LIGHT CURVES FOR SUPERNOVA SN2006JC

by

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ABSTRACT

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Senior Thesis

On October ninth of 2006 a supernova was discovered in the galaxy UGC 4904. It was designated SN 2006jc. This SN is thought to be either a type Ib, a type Ic, or a type Ibc supernova. The progenitor star is thought to have been a Wolf-Rayet star that had a massive eruption two years before the supernova. Alternatively the progenitor may have been a Wolf-Rayet Star in a binary system with the LBV star that had the outburst.

We observed this SN for 23 nights from October 26, 2006 to January 3, 2007 using the Tenagra II telescope. These observations were made in V, R, and I filters. We reduced the data and graphed the SN magnitude versus Julian date to make light curves for the three filters. The data obtained and analyzed in this thesis are part of the Swift SN Multi-wavelength Monitoring Project.

Based on our light curve we can't distinguish between type Ib, Ic, or Ibc.

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Chapter 1

Introduction and Background

1.1 Introduction

Supernovae (SNe) are very bright stellar explosions. This is a unique SN of a rare type. Stars of the class of the probable progenitor are very rare. Barely a hundred of these Wolf-Rayet stars have been observed in our own galaxy of hundreds of billions of stars. A similar low number are seen in the Andromeda Galaxy.

1.2 History

The first recorded supernova (SN) was observed by Chinese astronomers in 185 A.D. Other SNe were observed by the Chinese, Koreans, Japanese, Iraqis and Arabs in 393 A.D., 1006 A.D., and 1054 A.D. and possibly in other years.

Tycho Brahe reported the discovery of a new star in 1572 and called it a "nova". This was the first use of the term nova which is Latin for "new". The appearance of a new star challenged Aristotle's idea, which was dominant in Europe at the time, that the heavens never change. Johannes Kepler observed a SN in 1604 A.D. which was the last supernova we have detected in our own galaxy.

The objects we now call novae are similar to type Ia SNe, except a type Ia SN is considerably more luminous than a nova. Novae can repeat whereas SNe cannot, since in a SN the star is destroyed but in a nova it is not. We know now that Tycho's Nova was actually a SN. Walter Baade and Fritz Zwicky first used the term SN to distinguish regular novae from much brighter objects.

On average SNe occur only once in a hundred years in galaxies similar to our own. However, because of obscuring dust we are not able to detect all those erupting in the Milky Way Galaxy. There is now evidence that a SN occurred that would have been observed in the late 1600s if not for interstellar dust. More recently another SN remnant, which was at first thought to have been formed between 400 and a 1000 years ago, has been observed to be expanding at such a fast rate that it is now thought to have been formed from a SN that would have been observed on Earth no more than 140 years ago. This remnant is called G1.9+0.3. It lies very close to the center of our galaxy. (Reynolds 2008)

As telescopes have improved we have been able to detect many SNe in distant galaxies. In 1987, astronomers were lucky to observe a SN in the Large Magellanic Cloud, only 160,000 lightyears away. This was the closest supernova to us to occur in more than a hundred of year, that we know of. It could be seen with the naked eye. Since it was so close astronomers learned a great deal about SNe. One thing that was learned was that the progenitor was not a red supergiant, as had been predicted by the theories, but it was a blue supergiant.

1.3 Types of Supernovae

There are two main types of SNe, each with several subtypes. Type I and II are distinguished by their spectra. Types I SNe lack hydrogen lines, whereas Type II supernovae do have hydrogen lines. (Filippenko 1997)

Type Ia SNe are formed when a white dwarf accretes a certain amount of mass from a companion star. (Woolsey 2005) In a type Ia SN the accreted hydrogen (H) triggers the carbon of the white dwarf itself to undergo fusion. Type Ia SNe are very useful for finding the distance to the galaxies in which they occur. This is possible because these SN act as standard candles since all the white dwarfs that are their progenitors must be composed of essentially the same proportions of carbon and oxygen and be within a small range of masses.

All other SNe are stars that as main sequence stars had at least 8 times the mass of the sun. These stars undergo core collapse and explode, leaving a neutron star or a black hole as a remnant. Even though types Ia and Ib arise from completely different processes, they are both type I because of the lack of H lines in their spectra. Type Ib stars have evolved to the point where they have lost much of their H, probably through high stellar winds that scattered their outer H rich layers revealing the dense onion-like core where successive phases of fusion have transmuted most of the H into helium (He) and heavier elements.

Type Ic SNe lack not only H lines but also lack He lines as well, or at least their He lines are very weak. These SNe are thought to come from massive stars, like the type Ibs, except they are even further evolved to the point where they have lost most of their He as well as their H.

Type II SN still have H lines, so they are thought to have come from massive stars that retained their H atmosphere until they became SNe. There are four subtypes of type II SNe: type IIp, type IIl, type IIb, and type IIn. Type IIp have a plateau in their light curve, meaning that the rate at which the SN gets dimmer over time slows down for a period of time, then speeds up again. In Type IIl the l stands for linear. These SNe lack the plateau found in type IIp SNe. Type IIb have only a small amount of H. Type IIn have "narrow emmision lines on top of broad emmision features." (Richmond1996)

1.4 The Significance of Supernovae

Type Ia SNe are used as standard candles to calculate distances to very distant objects. Other SNe are of interest because they have produced most of the heavy elements in the universe. Also, a SN close enough to the earth could be dangerous. In fact Melott et. al. (2003) have proposed that a gamma ray bust from a very large SN (sometimes called a hypernova) was responsible for the Ordovician extinction 450 million years ago. One of the most likely stars to go SN in our galaxy is Eta Carina.

SNe have a massive impact on the interstellar medium. They form and mold nebulae. They contribute greatly to metalicity. They may trigger the formation of other stars.

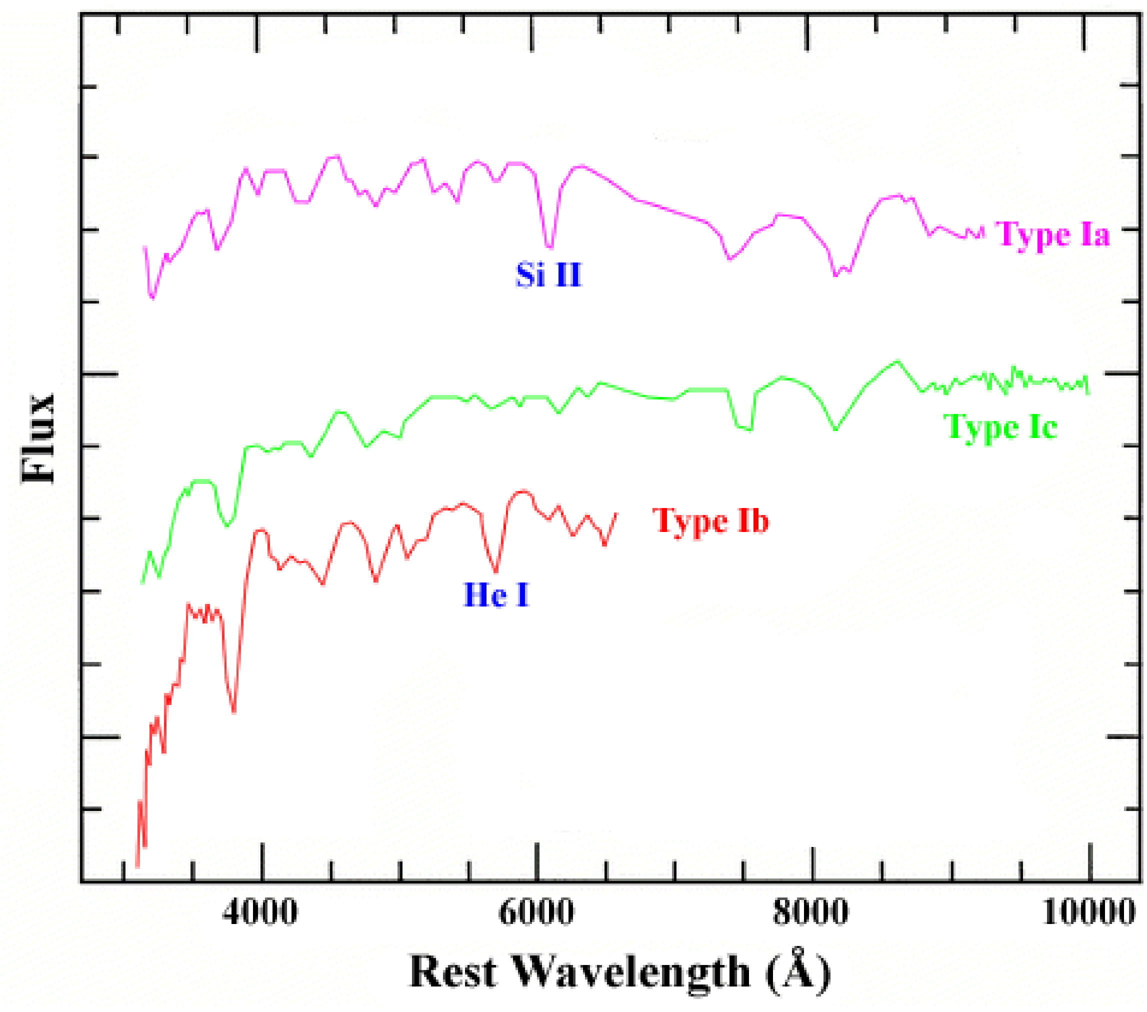

Figure 1.1: An example of Spectroscopy from COSMOS - The SAO Encyclopedia of astronomy. (Cosmos 2008)

1.5 The Process of a Core Collapse Supernova

Sne of Types Ib, Ic, and II are basically the same process. They entail the collapse under gravity of the core of a star of 8 solar masses or greater. As mentioned above, the differences in the three types have to do with how much of the outer envelope is left by the time the SN occurs.

In the cores of all stars fusion begins with the fusing of H into He. This is the main sequence stage of the evolution of a star. At this stage massive stars have spectral types O or B. As the H in the core runs out, the core contracts until it starts fusing H in a shell around the core. Most stars become a red giant at this stage. This swelling is due to the increased energy output of the core heating the outer layers which expand. However, the most massive stars do not become red giants. They become Luminous Blue Variables and then Wolf Rayet stars. This is what is thought to have happened in the case of the progenitor of SN 2006jc. In either case, as the core contracts it gets hot enough for He to fuse into carbon. Then carbon starts to fuse into oxygen, which fuses into neon, and so on until you get to iron. When iron is fused into heavier elements it no longer produces energy, so the star's core collapses further into a neutron star or a black hole.

If the core collapses into a neutron star, the outer layers will bounce off of it and expand into space in a shock wave, releasing much of the energy contained in a very short time.

If the core collapses to a black hole, the black hole starts to consume the rest of the star. An accretion disk forms inside the star and powerful beams punch out of the poles. The beams are one explanation of gamma ray bursts.

Most of the elements heavier than iron are formed during the supernova in endothermic fusion reactions, such as neutron capture. The prolonged glow of a supernova is thought to be mostly due to the decay of the radioactive elements produced during this process.

1.6 The Naming of Supernovae

The naming of SNe follows a specific pattern. The name begins with the letters SN which stand for Supernova. This is followed by the year it was observed on Earth. If multiple SNe are detected in a single year they are lettered. With modern telescopes it is now common for hundreds of SNe to be discovered each year. The first 26 SNe in a given year are lettered a through z. The next 26 are lettered aa to az. The next set are lettered ba to bz. This pattern continues. From a to zz there are 702 letter combinations. We have not yet reached the point where more than 702 SNe have been discovered in a year, but, we are getting close. In 2007, 572 SNe were discovered, the last one being SN 2007uz. 2006jc was the 263rd supernova of 2006.

1.7 The Object Under Study: The SN 2006jc

SN 2006jc was discovered simultaneously on October 9th 2006 by Koichi Itagaki and by Tim Puckett and R. Gorelli (Green 2006a). We observed it on 20 nights from October 26th to February 27th. One web site claimed it was a type Ia SN. However, several other sources claim it is a type Ib SN. One example was Benetti et al., who claimed it to be a rare type related to a type Ib Supernova. They compare it to SN 1999cq and 2002ao, both of which had strong He I emmision lines (Green 2006b). Smith et al. (2007) called it a type Ib/c SN. They contend it was really a type Ic supernova and the He lines come from the circumstellar medium enriched by the recent outburst two years ago. The previous outburst was also detected by K. Itagaki and was initially mistaken for a SN. They also proposed that they observed dust formation. They specifically studied the spectral lines He I λ 5876, He I λ 7065, H alpha, and Ca II IR.

1.8 The Position of SN 2006jc

The position of SN 2006jc is Right Ascension (RA): 9 hours 17 minutes 20.78 seconds and declination (dec) +41 degrees 54 minutes 32.7 seconds. This puts it in the constellation of the Lynx. It is offset from the nucleus of the host galaxy by -11 seconds in RA, and -7 arcseconds in dec. It is located in the galaxy UGC 04904 which is 77 million light years away. It is likely within the Local Supercluster, on the far side of the Virgo Cluster. The Local Supercluster of galaxies is also known as the Virgo Supercluster since the Virgo cluster is the core of the Local Supercluster. It may be somewhere near the Leo II Groups of Galaxies, or perhaps an outlying part of one of the Leo II groups. (See the Atlas of the Universe)

1.9 The Nature of SN 2006jc

The maximum apparent magnitude was 13.8. Unfortunately the peak magnitude occurred before observations began. According to a Chandra press release Foley proposed that it was a Luminous Blue variable (LBV) that changed into a Wolf Rayet star just a few years before it exploded. As previously mentioned, Koichi Itagaki observed that a massive outburst occured in the same area two years before this SN. It has also been proposed that the progenitor may have been a Wolf-Rayet Star in a binary system with the LBV star that had the outburst.

1.10 Luminous Blue Variables

The progenitor of this SN is thought to have recently gone through a LBV stage. This is likely the case even if the progenitor was not responsible for the earlier outburst. However, if it was not responsible, it is likely that it became a LBV thousands of years ago, rather than 2 years ago.

As the name suggests LBVs are massive blue stars that are variable. Such stars are in a short phase at the end of the lives of massive stars lasting perhaps only 40,000 years. They appear as spectral class B supergiants with photospheric temperatures of 15 - 20,000 Kelvin. Then, when active, when they expand and cool to class A or F type stars of only 8,000 degrees. They have luminosities of one million times the sun's luminosity. They have three levels of variations. The lowest level is micro variations on the order of a tenth to a fifth of a magnitude each day. There are also variations of a magnitude or two over years or decades. Finally there are massive outbursts every few centuries that increase the brightness by more than three magnitudes. They have mass loss of a solar mass over a period of 10,000 to 100,000 years. They have masses of over 40 times that of the sun. Nathan Smith and Stanley P. Owocki suggest that the massive outbursts are an important way in which these stars lose mass. (Smith 2006)

1.11 Wolf - Rayet Stars

Wolf-Rayet (W-R) stars, such as the one that may have been the progenitor of SN 2006jc, are very massive and very hot objects with unusual spectra. They had more than 40 solar masses when they were on the main sequence. They are the massive stars that are about to become SNe. They have lost most of their outer atmosphere, revealing the underlying layers that have been transmuted into heavier elements by nuclear fusion. There are three main types differentiated by their spectra. These types are the WN, which have spectral lines of He and nitrogen ions; and WC, which have spectral lines of He, carbon, and oxygen ions. (Abbot 1987) W-R stars themselves are usually only 20 solar masses or less. It is likely that at least some of the most massive stars go through this phase if they do not become SNe first. Therefore, the progenitors of these stars must lose between 30 to 130 solar masses in in order to become W-R stars. (Smith 2006) How they do this is not yet well understood. Stars of this mass only last a few million years total, while the W-R stage itself lasts only thousands of years.

Chapter 2

Data Reduction

2.1 The Data and Getting Started

Data on this SN was taken from October 26th 2006 until January 3rd 2007. The Tenagra[1]II Robotic telescope was used to get the data. It is a 0.81 meter telescope in Arizona near Mt. Hopkins and Kitt Peak. Specifically it is located at 110 degrees 52' 44.8" west longitude, 31 degrees 27'44.4" north latitude and altitude 1,312m. Its camera uses a chip based on SITe 1K X 1K X 24u chips. It is an f/7 Ritchey Chretien with an AP-8 CCD.

2.2 Reduction

Doctor Moody provided five scripts for working with the data. These scripts were login.cl, hchange.cl, ten1headfix.cl, ten2headfix.cl, reduce1.cl, and reduce2.cl. The scripts ten1headfix.cl and ten2headfix.cl were written by Professor Michael Joner. Unfortunately, the flats had many bright stars. Because of this problem with the flats the scripts reduce1.cl and reduce2.cl could not be used. Instead we reduced the data by hand.

Standard IRAF procedures were used to reduce the data, with a few minor modifications. Because of the problems with the flats we inspected all of the flat frames and combined the good ones from four days into one set of flats to use for those four days. Finally, the flat correction was applied to the object frames.

[1]The name Tenagra is an allusion to an episode of Star Trek: The Next Generation. In the episode the Enterprise encounters an alien race called the Children of Tama. They have difficulty communicating despite the universal translator. This is because the alien language relies heavily on allusions to historical or mythical figures, therefore many of their words are actually proper names. The term Tenagra has to do with the location where communication and trust were established.

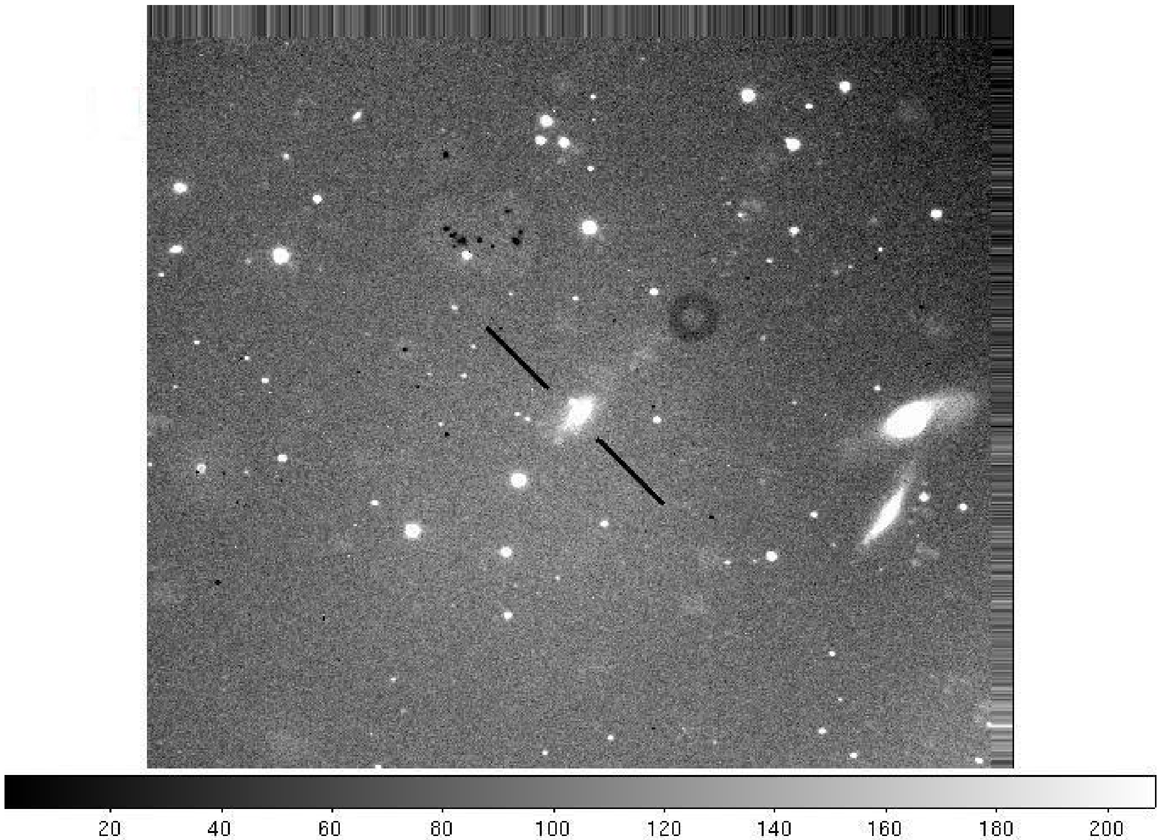

Figure 2.1: Reduced image from November 3, 2006

In order to compare the images it was necessary to adjust them so they were comparable. First we scaled the background to the same value. Then we subtracted an image where the the supernova was no longer visible from the rest of the images in order to reduce light from the host galaxy. This made photometry of the SN itself more accurate. We lost a little of the supernova, but we think it was worth it.

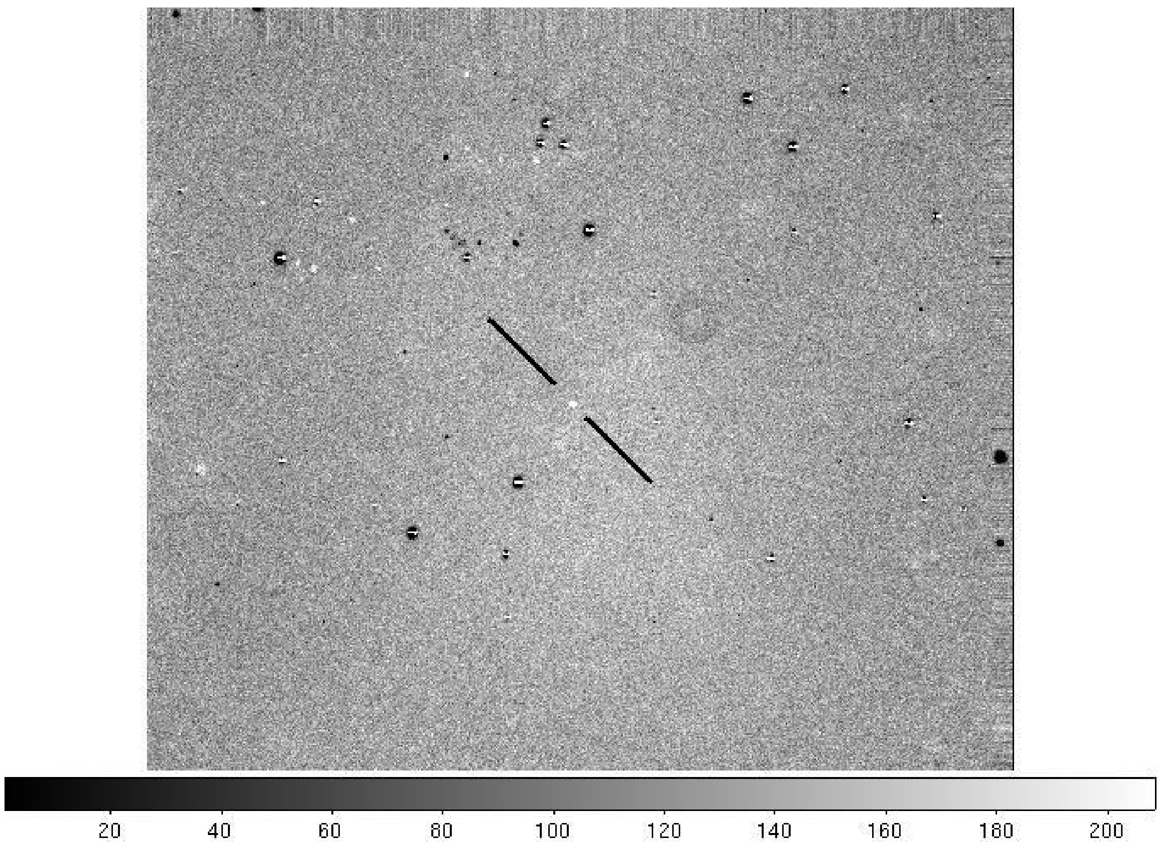

Figure 2.2: Reduced image from November 3, 2006 minus image after SN 2006jc is no longer visible

Chapter 3

Results and Conclusions

3.1 Data

In the V filter we got 27 magnitudes for 29 observations on 19 nights over a ten-week period from October 26th to December 30th. Likewise we got 26 magnitudes for 29 observations on 19 nights over the same period in the R filter, and 27 magnitudes on 17 nights in the I filter. Unfortunately, the data from October 26th and 31st were of poor quality, therefore we decided to discard these data. See table 3.1.

On the internet I found a collection of data taken by 9 sets of observers from October 9th to December 1st. They used five different filters. In addition to the V and R filters that Tenagra II used these observers used C, B, and CR filters. I included their data in table 3.2.

Table 3.1. Our Data

Date of Observation	Visible Filter	Red Filter	Infrared Filter
November 3	14.066	13.23	14.012
November 3	14.044	12.761	13.985
November 4	14.216	12.902	14.009
November 4	14.155	13.049	13.84
November 7	14.527	13.097	14.055
November 7	14.327	12.784	13.942
November 8	14.429	12.957	14.01
November 8	14.35	12.907	13.996
November 15	14.778	14.744	NA
November 16	15.161	14.875	NA
November 19	15.204	14.899	14.976
November 19	15.101	14.801	14.897
November 20	15.141	14.805	15.094
November 20	15.162	14.869	14.993
November 23	15.247	14.931	15.022
November 23	NA	NA	14.879
November 24	15.135	14.826	15.011
November 24	15.145	14.82	14.946
November 27	15.472	15.141	15.196
November 27	15.323	15.091	15.135
December 1	16.229	16.669	16.577
December 21	18.674	18.207	17.708
December 22	18.674	18.633	17.906
December 25	Indef	18.763	18.322
December 26	20.212	Indef	18.418
December 30	Indef	Indef	19.719

Note. — No I filter observations were made on November 15th or 16th. On November 23rd two frames were taken in the I filter but only one in the other 2 filters

Table 3.2. Data from other Observers

Date of Observation	Magnitude	Band	Observer
October 09.750	13.80	C	Unknown
October 10.330	13.80	C	Puckett and Gorelli
October 10.725	13.90	C	Itagaki
October 11.340	13.70	C	D. lane, Stillwater Lake, NS, 0.28-m
October 12.191	13.90	C	G. Masi and S. Foglia, Ceccano, Ital
October 12.758	13.99	V	H. Maehara
October 12.761	13.98	B	H. Maehara
October 13.674	14.30	V	Swift-uvot
October 14.125	14.20	R	J. Llapasset
October 14.173	13.90	CR	J. Llapasset
October 16.644	14.62	CR	Y. Sano
October 20.141	14.40	CR	J. Llapasset
October 20.149	14.30	R	J. Llapasset
October 20.153	14.90*	V	J. Llapasset
October 22.652	14.96	CR	Y. Sano
October 23.705	15.12	CR	Y. Sano
October 28.116	15.30	CR	J. Llapasset
October 28.121	15.20	R	J. Llapasset
October 28.124	15.80*	V	J. Llapasset
October 30.000	15.40	R	J. Llapasset
October 30.213	15.40	CR	J. Llapasset
October 30.221	16.00	V	J. Nicolas
November 10.120	16.20	CR	J. Nicolas
November 10.164	16.00	R	J. Nicolas
November 10.180	16.30*	V	J. Nicolas
November 14.104	16.30	CR	J. Nicolas
November 14.122	16.70	R	J. Nicolas
November 14.140	16.40*	V	J. Nicolas
November 14.217	16.20	CR	J. Llapasset
November 14.219	16.50	R	J. Llapasset
November 14.223	16.50*	V	J. Llapasset
November 19.113	16.50	CR	J. Nicolas
November 19.136	16.90	R	J. Nicolas
November 19.154	16.80*	V	J. Nicolas
November 24.159	16.50	CR	J. Llapasset

Table 3.2 (continued)

Date of Observation	Magnitude	Band	Observer
November 26.981	17.00	CR	J. Nicolas
November 30.140	17.10	CR	J. Nicolas
November 30.141	17.20	R	J. Llapasset
December 01.076	17.00	CR	J. Nicolas

Note. — This Data is from a the website http://www.astrosurf.com/snweb2/2006/06jc/06jcMeas.htm dedicated to SN2006jc. The * denotes magnitudes that are considered unreliable. This data is refered to elsewhere in the paper as site 1 data. Site 2 is referenced but not listed as in this table. The Site 2 data was only slightly diferent

Table 3.3. Combined Flats

Date of First Flat in Set	Date of Last Flat in Set
October 26	November 4
November 6	November 10
November 14	November 17
November 19	November 24
November 26	December 1
December 21	December 26
December 30	January 3

Note. — We combined flats from 4 days to get one good one.

3.2 Light Curves

We graphed the data we received in three light curves, one for each filter. See figures 3.1 through 3.3.

Figures 3.4 and 3.5 show a comparison between our data, denoted by the pale triangles, and the data found on the two websites.

http://www.astrosurf.com/snweb2/2006/06jc/06jcHome.htm is the first website, referred to as site 1. It is denoted by the dark diamonds.

http://www.supernovae.net/sn2006/sn2006jc.html is the second website, referred to as site 2. This website is denoted by the dark squares. Figure 3.4 shows the data from the V filter. Figure 3.5 shows the data from the R filter.

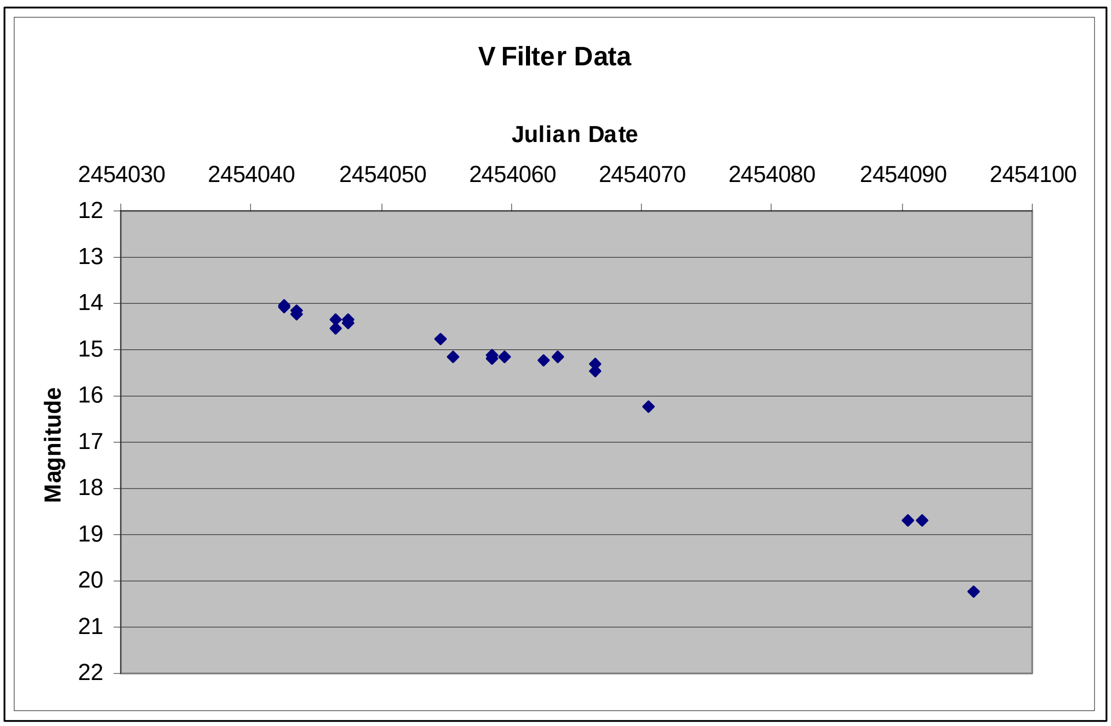

Figure 3.1: V filter light curve

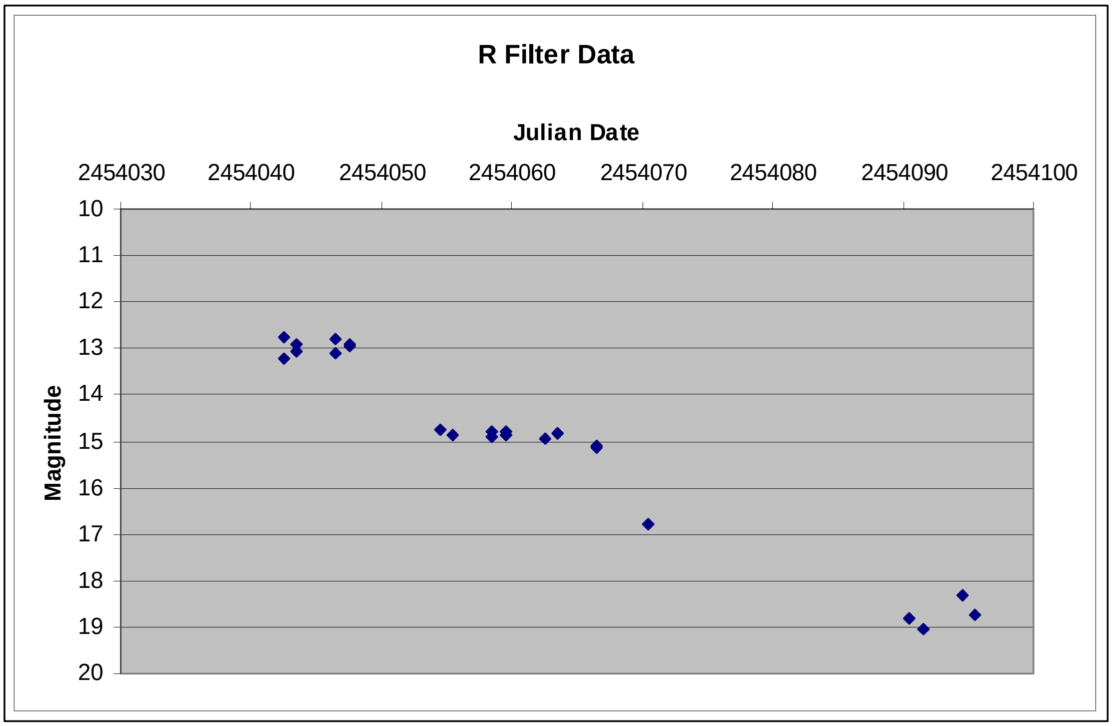

Figure 3.2: R filter light curve

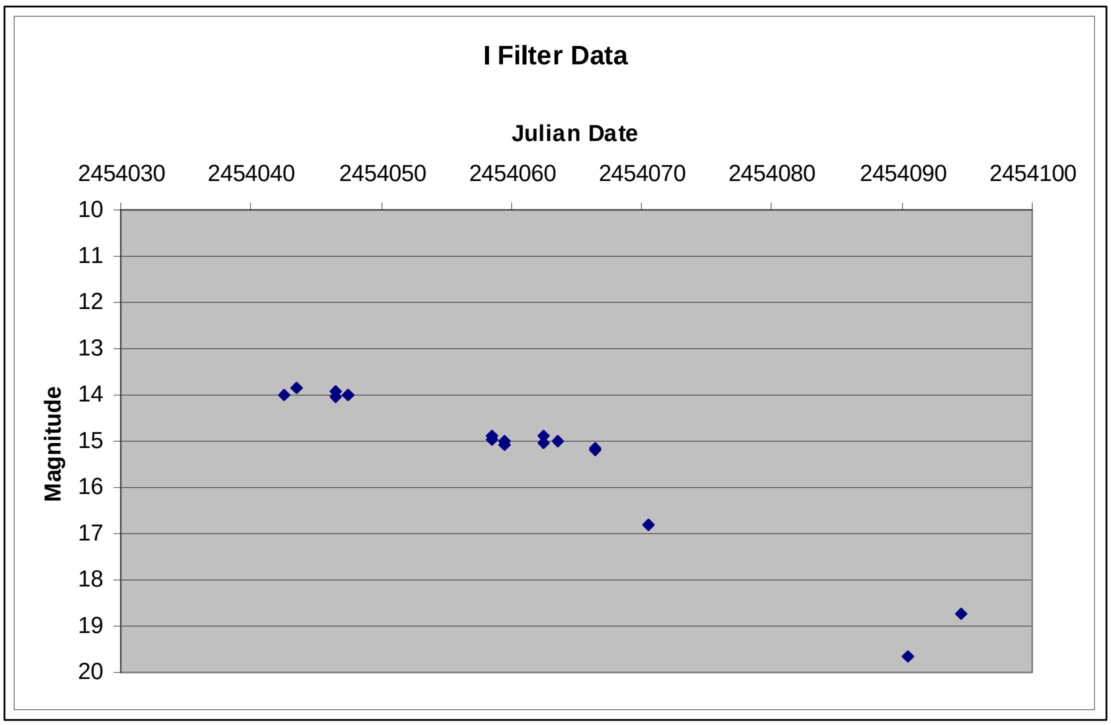

Figure 3.3: I filter light curve

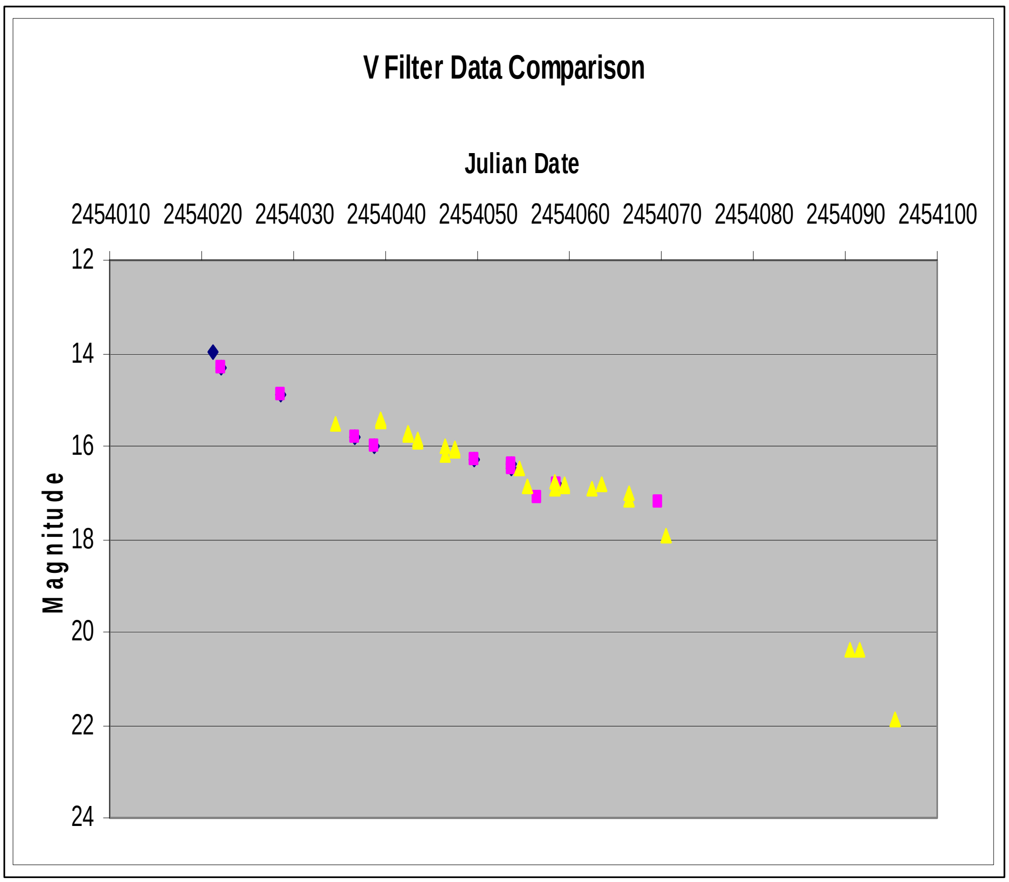

Figure 3.4: Comparison between our data (the pale triangles), the data from the website http://www.astrosurf.com/snweb2/2006/06jc/06jcHome.htm (the dark diamonds), and the data from the website http://www.supernovae.net /sn2006/sn2006jc.html (the dark squares), all in the V filter.

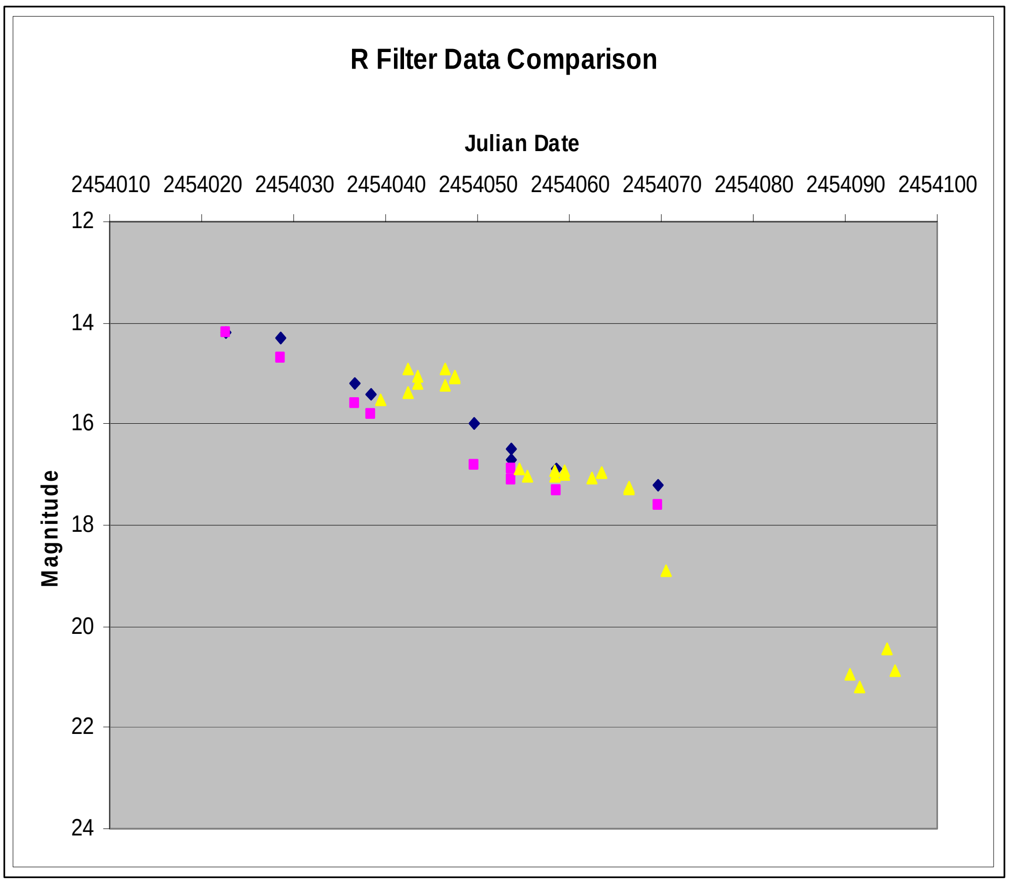

Figure 3.5: Data Comparison similar to the previous figure. This data is all in the R filter.

3.3 Conclusions

Although it is no longer possible to observe SN 2006jc, similar SNe will continue to occur in the future, albeit rarely. More study is needed to fully understand these rarest of SNe.

Unfortunately we did not start observations soon enough to see the peak. Of course no one else did either. Our data showed a gradual decline from 14th magnitude to 20th magnitude in the V filter over a two month period.

We did a treadline for the data from the other observers in the filters V and R, plugged the dates of our observations into these equations, subtracted our data from these expected magnitudes and took an average. We then shifted our data by these amount in the two filters.

$$M = -0.0009xD^2 + 0.1023xD + 14.269 \tag{3.1}$$

$$M = -0.0009xD^2 + 0.0968xD + 13.992 \tag{3.2}$$

The shift in the V filter was 1.689544 magnitudes. The shift in the R filter was 2.13847 magnitudes. The standard deviation for the V filter data is 1.626269. The standard deviation for the R filter data is 1.341089.

There does appear to be a plateau. In the V filter it looks like there may be one plateau, although this would be more clear if we had more data especially between December 1st and December 21st. In the R Filter there appears to be 2 separate plateaus. there is also evidence for a plateau in the I filter. However this is less clear since we do not have corroborating data in this filter.

Our data agrees well with the published values. The V band data fill in the curve well. The R band is not as clear. The first plateau may be a calibration error. The type of supernova could be type Ib, Ic, or Ibc. However, these types are distinguished by their spectra, so our photometry can't tell us which is which. To really understand this SN, we must look closely at the spectroscopy.

References

Abbott, D. C. & Conti P. S. 1987, Ann. Rev. Astron. Astrophys., 25, 113-50

Baade, W & Minkowski, R. 1954, ApJ, 11 9, 206-214

Bennetti, S., et al. 2006, Cent. Electron. Tel., 674, 2

Cassiopia A and SN 1680 or 1667,
(http://www.seds.org/ spider/spider/Vars/casA.html)

Clarke, D. H. & Stephenson, F. R. 1982, In: Supernovae: A survey of current research, Cambridge, 355-370

Cosmos - The SAO Encyclopedia of Astronomy, 2008,
(http://astronomy.swin.edu.au/cosmos/)

Filipenko, A. V. 1997, ARAandA, 35, 309

Gamezo et al. 2003, Science, 299, 77-81

General Catalogue of Variable Stars 2004,
(http://www.sai.msu.su/groups/cluster/gcvs/gcvs/iii/vartype.txt)

Green, D. W. E., Possible Supernova in UGC 4904. 2006, CBET, 666

Green, D. W. E., Supernova 2006jc in UGC 4904. 2006, CBET, 674

International Supernova Network 2008,
(http://www.supernovae.net/isn.htm)

Melott, A. L. et al. 2003 (http://bear.phsx.ku.edu/ medvedev/grbio/grbio.pdf)

Pastorello, A. et al. 2006, Nature, 447, 829-832

Peripatus LBV website, (http://www.peripatus.gen.nz/Astronomy/LumBluVar.html)

Reynolds, Stephen P., The Youngest Galactic Supernova Remnant. 2008, ApJ, 680, L41-L44

Richmond, M. SN Taxonomy 1996, (http://stupendous.rit.edu/richmond/answers/sntypes.txt)

Bright Supernovae - 2006 (http://www.rochesterastronomy.org/snimages/)

SIMBAD database 2008, (http://simbad.harvard.edu/cgi-bin/WSimbad.pl)

Smith, N. & Owocki, S. P. 2006, Ap. J., 645, L45

Smith, N., Foley, R.J., & Filipenko, A. V. 2007 draft arXiv: 0704.2249vl

Supernova 2006jc in UGC 4904. 2006, Supernovae.net, (http://www.supernovae.net/sn2006/sn2006jc.html)

Tenagra Website, (http://www.geocities.com/SiliconValley/Garage/9531/tenagratelescopes.htm)

Tenagra Website, (http://www.tenagraobservatories.com)

University of Cambridge 2008, (http://www.admin.cam.ac.uk/news/dp/2008051901)

Vacca, W. D., Rayner, J. T., & Cushing, M. C. IRTF Near Infrared Spectral Atlas. I. Wolf-rayet Stars. 2003, IRTF Science Highlights 23

Woosley, S. & Janka, T. The Physics of Core Collapse Supernovae