Color Photometry of The Type IIP Supernova 2020nyb

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Abstract

[1] Our journey with the Supernova 2020nyb began from first locating it on the Rochester Astronomy database[4] where we learned the Right Ascension and Declination of the celestial object ($R.A. = 01h59m08s.115, Decl. = +86°40'34".26$). Following this, in order to start collecting data and making sense of the object's behavioural patterns, we expanded our understanding of maneuvering telescopes, astronomical concepts, calibrating of data, important relationships between the colored filters and how to use our data to predict key events in the supernova's timeline. Prior to this project, numerous identifiers of the supernova were yet to be deduced: most importantly its type, apparent and instrumental magnitudes, and its brightness. Hence, this is what the study aims to examine and identify for the 2020nyb Supernova. The process that we adopted starts with remotely collecting data mainly of the Sloan G and Sloan R filters from the two telescopes and calibrating the data to minimise various sources of noise that may corrupt our graphs. Next, using the relevant calibrated color filter data, we used python to produce light curves and graphs detailing the relationship between its apparent and instrumental magnitude. The most valuable outcome of this study is our deduction that 2020nyb is a Type IIP Supernova derived from the comparison of our formulated light curve graphs with the established Type IIP supernova light curve.

[1]Written by Uditi Gupta

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1 Introduction

[2] This research is on Supernova 2020nyb and our findings through the past three weeks of data. Our group of students in iYSPA have been researching supernovae throughout the program in hopes to learn more about how to perform astronomical calculations and apply code that we have written as tools to make them. The most important calculation we have made is a light curve of SN2020nyb's brightness over a period of 3 weeks. All stellar objects radiate some frequency of light which can be gathered by sensors on Earth. A light curve is a graph of the amount of light gathered by a sensor in relation to time over multiple observations. Creating a light curve for a supernova is essential to understanding the supernova's type. For example a type Ia supernova will have a steeper slope compared to a type II-L which plateaus in brightness close to twenty days after the explosion. The type of a supernova tells us many useful aspects about the star that exploded and the manner in which it collapsed. This information is vital for explaining and understanding stellar events that occurred thousands of parsecs away from the Earth.

Our supernova target, AT2020nyb, is located inside the UGC 1285 spiral galaxy at 1hr 59min RA, 86°Declination. This SBd shaped galaxy is located in the northern hemisphere and will never be seen by people living below $-5°$ Latitude. When looking at the nighttime sky, the galaxy is visible in the constellation of Cepheus[7]. The supernova is located at the bottom right corner of the galaxy as seen from our telescope observations.

[2]Written by Oliver Fong

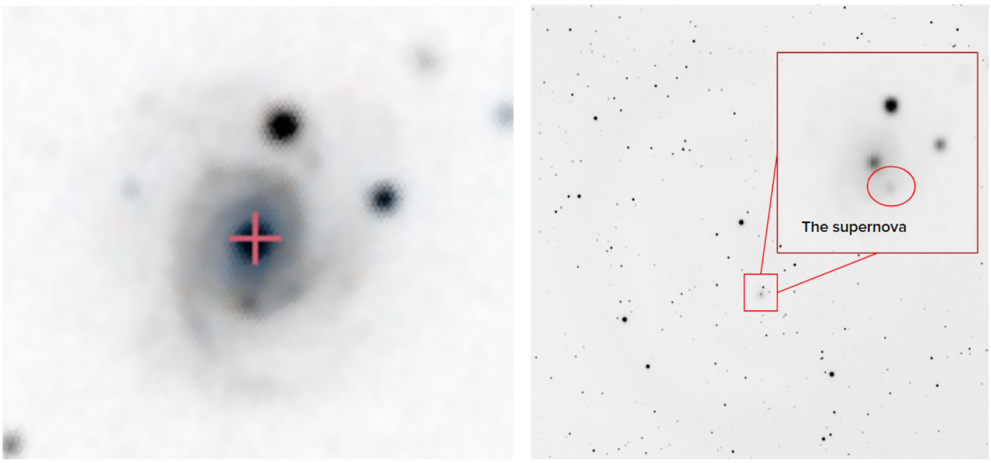

Figure 1.1: UGC 1285 Galaxy & 2020nyb Supernova

Our observations have been made from Yale's Leitner Family Observatory and Planetarium telescopes in New Haven, Connecticut, and the T21 telescope from New Mexico Skies Observatory in New Mexico. Both telescopes are automatically run to observe our supernova's during the nighttime for an optimal observing environment. Only the T21 telescope in New Mexico is run through the iTelescope website. The Leitner 16-inch telescope is run by Yale University which is also the .

2 Methods

2.1 Observations

[3] Data was collected through remote observations from two locations. The 16-inch Ritchey-Chretien Telescope at the Leitner Family Observatory and Planetarium (hereinafter Leitner) paired with the SBIG STL-1001E CCD camera was the primary source of our data. Additional data was sourced from the T21 Telescope[5] (hereinafter T21) in the iTelescope.net remote observing network, a Planewave 17-inch CDK Reflector Telescope with a FLI-PL6303E CCD camera at the New Mexico Skies Observatory. Images were taken through the Sloan G and Sloan R filters at Leitner, and the Johnson V and R filters at T21.

Observations were done over the course of about two weeks, with eight nights of data collected in total. Our observation schedule and details are shown in Table 2.1, with the leftmost column being the date of the night each observation was done in Eastern Daylight Time:

[3] Written by Sarah Zhang

Table 2.1: SN2020nyb Observation Schedule

Observed on Night of (EDT)	Time Observed (UT, mm/dd/yyyy hr:min:sec)	Telescope	Filter	Effective Exposure Time (s)
7-17	07/18/2020 9:44:38.40	T21	R	900
7-17	07/18/2020 9:44:38.40	T21	V	900
7-18	07/19/2020 4:48:0.00	Leitner	sR	1200
7-18	07/19/2020 4:48:0.00	Leitner	sG	1200
7-20	07/21/2020 5:44:9.60	Leitner	sR	1500
7-20	07/21/2020 5:44:9.60	Leitner	sG	1500
7-25	07/26/2020 4:13:26.40	Leitner	sR	900
7-25	07/26/2020 4:13:26.40	Leitner	sG	900
7-27	07/28/2020 4:13:26.40	Leitner	sR	900
7-27	07/28/2020 4:13:26.40	Leitner	sG	660
7-29	07/30/2020 3:24:28.80	Leitner	sR	900
7-29	07/30/2020 3:24:28.80	Leitner	sG	1380
7-31	08/01/2020 3:44:38.40	Leitner	sR	900
7-31	08/01/2020 3:44:38.40	Leitner	sG	1140
7-31	08/01/2020 10:55:12.00	T21	R	1200
7-31	08/01/2020 10:55:12.00	T21	V	1200

2.2 Photometry: Models and Methods

[4] In MaxIm DL 3, the raw images from each night of observations were flat field calibrated, aligned, and median combined to form one image per filter per observation session, yielding sixteen combined images. Astrometry was performed through nova.astrometry.net[1], where we obtained the R.A./Dec and world coordinates system file of our combined images. Next, we gathered the standard calibration stars within the field of view of our images from the American Association of Variable Star Observers Photometric All-Sky Survey (APASS) Data Release 10[2] catalog. In Excel, the APASS calibration star list was trimmed to only include data on Sloan G and R filters for stars with magnitudes greater than 17th magnitude and photometric errors under 0.1 mag.

Subsequently, aperture photometry with a circular aperture and annulus was performed with the python package `photutils` to extract the fluxes of the standard stars in our images. These calculated fluxes were converted to instrumental magnitudes using the following conversion:

$$\text{instrumental magnitude} = -2.5 \cdot \log_{10}(\text{flux}). \quad (1)$$

[5] Subsequently, we calibrated our Johnson V and R and Sloan R and G instrumental magnitudes to standard Sloan G and R. Note that observations from Leitner were done through Sloan G and R filters while T21 observations were done through Johnson V and R filters, and while the Johnson and Sloan filters are not identical, they are of similar bandwidth and wavelength, making it reasonable to

[4] Written by Sarah Zhang
[5] Written by Eric Erqian Cai, edited by Sarah Zhang

calibrate them to the same set of standards. Additionally, APASS standards did not include Johnson R filter data, so to handle this inconsistency, all instrumental Johnson V and R data were calibrated to standard Sloan G and R.

We used the following color and magnitude transformation equations for BVR photometry[3],

$$V - R = T_{vr}(v - r) + C_{vr} \tag{2}$$

and

$$V = v + T_v(V - R) + C_v \tag{3}$$

where V and R are apparent Sloan G and R magnitudes, v and r are instrumental Johnson V and R/Sloan G and R magnitudes (depending on the telescope), respectively. We used the python method `numpy.polyfit` to perform least squares linear fitting to $\hat{y} = mx + b$ where m and b are defined as follows:

$$m = \frac{\sum x_i(y_i - \bar{y})}{\sum(x_i^2 - x_i\bar{x})} \tag{4}$$

$$b = \bar{y} - m\bar{x}. \tag{5}$$

We applied linear regressions with the mappings $x = v - r$ and $y = V - R$, which returned the color and magnitude transformation coefficients T_{vr}, C_{vr}, T_v, C_v and their uncertainties for each night and filter. The uncertainties, which are one standard deviation, were determined from taking the square root of the diagonals from the covariance matrix returned by `np.polyfit`. Results of color and magnitude calibrations are shown in Table 3.1 and 3.2.

Finally, the transformation coefficients were applied to the instrumental magnitude at the location of SN2020nyb to calculate the apparent Sloan G and Sloan R magnitudes of the supernova for each night and filter. The uncertainties of the calibrated standard magnitudes were determined through taking the root mean square of the residuals in the $V - R$ vs. $V - v$ color calibration least squares fit.

2.3 Light Curve

[6]The light curve for SN2020nyb was formed by plotting our calibrated apparent magnitudes over time. We manually fit our light curve to the expected light curves of Type Ia, Type Ib, Type IIL, and Type IIP supernovas to distinguish which supernova type SN2020nyb was.

3 Results

[7] Tables 3.1 and 3.2 show the calculated transformation coefficients and their uncertainties as described in the Methods section:

[6]Written by Sarah Zhang

[7]Written by Eric Erqian Cai, plots produced by Sarah Zhang

Table 3.1: Linear Fit of V-R index (Color Calibration)

Date	Telescope	T_{vr}	C_{vr}
7-17	T21	1.185 ± 0.050	-0.039 ± 0.029
7-18	Leitner	0.855 ± 0.062	-0.986 ± 0.029
7-20	Leitner	1.003 ± 0.070	-0.203 ± 0.029
7-25	Leitner	0.898 ± 0.046	-0.142 ± 0.029
7-27	Leitner	0.946 ± 0.027	-0.258 ± 0.029
7-29	Leitner	0.871 ± 0.042	-0.126 ± 0.029
7-31	Leitner	0.920 ± 0.031	-0.164 ± 0.029
7-31	T21	1.155 ± 0.057	-0.173 ± 0.040

Table 3.2: Linear Fit of V (Magnitude Calibration)

Date	Telescope	T_v	C_v
7-17	T21	0.000 ± 0.055	23.224 ± 037
7-18	Leitner	-0.046 ± 0.063	24.646 ± 0.036
7-20	Leitner	-0.025 ± 0.070	24.893 ± 0.047
7-25	Leitner	-0.014 ± 0.097	24.684 ± 0.066
7-27	Leitner	-0.025 ± 0.053	24.782 ± 0.036
7-29	Leitner	-0.023 ± 0.065	24.648± 0.044
7-31	Leitner	-0.033 ± 0.058	24.874± 0.040
7-31	T21	0.005 ± 0.060	25.973± 0.040

The color and magnitude calibration graphs are as follows. The x-values of the left column represent the difference between instrumental v and instrumental r, while the y-values represent the difference between the standard v and standard r. Similarly, the x-values of the right column represent the difference between standard v and standard r, while the y-values represent the difference between the standard v and instrumental v. All values on the plot axes rare in units of magnitude.

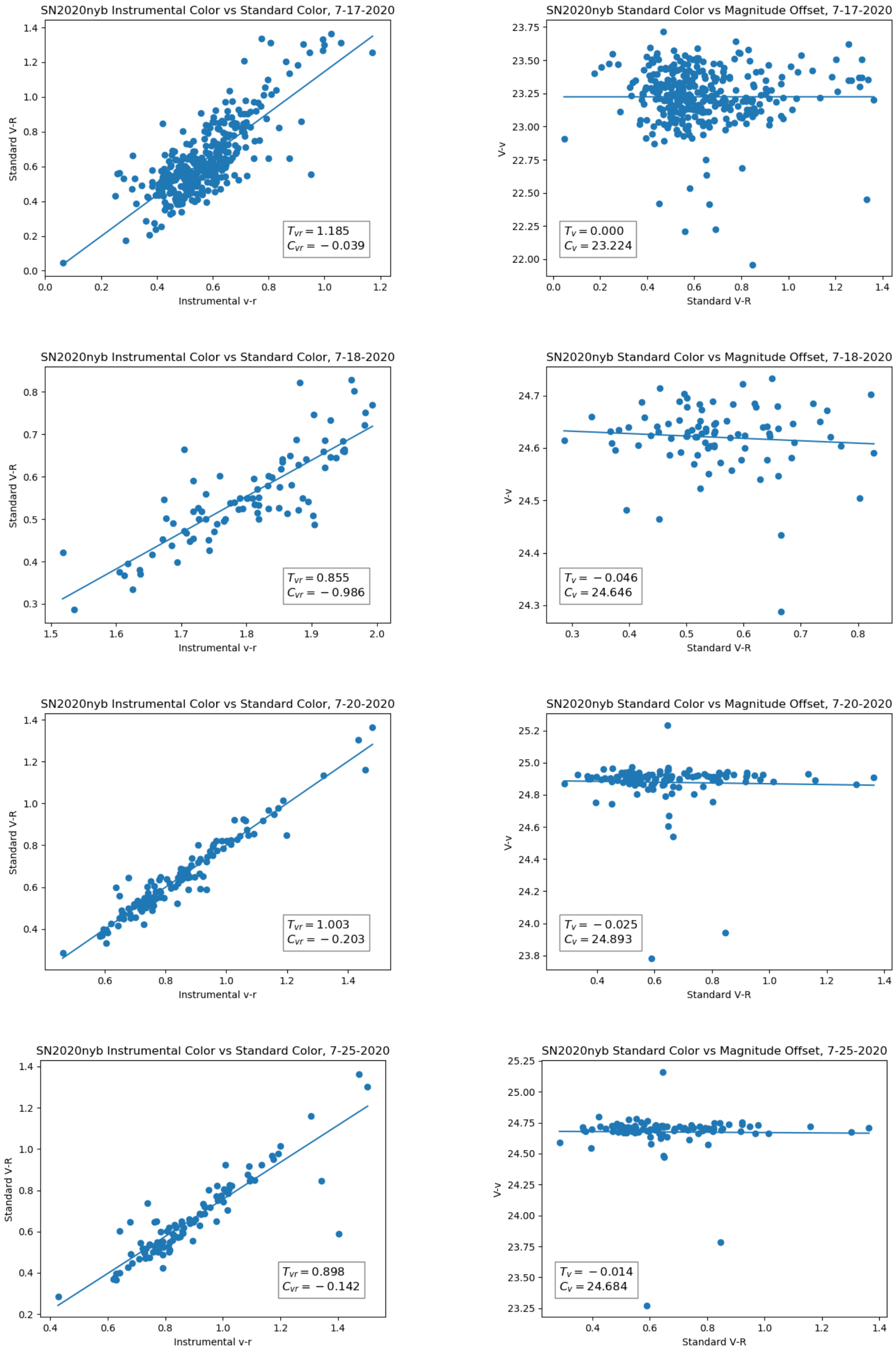

Figure 3.1: Color and magnitude calibrations of observations from the nights of 7-17 to 7-25

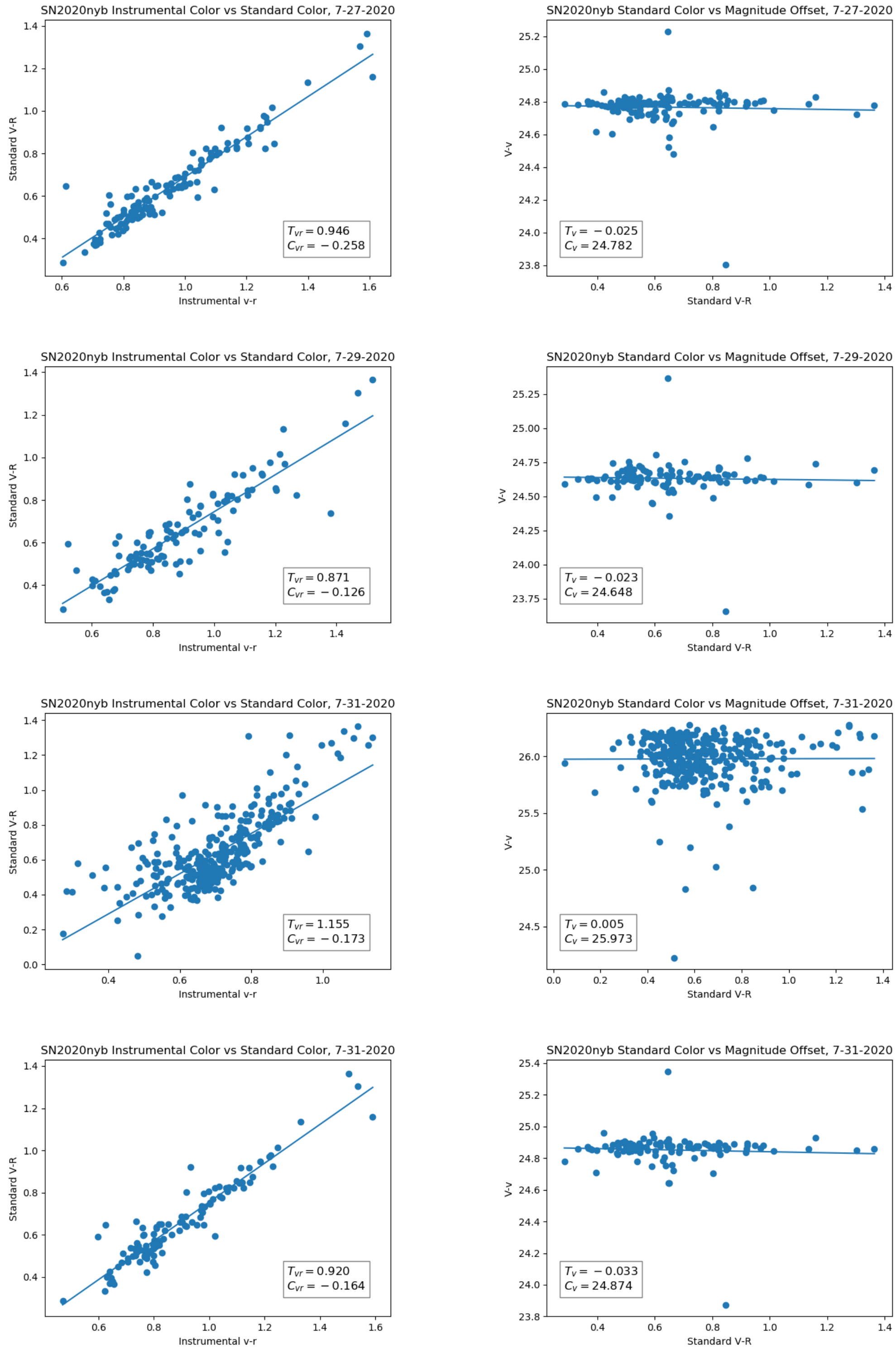

Figure 3.2: Color and magnitude calibrations of observations from the nights of 7-27-20 to 7-31-20

Tables 3.3 and 3.4 show measured instrumental magnitudes and calibrated standard magnitudes after color photometry:

Table 3.3: Supernova Instrumental Magnitude

Date	Telescope	sG/V filter Instrumental Magnitude	sR/R filter Instrumental Magnitude
7-17	T21	-4.719	-5.074
7-18	Leitner	-5.655	-6.448
7-20	Leitner	-6.686	-6.773
7-25	Leitner	-6.296	-6.027
7-27	Leitner	-6.232	-6.726
7-29	Leitner	-5.735	-6.189
7-31	Leitner	-6.254	-6.620
7-31	T21	-7.558	-8.083

Table 3.4: Supernova Apparent Magnitude

Date	Telescope	sg calibrated std mag	sr calibrated std mag
7-17	T21	18.505	18.123
7-18	Leitner	19.004	19.312
7-20	Leitner	18.210	18.326
7-25	Leitner	18.393	18.777
7-27	Leitner	18.545	18.335
7-29	Leitner	18.907	18.637
7-31	Leitner	18.614	18.442
7-31	T21	18.418	17.985

Table 3.5: Uncertainties of the Apparent Magnitude

Date	Telescope	$\Delta v - r$	Δv
7-17	T21	0.129	0.215
7-18	Leitner	0.061	0.064
7-20	Leitner	0.049	0.147
7-25	Leitner	0.085	0.183
7-27	Leitner	0.058	0.112
7-29	Leitner	0.089	0.133
7-31	Leitner	0.065	0.118
7-31	T21	0.136	0.223

Comparing the light curve with prior supernova information of four different types, we find that our supernova is highly possible to be a type II supernova. The light curve for 2020nyb shows great similarity with examples of type II supernova light curve.

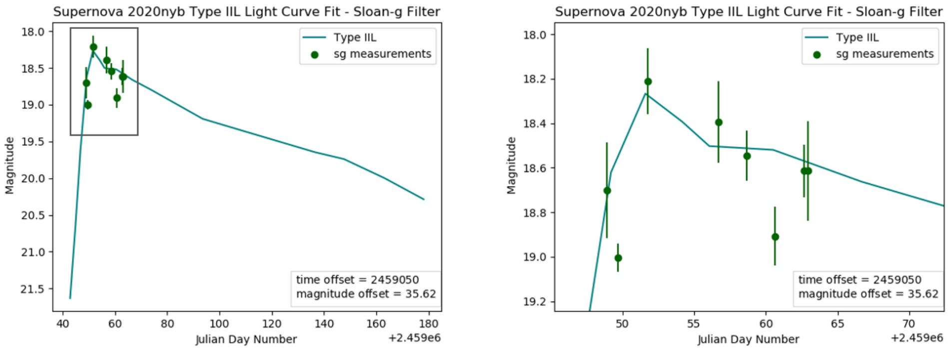

Figure 3.3: light curve IIL Sloan green

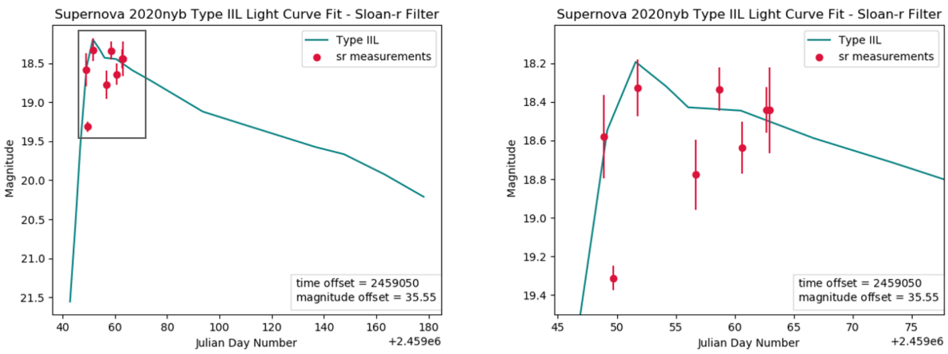

Figure 3.4: light curve IIL Sloan red

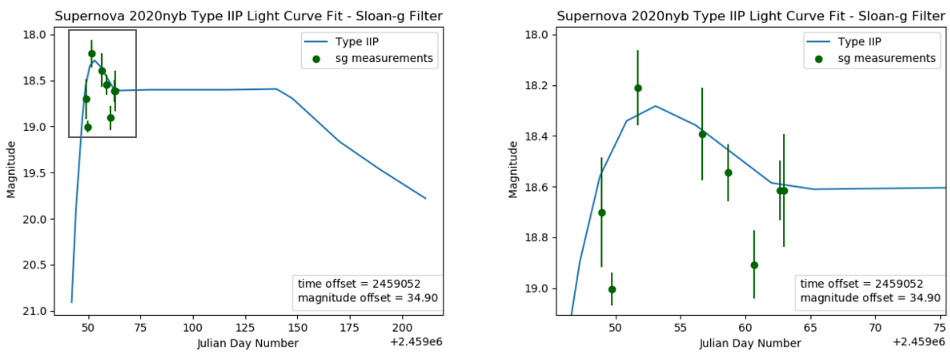

Figure 3.5: light curve IIL Sloan green, Sloan red

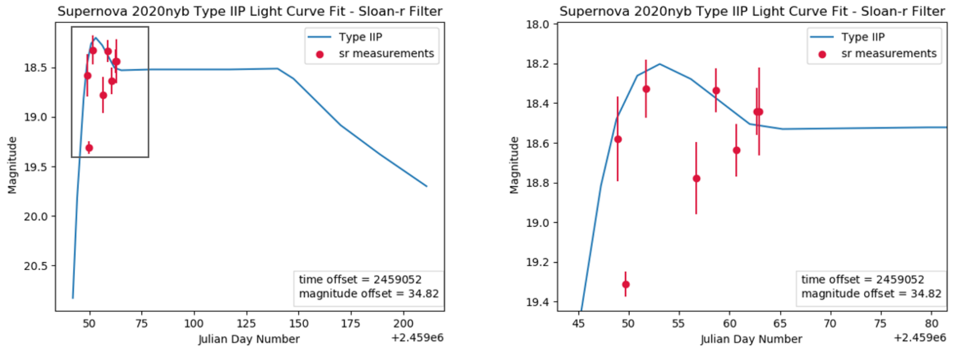

Figure 3.6: light curve IIL Sloan green, Sloan red

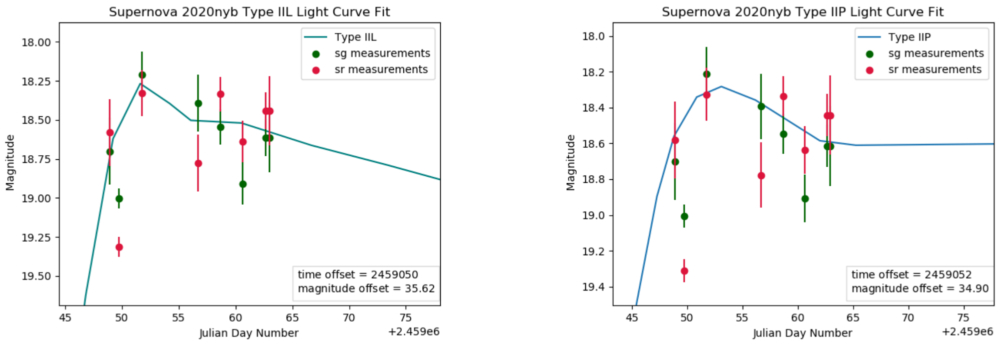

Figure 3.7: light curve IIL and IIP Sloan green, Sloan red

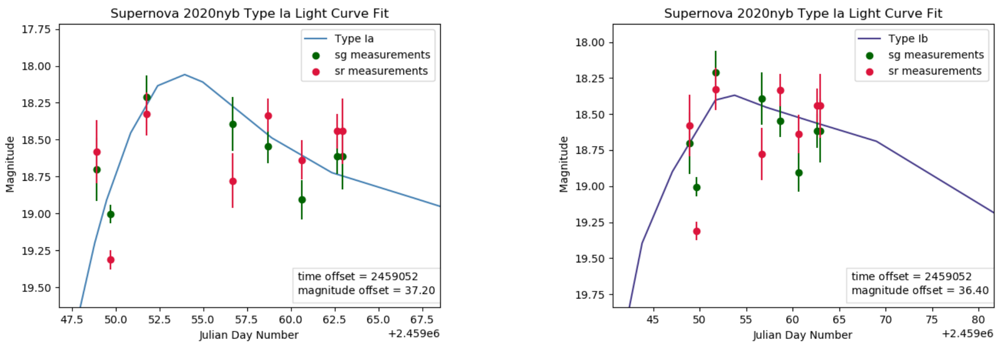

Figure 3.8: light curve Ia and Ib Sloan green, Sloan red

4 Analysis

8

According to our results, the supernova 2020nyb is most likely a Type IIP supernova. The supernova is not very possible to be a type Ia or type Ib because

[8] Written by Eric Erqian Cai

the curve does not pass most of the data points within the error bar. The light curve shows more similarities with type IIL and type IIP as presented in the result section. However, the reason why we decided that the supernova is a type IIP is because our data points do not show a significant small platform which type IIL shows at around mark 60 on the x-axis.

However, the great uncertainty of the data points and several extreme values cast doubt on this result. Both light curve with respect to type IIL and type IIP supernova models do not cross all of the data point within the error bar, making it almost impossible to make a definitive classification.

We also compared our work with the Lasair program[6]. Surprisingly, our apparent magnitude is on average one mag greater than their result, which cast doubt on the validity of our result. However, they also classified this supernova as an type II, which backed up our result. In comparing our images with theirs, it appears that the primary difference is image resolution and signal to noise ratio, which lends us to believe longer exposures may have improved the accuracy of our measurements.

Another potential flaw for the project is that we do not have enough observation time. The distinguishing features between a Type IIL and IIP supernova are whether the light curve plateaus or continues to grow dimmer over time. If the supernova is indeed a Type IIP, we haven't reached it's platform period yet, which is the most outstanding feature of a type IIP light curve.

The supernova is very dim for the telescopes we are using in this program. As a result, we were unable to observe and analysis its spectrum. Otherwise, it would be possible to further classify the supernova using the spectrum information.

5 Conclusion

[9] Despite the intricate process adopted in order to mitigate the risks of uncertainties when finding the type of Supernova nyb, it is important to keep in mind that there are still a range of other uncertainties that are unaccounted for. Potential sources of these are: cosmic ray interference and non-zero noise capture during cloudy evenings.

With further observing time, we believe that a more affirmative prediction, that our Supernova AT2020nyb is Type IIP, could be achieved as the calibration of our data will be more accurate and more of the above mentioned uncertainties can be factored in.

5.1 Wider Implications of our Findings

[10] If our light curves were to become publicly accessible, it would be valuable to astronomers who are also trying to deduce the nature or type of the celestial objects they are observing. By contributing more data, the process of comparing and noticing patterns will become more accurate and therefore, lead the person to reach a conclusion much earlier. In addition to this, our prediction for the type of

[9] Uditi Gupta
[10] Uditi Gupta

Supernova 2020nyb provides more detail in the current database which is useful to the astronomer community when understanding the events in certain regions of the sky. Another way our findings can be taken forward is by interpreting our multiple models to determine certain characteristics of the gas cloud and its emissions as it propagates through space. This could be relevant for further research into concepts such as dark energy, gravitational waves and cosmic rays.

6 Acknowledgements

We are incredibly thankful for the guidance and mentorship of our research group supervisor, Dr. Michael Faison. His fantastic instruction and engaging lectures as Academic Director were invaluable in providing us with the astronomy and astrophysics knowledge to complete this project. Additionally, instructor Michael Warrener played an instrumental role in teaching and helping us understand the data analysis and programming techniques required. Both Dr. Faison and Mr. Warrener's approachability, humor, kindness, and patience have truly made this journey a pleasure. The development in our understanding of the universe and our close contact with the heights of technology here on Earth today would not have been possible without their unfaltering support. The welcoming, respectful and challenging academic environment fostered during the program has made this an unforgettable experience.

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References

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