data was fitted with a parabola due to the limited data in those filters and the g, r, and i data were fitted with a fourth-order polynomial. The fits are successful for some filters while not so much for others. Better fits were generated using SNooPy as evident in Fig. 3; this is because SNooPy generates fits that are based on the collection of SN photometry from the Carnegie SN Project-I (CSP-I) which means that these fitted curves do not have a closed mathematical form. From these curves, we calculated values for Δm_{15} and s_{BV} which, as described in Section I, led us to estimates for *d* and H_0. All of our numerical results and errors can be found in Table 1. A few things are evident from that table. First, the distance inferred using Eq. 2 is consistent with the known redshift; second, our Hubble constant is in agreement with the estimates of both Riess et al. (2016) and the Planck Collaboration et al. (2016) respectively; and third, SN 2018bgz seems to be a normally declining SN meaning its luminosity is also normal. Additionally, there is a minimal amount of host reddening due to how the SN is located in the outskirts of its host as seen in Fig. 1.

IV. CONCLUSION/DISCUSSION

Evidently, all of our results are both self-consistent and consistent with the results in the SN and cosmology literature. This points to the effectiveness of the traditional methods of calibrating one's images and photometry as our final result of a reasonable Hubble constant was obtained with a single normally declining SN at a redshift of $z = 0.034$. Evidently, this adds to the existing motivation to continue to incorporate this type of calibration in future SN surveys such as the CSP-II which seeks to provide better SN Ia data to help answer the outstanding questions of cosmology. This presentation and its results demonstrate that all is well in the field of SN research.

α^*	222.41°
δ^*	25.37°
$E(B-V)_{host}$	0.013 ± 0.007 ± 0.060
z^*	0.034
d	142.4 Mpc
v^*_{hc}	10171 ± 300 km s^{-1}
H_0	71.4 ± 3.4 km s^{-1} Mpc^{-1}
s_{BV}	1.089 ± 0.018 ± 0.030
Δm_{15}	0.98 ± 0.04

Table 1: Table containing the values of our the quantities of the SN measured through Aperture Photometry (stared values are those that were previously known.). Evidently, these quantities are (top to bottom): Right Ascension, Declination, host color excess, distance to the SN, redshift of SN, heliocentric velocity of UGC 9544, inferred Hubble Constant, the SN's Burns stretch-BV value, and its Phillips Parameter. The order that the uncertainties come in are random and systematic.

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