

# Producing and fitting light curves for Type Ia supernova explosions

Jacky Cao, AstroLabs Michaelmas, Lab Partner: Duncan Middlemiss  
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We have measured the magnitude of supernova explosions over an extended period of 34 days using 0.5 m and 1.2 m telescopes situated in Durham and La Palma. We have plotted several light curves and identified Type Ia, Type II, and ?? supernovae. Our fittings have had  $\chi^2$  analysis has performed, and it has produced values of ?, ?, ?. We expect our biggest source of uncertainty arose due to the conditions and data analysis that we performed. Using a Type Ia supernova of brightness 00.00 mag, we have managed to produce a value for Hubble's Constant,  $H_0 = 74 \text{ km s}^{-1} \text{ Mpc}^{-1}$ . We attempted to calculate Einstein's coefficient,  $\Lambda$ , but this was unsuccessful due to redshift of something.

## I. INTRODUCTION

In astronomy, one of the most violent and luminous events which can occur are supernova explosions. At the end of a massive star's lifetime, as a star runs out of nuclear fuel to burn, there is a possibility that the equilibrium configurations for a star will cease to exist. This leads to a final cataclysmic event, a supernova explosion. The luminosity of such, when at its peak, can be as bright as a small galaxy [10].

Observing these events and measuring their magnitude over a period of time allows us to plot light curves. The likes of which can then be used to visualise the evolution of a supernova. Using these plots we can draw the conclusion that there is order in the explosions. We find that if our sample of supernovae is large enough, we see that they can be grouped together into different types just by features from their light curves. The two general types of supernova are Type I and Type II, the difference between them being that Type I lacks the Balmer hydrogen features in its spectra [10], and that Type II events are very hydrogen-rich [6].

### a. Supernovae Classification

If we were to further study the light curve shapes and also the spectra of the supernovae from our sample, we would begin to recognise that there are further sub-classifications within Type I and Type II. In Table I some of these subtypes are specified.

Type	Characteristic
Ia	Si II line present at 616.0 nm in spectra
Ia-91bg	Absorption trough at 400 – 450 nm in spectra <i>Type Ib and Type Ic also exist</i>
IIP	Reaches a plateau in its light curve
IIL	Rapid linear decrease in light curve <i>Type IIn and Type Ib also exist</i>

TABLE I: Some of the sub-classifications of supernova and their respective characteristics which distinguish between them from each other [6, 10].

In the application to cosmology one of the most used types of supernovae are Type Ia, their light curve profiles are generally homogenous which allows them to be used as standard candles, thus providing a reliable distance indicator.

We can see this homogeneity in Figure 1. This plot was produced by superimposing and translating multiple sets of Type Ia data. The light curves in the B and V bands follow a general path in their evolution: they initially increase in brightness until they reach a

peak magnitude, after this point the magnitude of the supernova decreases until no noticeable change can be detected by our telescopes. We note that whilst Type Ia's do peak at different magnitudes in when observed from in different bands, it is not as pronounced as is shown in Figure 1.

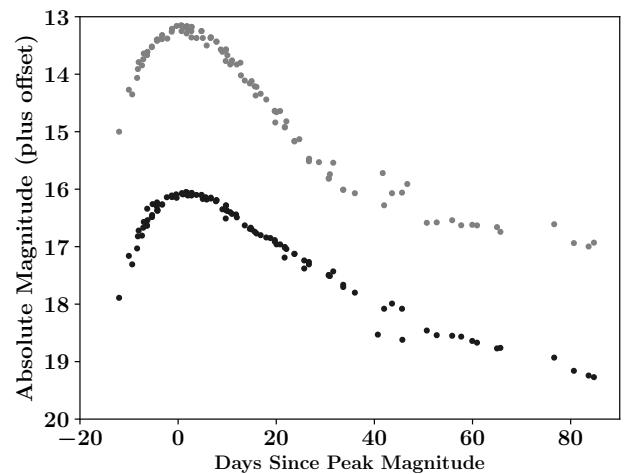


FIG. 1: Plot showing the general forms of Type Ia supernovae in the B and V bands. Archival data was translated along the time axis and magnitude axis to produce the general forms of the light curves. The B band has been offset by a magnitude of 3 to allow us to see both graphs clearly. The supernovae which were used to plot this graph are: 1994ae, 1994S, 1995bd, 1996bo, and 1998aq [8, 11].

In understanding the consistency of Type Ia light curves, we must explore and understand the mechanisms which lead to these events.

In understanding why the optical spectra of Type I supernovae do not contain the Balmer hydrogen features, we must look at the physical composition of the objects. Type I SNe occur with stars which have lost their hydrogen envelopes, either from strong mass-loss from their surface layers, or because they involve the explosion of white dwarfs which lost their hydrogen envelopes when they were formed [10] [[does that make sense??]].

With the importance of Type Ia supernovae as distance moduli we will explore the systems that lead up to their explosion, the explosion mechanism, and what occurs post explosion.

The general consensus for the presupernova of Type Ia supernovae, there is a white dwarf within a binary system which accretes matter from a donor star. However, this is also the initial system for dwarf novae and

classical novae, better known together as cataclysmic variables [4]. They too increase in brightness which can lead to some confusion with supernovae, especially if you observe them initially optically. If observed spectroscopically we could potentially determine whether it is a supernova and which type as we would be able to identify which elements are present [[not sure about this]]. With classical novae as they increase in their brightness by a factor of  $\sim 10^6$  [4]. [more detail??]

The distinction for supernovae is drawn as the white dwarf will increase in its mass until it reaches the critical Chandrasekhar mass,  $1.4M_{\odot}$  [10, 13]. As the material is continually compressed on and in the white dwarf, it is heated to a temperature of  $T \geq 10^9$  K [10], the fusion of the rich carbon and oxygen core can begin. Thermonuclear energy is released and the white dwarf loses its electron degeneracy pressure, the object is now gravitationally unstable [10]. However, this energy that is produced disrupts the star and prevents a total collapse into a neutron star, this disruption leads to a supernova explosion [13].

This white dwarf-companion star mechanism has support from spectroscopic observations of Type Ia supernovae at maximum light. We find the spectra has silicon, calcium, magnesium, sulphur and oxygen present. These are elements which are the products for when carbon and oxygen are burned in the nuclear fusion processes of ( $^{12}\text{C} + ^{12}\text{C}$ ), and ( $^{16}\text{O} + ^{16}\text{O}$ ) [10].

From spectral fits, we can calculate the velocities of the ejecta material which have been measured to have a range from a mean value of  $5,000 \text{ km s}^{-1}$ , to a peak that exceeds  $20,000 \text{ km s}^{-1}$  [7], approximately 7% of the speed of light. Supernovae are incredibly energetic events with the majority of the explosion energy being converted into kinetic [13], these explosions offer us a chance to calculate some fundamental properties of the universe [???].

As this process relies on the Chandrasekhar limit, each Type Ia supernova which occurs will be the same as they would follow the same process of collapsing. They are useful as they

When plotting their magnitudes against time passed we see that their light curves are generally homogeneous. These objects are the most luminous supernovae known, their absolute magnitudes in the B band are typically  $M_B = -19.5 \pm 0.1$  [13]. Using light curve relationships and models we can determine precisely the magnitudes of very distant SNe, this has allowed astronomers to determine the redshift-distance relation for redshifts high redshift objects ( $z > 1$ ). Then, with these calculated values it is then possible to estimate the cosmological parameters  $\Omega_0$  and  $\Omega_\Lambda$ . In doing so, it has been found that using Type Ia SNe has produced agreement with the literature value. so and so (cite paper) have done this and produced values of.

## b. Supernova Discovery

In discovering supernovae it is important that the search is not focussed on a singular part of the sky as there is a possibility that they could occur in any region of the sky. What is required is a survey which covers the entire visible sky. Then, the general method that is employed is that each night's data can be compared on a day-to-day basis and any new objects that appear could be classified as a supernovae. Follow up obser-

vations are required though to verify if it actually is a new object exploding or whether it is an anomalous object such as a cataclysmic variable. [reference]

One such survey that employs this is the *All-Sky Automated Survey for Supernovae* (or ASAS-SN). Their setup (??) involves two stations based in Haleakala Observatory in Hawaii, and Cerro Tololo International Observatory in Chile. Together they can produce a survey of the entire visible sky up to a depth of  $\sim 17$  mag [9].

With this case specifically it has been set so that the data is taken automatically, but it requires humans to go over it. Another method that can be used is to observe a location such as a galactic cluster and do essentially the same method.

In the classification of supernovae and in determining their redshifts, spectroscopic observations are required on the objects after they have been discovered [2]. While we can use light curves to find the type of a supernova, it is more effective to use their spectra as that will allow us to be more certain [??].

## c. Application to Cosmology

In discovering supernovae we can calculate the rates at which supernovae occur. Surveying different parts of the sky we can produce an estimate for the rate at which supernova explosions happen.

Using samples of nearby (redshift  $z \lesssim 0.1$ ) Type Ia supernovae, we can derive a value for Hubble's Constant,  $H_0$ , by plotting them on a Hubble diagram [1]. It would also be possible to use Type Ia's to provide statistical constraints on cosmological models, for example with an  $\Omega_M$ ,  $\Omega_\Lambda$  Universe (where  $\Omega_M$  is the mass density which includes ordinary and dark matter, and  $\Omega_\Lambda$  is the effective mass density of dark energy) [1, 4]. On top of that you, could measure the time-averaged equation of state of dark energy [5],  $w$ , a value which can be used to characterise the state of the universe. For an accelerating, dark energy dominated universe we would find that  $w \approx -1$  [10]. [[paragraph to use as a basis for this section]]

asdasd [12]

$$v = H_0 d, \quad (1)$$

with  $v$  as the velocity of the receding object,  $H_0$  as the value for Hubble's find a reference for this.

## d. Project Aims

This paper outlines the study that was undertaken in an attempt to understand the evolution of the magnitudes of different supernovae over a time period [[?]]. From collected data it would be possible to produce light curves which we can use to identify the type of supernova that we were observing. In also understanding the uncertainties further analysis could be performed such as galaxy subtraction or [[think of something for here...]].

Section II describes the methods used to collect and analyse the data, plus the uncertainties that arise during the experiment and how they were dealt with. Our final light curves, and the methods that were used to fit these models to the observations is summarised in Section III. Section IV discusses the different blahj blah blah, and explores potential work that could be

performed. With Section V providing a summary and conclusion.

We also focussed on understanding the sources of uncertainties and attempted to reduce them within our analysis to produce magnitudes which would be more true to what they should be [??].

## II. OBSERVATIONS

### a. Data Collection

Observing supernova explosions requires instruments which are sensitive enough to receive the photons which have travelled for vast distances before being recorded. In performing such observations (?) our main equipment are telescopes - they come in a wide variety of configurations and each can produce different results.

In collecting the data for our supernova we used three different types of telescopes. Two of them based in Durham on the Department of Physics's Roof, and one in La Palma.

As we were observing objects which were faint we required that we either have a large telescope to collect as much light as possible [reference], or have good seeing conditions which allowed us to collect as much light as possible over a large observation time.

In performing our observations, Far-East-16 and pt5m (give basic broad descriptions of these telescopes - tell how they are big and thus how much light they can collect?) was used.

Talk about the CCDs, their specs, and what that implies. Any uncertainties work should be either stated here, or in the uncertainties section, or spoken about in both.

Reliant on weather conditions being acceptable to observe in, define acceptable, discuss clouds, seeing, atmospheric turbulence, Lumiere, temperature, ...etc in observations how has the moon affected us

### b. Observations Made

Over a period of (?) days we took images of SNe, however this also depended on the conditions and whether it was worth observing if the seeing was bad e.g. obscured by bad weather.

In making observations there were various factors which required to be known.

In Appendix V is detailed all the objects that we chose to view over our experimental period, and in Appendix V is a more detailed description of the data that we took.

### c. Data Analysis

[[WHAT TENSE AM I SUPPOSED TO USE? PAST OR PRESENT??]]

As we collected our supernova data over our experimental period we were then required to perform various photometry techniques to calculate the magnitudes of the explosions. It is important that this method was correct as we wanted accurate representations of the light curves.

With our rawdata we firstly needed to identify our supernova object, as these objects can blend in with the background of stars we had to look it up for the right ascension and declination reference. All of our supernova objects were discovered by other astronomers so they had an initial set of information we could use

like, astronomical location on the celestial sphere, initial magnitude and the discovery date.

Once we had found our object we needed to find the magnitude of it. Using an astronomical analysis package such as GAIA [[reference and improve this]], we used various tools to perform this. We had to understand that we wanted to find the absolute magnitude of the supernova, this value being the 'actual magnitude', and not relative to other objects [??]. To perform this we had to choose at least two calibration stars which have known absolute magnitudes.

To count the number of counts that we are receiving from our supernova and calibration objects we have to choose an aperture size to place over these objects. It is important that the radius that is chosen maximises the signal whilst reducing the amount of noise that we are receiving as well, it is important that we have the cleanest signal possible.

To do this an object was selected which was close to the supernova and appeared to be similar in size, this was normally one of the calibration stars that we would be using. With our software package [[and for astronomy?]] we also had to choose a size for the 'sky aperture', this was so that the sky noise could be removed from the counts as well. In choosing this we had to account for the proximity of the supernova to its host galaxy's nucleus and also on how close the calibration stars are to other stars. We did not want to include unnecessary data that would produce an erroneous result.

After a sky aperture had been chosen we would then try and find the best radius to use when doing our photometry. This radius would be constant for our calibration objects and for our supernova as well, and also for each day's data frames. This would ensure that we would be not 'cherrypicking' the signal that we are receiving and that it would be an 'equal opportunity' for the signal to be detected to be the same each time [??].

This radius would be chosen by adjusting it from one to twenty in integer steps of one, noting down number of counts, the uncertainty on that value, and the sky noise counts. After these values had been collected we would plot the signal to noise against radius. In the plot, where the graph reaches a peak and decreases after this point would be our radius size as this would be the radius where we would achieve maximum signal to noise.

Then we can collect the values for the counts of the supernova and calibration objects, once we have this data we can use equation 2 to find the absolute magnitude of the supernova. [[give a reference for the equation from a paper]]

$$m = z - 2.5 \log_{10} C, \quad (2)$$

where  $m$  is the absolute magnitude that we are trying to find,  $z$  is the 'zero-point' of our frame [[is it how much it's offset by??]], and  $C$  is the number of counts we receive from our object.

In using this equation we must have the correct zero-point,  $z$ , otherwise we would not be finding the absolute magnitude, instead the apparent magnitude relative to our calibration stars. So, rearranging the equation for  $z$  we can calculate the zero-points for the calibration

objects in the required observation bands. We have the counts for each object and we have their known magnitude which has been found by other astronomers. Then we can average the  $z$ -values together for their respective bands.

With this  $z$  value we can then use the form of the equation as given in equation 2 and calculate the absolute magnitude of our supernovae.

Now with our magnitude values and the date that the data was taken on, we can plot a basic light curve.

In fitting templates and models it can be manually done, or you could use a software package light *SNooPy*. All it requires is the data, redshift, and the right ascension and declination of the supernova object. It will fit Type Ia templates to the data and then return what it thinks is the best fitting.

Once we had collected our data we then proceeded to perform analysis

Data reduction, what was required, blah blah blah. What was used. Don't say dstack script, say a script was used which allowed us to stack images together. should i just blend uncertainties into here?

fitting supernova templates using python programs, *SNooPy* - in depth analysis of snoopy should not be mentioned here, probably not

understanding type ia models of data and how from our data we cannot be sure. cb Photometry work

#### d. Data Uncertainties

Throughout the experiment it was important that we kept in mind the uncertainties which may arise from different areas of the experiment. Quantifying these errors allows us to judge whether the data and fittings that we created were good or not.

Uncertainties from the CCD and those type of astronomy data noise: mention here their effect, and how they were dealt with.

#### e. Final Data

Below is the final data set for supernova 2017hhz, and 2017hle.

Date Observed	$m_B$	$\Delta m_B$	$m_V$	$\Delta m_V$
20/10/17	16.8	0.1	17.1	0.1
22/10/17	16.9	0.1	16.8	0.1
23/10/17	16.8	0.2	16.9	0.1
26/10/17	17.0	0.2	17.0	0.1
29/10/17	17.2	0.1	17.0	0.1
30/10/17	17.3	0.1	17.1	0.1
05/11/17	17.7	0.2	17.3	0.2
11/11/17	18.2	0.4	17.5	0.2
16/11/17	18.6	0.2	17.8	0.1
17/11/17	18.8	0.2	18.2	0.4

TABLE II: The B and V band magnitudes and their uncertainties for SNe 2017hhz on the given dates. The former values were calculated using equation ?? and the latter using equation ??.

asdfsdfsadfsdf

### III. ANALYSIS

#### a. Supernovae Models

In fitting the supernova templates to our data sets we used the software package *SNooPy*

Date Observed	$m_B$	$\Delta m_B$	$m_V$	$\Delta m_V$
26/10/17	17.8	0.3	16.8	0.1
29/10/17	18.4	0.2	17.0	0.1
30/10/17	18.6	0.2	17.1	0.1
16/11/17	19.5	0.3	18.9	0.2
17/11/17	19.3	0.4	18.7	0.3
18/11/17	19.6	0.5	18.7	0.3

TABLE III: The B and V band magnitudes and their uncertainties for SNe 2017hle on the given dates. The former values were calculated using equation ?? and the latter using equation ??.

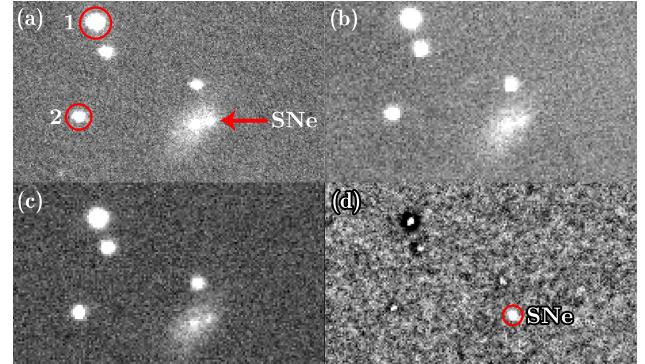


FIG. 2: Images of the supernova 2017hhz, its host galaxy, and the surrounding area. (a) Data was taken on the 20th October 2017. The calibration stars that were chosen have been labelled, 1 corresponds to star 512-002598, and 2 to 512-002599. These classifications were taken from the UCAC4 Catalog [reference]. The supernova 2017hhz has been shown with an arrow and label SNe. (b) Data from 23rd November 2017. (c) Data has been flat fielded for the 23rd November 2017. (d) An attempt has been made to remove the background galaxy for the data from 20th October 2017.

Discuss how *SNooPy* fit's its models here? [3]

Usage of different models, if I can, find different models and fit them to our data and see how it would differ. What kind of techniques would be required to do so.

#### b. Results

sdfsdfsfa

Supernova	$\chi^2$	$\chi_\nu^2$
2017hhz	1	1
2017hle	2	2

TABLE IV:  $\chi^2$  and  $\chi_\nu^2$  values that have been calculated for supernovae 2017hhz and 2017hle.

## IV. DISCUSSION

#### a. Using *SNooPy* to fit templates to supernovae

*SNooPy* uses the Levenberg-Marquardt least-squares fitter to fit the model to the data [cite].

#### b. Observing supernovae

sdasd

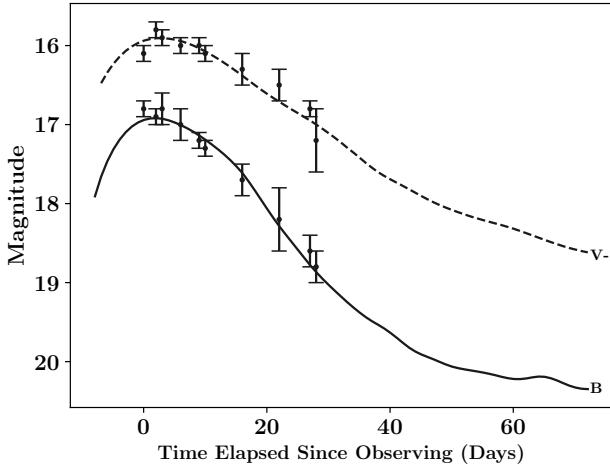


FIG. 3: The light curves for supernova 2017hhz. In the B band, the data has been plotted with the uncertainty in the magnitude plotted as well. The first observation, for day zero, was made on Friday 20th October 2017.

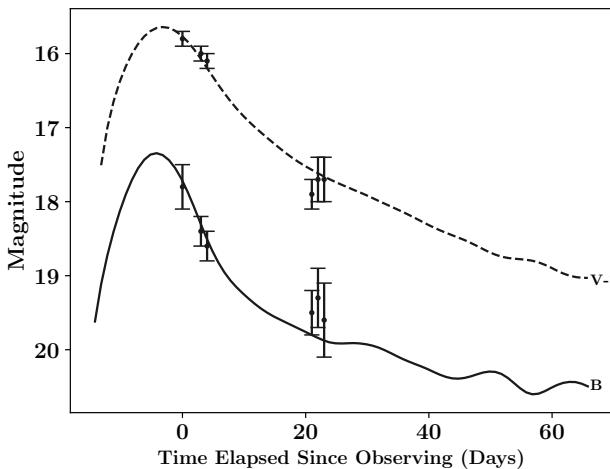


FIG. 4: The light curves for supernova 2017hle. In the B band, the data has been plotted with the uncertainty in the magnitude plotted as well,

### c. Supernovae in cosmology

It is highly unlikely that we will see supernova remnants for the supernova that we have been studying, in the shape of the Crab Nebula. Much longer time periods would be required for this.

In observing objects which are so faint we have the problem of trying to observe them. We need to balance the observing time to ensure that we do not oversaturate our frame with other stars. From the databases that we use, for this observation period the majority of our objects had been around the magnitudes of  $\sim 18$  mag. But, we do not achieve this magnitude as there are various factors such as extinction affecting data collection.

We can calculate the limiting magnitude that our telescopes could detect by analysing our frames

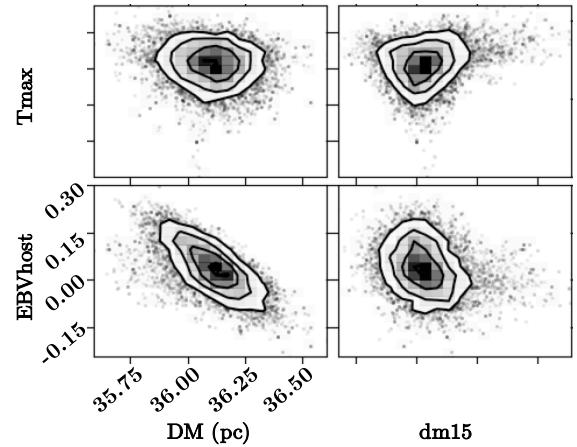


FIG. 5: Covariance between four variables, [[give them]], state which ones have been excluded and why we chose to view these one. These plots were produced using the fitMCMC function in SNOoPy and they used the B and V band data for supernova 2017hhz.

[neutrino studying]?

in using snoopy, how does it really fit the models to the data, what kind of parameters does it constrain. what is it's reliance on different parameters

try and produce some sort of covariance relation plot?

performing incorrect photometry and how that affects our results - not realising that we had to set a zero point, then having to find the zero point ourselves.

confusion in observations, novae, cataclysmic variables

there are other scripts which provide an automated way in finding the zero points from the data. what would this produce? why would this be beneficial to use this as opposed to our method?

justification of using the uncertainty equation, functional approach, why not use the uncertainty that was provided by the software? mention how it's one of the photon statistics things.

dstack, taking the median not mean , and why this is better - if I haven't discussed this already

what science have we addressed? well, we have limitations on the telescopes in terms of how 'deep' we can see: the limiting magnitude, how that was calculated - longer exposure times...etc

has it been possible to plot a light curve with reasonable uncertainties? how best could this experiment be changed?

big picture: justification of the uncertainties

using the jackknife method to discover the range of uncertainties after we had used snoopy to fit a model, the whole different parameters relating to each other

statisitcal, experimental - different uncertainties

extinction and galaxy extinction taking them into calculations

hubble flow????

how using different fitting models to check the quality of the data, right now we haven't really explored the quality of our data.

#### d. Improvements and extensions

How could we improve upon our experiment, what else could we work on for extension projects.

#### V. CONCLUSIONS

sdfsdfasdas

#### Acknowledgements

We thank J. Lucey, M. Swinbank, and U. Dudzevičiūtė for their continual support and help which was provided over our entire experimental period. We also thank the staff at the Department of Physics at Durham University for the continual upkeep of the telescopes on the department's roof, and we thank R. Wilson for the maintenance of the robotic telescope at La Palma.

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### Appendix A - Objects Log

A list of the objects that were chosen to be observed, and then the subsequent notes on them. Not all objects were chosen to be observed for an extended period, the ones noted were observed for a couple of nights to ensure suitability. The subsequent observation logs can be found in Appendix B.

Object	RA	Dec	Magnitude	First Discovered	Type	Notes
*ASASSN-17mz	23:56:21.82	+32:27:24.08	14.6	2017/09/30.500	Ia	Too close to galactic nucleus, cannot see
*AT2017hld	22:18:22.849	+34:45:08.46	16.1	2017/10/17.339	CV	Cataclysmic Variable, stopped observing
*2017hky	11:23:30.514	+63:21:59.43	16.2	2017/10/16.640	II	Not viewable from Durham or La Palma
2017hhz	01:44:16.75	+12:15:18.00	16.83	2017/10/16.140	Ia	A measured redshift, $z = 0.0392$
AT2017gvb	08:04:42.34	+61:31:41.50	17.33	2017/09/26.59	unk	-
*ASASSN-17nb	07:27:37.32	+35:36:28.30	17.31	2017/09/25.59	II	Object is dwarfed by brightness of the galaxy
2017hle	01:07:36.060	+32:24:30.00	18.0	2017/10/18.684	Ia-91bg	-
2017hou	04:09:02.140	-01:09:36.40	17.9	2017/10/24.370	Ia	Viewable from La Palma
*AT2017hmw	01:07:16.570	+31:25:28.88	17.2	2017/10/19.415	CV	Cataclysmic Variable
2017hpa	04:39:50.750	+07:03:54.90	17.9	2017/10/15.346	Ia	Viewable from La Palma
*AT2017hnm	01:42:03.24	+42:31:08.50	16.69	2017/10/23.44	unk	Another star in the image dwarfs the SN in brightness
AT2017hpm	08:04:15.100	-00:03:58.03	16.4	2017/10/26.290	unk	-
*AT2017hqa	01:08:59.160	+32:38:04.10	17.3	2017/10/26.740	unk	Unobservable, too close to galactic centre
2017hqc	23:23:08.210	+10:38:54.63	18.0	2017/10/27.490	Ia	-
*AT2017hrr	11:29:06.490	-08:59:18.56	15.4	2017/10/30.607	unk	Cannot view from Durham or La Palma
*AT2017hhq	00:42:50.230	+41:15:27.10	17.7	2017/10/30.599	NV	A nova close to M31
AT2017htb	22:09:38.520	+17:39:39.56	15.7	2017/11/02.190	unk	-
AT2017hwz	02:05:18.337	+53:12:13.16	17.3	2017/11/13.410	Ia-CSM	-
2017igf	11:42:49.850	+77:22:12.94	15.4	2017/11/18.590	Ia	-

TABLE V: Objects that we chose to observe and notes on them. RA is the Right Ascension, given in units of hours : arcminutes : arcseconds. Dec is the Declination, degrees : minutes : seconds. The stated magnitude is the initial magnitude that the object was discovered in the V band. Objects marked with an asterisk \* were objects which we chose to stop observing, the reason provided in the notes.

## Appendix B - Observation Logs

Given below are all the observations which were made during our observation periods. The exposures column is of the following format:  $(x : y, z)$  s), where  $x$  is the band in which the images were taken in,  $y$  the number of exposures taken, and  $z$  the exposure time which was used, in units of seconds.

Date	Object	Time	Exposures	Conditions	Notes
20/10/17	2017hhz	22:25:34 to 22:58:50	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	ASASSN-17nb	02:56:08 to 03:23:36	B: 5, 60s V: 5, 60s	Cloudy	pt5m: Data was unusable due to noise from cloud.
21/10/17	-	-	-	Cloudy	<i>No observations: weather not sufficient in Durham or La Palma for observations.</i>
22/10/17	AT2017hmw	21:52:20 to 22:31:49	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hhz	22:40:20 to 23:19:50	B: 4, 60s V: 12, 60s	Clear	pt5m: -
	ASASSN-17nb	02:42:45 to 03:10:46	B: 5, 120s V: 5, 60s	Clear	pt5m: -
	AT2017gvb	03:12:31 to 03:58:58	B: 5, 180s V: 5, 120s	Clear	pt5m: -
23/10/17	2017hhz	22:53:12 to 23:32:42	B: 5, 120s V: 5, 120s	Cloudy	pt5m: Data produced has FWHM ranging from 1.6 to 9.9.
24/10/17	2017hhz	22:44:01 to 23:23:30	B: 5, 120s V: 5, 120s	Cloudy	pt5m: Data is noisy, potentially another object transited across the frame while observing.
25/10/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham, and items in pt5m queue were pushed out in favour of other objects.</i>
26/10/17	2017hle	20:54:44 to 21:09:03	B: 4, 60s V: 4, 60s	Clear	FE16: -
	2017hhz	21:18:00 to 21:25:31	B: 4, 60s V: 4, 60s	Clear	FE16: -
	AT2017hmw	21:29:15 to 21:39:36	B: 4, 60s V: 4, 60s	Cloudy	FE16: -
	Messier-7	21:50:23 to 21:54:47	C: 1, 60s	Slightly Cloudy	FE16: Test object for SN discovery.
	Messier-10	21:55:47 to 22:00:13	C: 1, 60s	Cloudy	FE16: Test object for SN discovery.
	AT2017hnm	23:27:22 to 23:41:55	B: 5, 120s V: 3, 120s	Clear	pt5m: -
	AT2017gvb	-	-	-	pt5m: Object pushed out of the queue in favour of others.
27/10/17	AT2017hqa	18:48:12 to 18:52:59	B: 4, 60s	Cloudy	FE16: Object too close to galactic nucleus.
	AT2017hnm	18:56:34 to 19:00:23	C: 1, 60s	Slightly Cloudy	FE16: Object too dim, cloud cover reduced light we were receiving.
	Abell 426	19:04:23 to 19:15:41	C: 1, 60s B: 9, 60s V: 9, 60s	Clear	E14: Object to observe to discover new SN.
	2017hhz	20:11:35 to 20:22:43	B: 4, 60s V: 4, 60s	Cloudy and Windy	E14: Seeing is bad due to the weather.
	2017hle	20:26:18 to 20:37:35	B: 4, 90s V: 4, 90s	Slightly Cloudy	E14: Seeing is bad in these images as well.
	2017hou	23:48:09 to 23:50:14	B: 2, 120s	-	pt5m: Only two frames taken, not sufficient data.

Date	Object	Time	Exposures	Conditions	Notes
27/10/17	AT2017gzb	02:16:01 to 03:03:05	B: 5, 120s V: 5, 120s	Clear/Cloudy	pt5m: Some images are more noisy due to clouds.
28/10/17	AT2017hnm	21:41:55 to 22:21:25	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hhz	21:28:50 to 21:30:50	B: 1, 120s	Clear	pt5m: -
29/10/17	2017hle	21:22:39 to 21:41:21	B: 10, 120s V: 1, 120s	Clear	pt5m: Mistake on our part to take so many images in B band, and only one in V band.
	AT2017hnm	21:55:34 to 22:35:04	B: 5, 120s V: 5, 120s	Slightly Cloudy	pt5m: -
	2017hhz	23:16:48 to 23:56:18	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hou	00:33:33 to 01:13:02	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hqc	01:16:20 to 01:41:20	B: 4, 120s V: 4, 120s	Clear	pt5m: -
	AT2017gzb	02:18:51 to 02:55:47	V: 13, 180s	Clear	pt5m: Long exposure and large number of exposures chosen as a test to see the quality of stacking them.
30/10/17	2017hle	21:18:56 to 21:58:25	B: 10, 120s V: 10, 120s	Clear	pt5m: -
	2017hhz	22:06:34 to 22:46:04	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	AT2017gzb	02:04:22 to 03:02:50	V: 20, 180s	Clear	pt5m: An human error, we re-selected this object from the previous night instead of the one with the correct number of required frames for each band.
31/10/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham and La Palma.</i>
01/11/17	2017hle	23:56:53 to 00:15:35	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	AT2017hnm	00:18:23 to 00:57:55	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hhz	01:00:47 to 01:40:17	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hou	01:43:38 to 02:23:08	B: 5, 120s V: 5, 120s	Clear	pt5m: -
02/11/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham and La Palma.</i>
03/11/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham and La Palma.</i>
04/11/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham and La Palma.</i>
05/11/17	ASASSN-17mz	17:53:45 to 18:09:34	B: 8, 60s V: 8, 60s	Clear	FE16: -
	2017hhz	18:50:39 to 19:24:43	B: 8, 120s V: 8, 60s	Clear	FE16: -
	AT2017htb	19:38:14 to 20:02:16	B: 8, 60s V: 8, 60s	Slightly Cloudy	W14: -
	2017hle	20:05:49 to 20:08:28	V: 2, 60s	Cloudy	W14: Stopped taking exposures after the weather worsened.
	2017hqc	20:14:16 to 20:18:25	V: 3, 60s	Cloudy	W14: Cleared up for a brief moment and then re-clouded over.
	AT2017hhq	20:33:58 to 20:42:26	B: 4, 60s V: 4, 60s	Clear	W14: -

Date	Object	Time	Exposures	Conditions	Notes
05/11/17	AT2017hhq	19:38:14 to 20:02:16	B: 3, 30s V: 3, 30s R: 3, 30s	Cloudy	E14: Images taken so that we can produce a colour image.
06/11/17	-	-	-	Cloudy, and Rain	<i>No observations: too cloudy for observations in Durham, and torrential rain in La Palma.</i>
07/11/17	-	-	-	Cloudy and Rain	<i>No observations: too cloudy for observations in Durham, and torrential rain in La Palma.</i>
08/11/17	-	-	-	Cloudy and Rain	<i>No observations: too cloudy for observations in Durham, and torrential rain in La Palma.</i>
09/11/17	-	-	-	Cloudy	<i>No observations: too cloudy for observations in Durham, La Palma was not functioning.</i>
10/11/17	2017hhz	19:15:32 to 19:31:57	B: 4, 90s V: 2, 90s	Cloudy	FE16: -
	2017hqc	19:37:27 to 19:49:15	B: 4, 90s V: 2, 90s	Cloudy	FE16: -
11/11/17	AT2017htb	19:08:41 to 19:26:15	B: 5, 60s V: 8, 60s	Clear	FE16: -
	2017hhz	19:34:43 to 19:43:48	B: 5, 60s V: 4, 60s	Clear	FE16: -
	2017hle	19:45:56 to 19:53:46	B: 4, 60s V: 4, 60s	Clear	FE16: -
	2017hqc	19:55:31 to 20:02:59	B: 4, 60s V: 4, 60s	Clear	FE16: -
	Abell 426	20:04:54 to 20:08:03	B: 4, 60s	Clear	FE16: -
	2017hhz	20:09:53 to 20:34:55	B: 15, 60s V: 7, 60s	Clear	FE16: It was made clear that having more frames would improve the quality of the final stacked frame. So more frames for this supernova were made.
12/11/17	2017hhz	20:35:15 to 20:53:08	V: 17, 60s	Clear	FE16: As the night progressed, conditions became more cloudy so we were unable to take in the B band.
	2017hle	21:03:54 to 21:22:36	B: 5: 120s V: 5, 120s	Clear	pt5m: We decided to input our remaining targets into the telescope in La Palma for observation.
	2017hqc	21:26:00 to 21:57:13	B: 4: 120s V: 4, 120s	Clear	pt5m: -
15/11/17	2017hhz	21:01:09 to 21:40:40	B: 5, 120s V: 5, 120s	Clear	pt5m: -
	2017hou	00:16:29 to 00:56:01	B: 4: 120s V: 4, 120s	Clear	pt5m: -
	AT2017gyb	01:33:35 to 02:32:04	V: 20, 180s	Clear	pt5m: We made a mistake with our entry into the telescope queue- we selected too high of an exposure number.
16/11/17	2017hhz	19:19:46 to 20:11:30	B: 8, 180s V: 8, 180s	Clear	FE16: -
	2017hle	20:20:05 to 20:48:31	B: 8, 90s V: 8, 90s	Clear	FE16: -
	Abell 426	21:01:35 to 21:17:03	B: 18, 30s	Clear	FE16: -
17/11/17	2017hhz	18:52:28 to 19:49:50	B: 8, 90s V: 8, 90s	Clear	FE16: -
	2017hle	19:52:09 to 20:15:48	B: 8, 90s V: 8, 90s	Clear	FE16: -
	AT2017htb	20:18:47 to 20:29:42	B: 4, 90s V: 4, 90s	Clear	FE16: -

Date	Object	Time	Exposures	Conditions	Notes
17/11/17	AT2017hwz	20:40:43 to 21:00:19	B: 16, 60s	Cloudy	FE16: Stopped observations as it had become cloudy.
18/11/17	2017hle	18:13:52 to 19:01:03	B: 15, 60s V: 24, 60s	Clear	FE16: -
	2017hhz	19:03:47 to 19:45:56	B: 16, 60s V: 24, 60s	Clear	FE16: -
23/11/17	2017hhz	19:38:31 to 20:34:04	B: 16, 60s V: 24, 60s	Clear	FE16: -
	2017hhz	20:36:52 to 21:00:00	V: 15, 90s	Clear	FE16: Clouded over at the end of our observations for V band.

TABLE VI: Observation logs for the entire observation period for our experiment.

**Appendix C - Set of Sample Data**

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**Appendix D - Uncertainties**