Comparison of Light Curves for Type Ia Supernovae in the Optical and Ultraviolet

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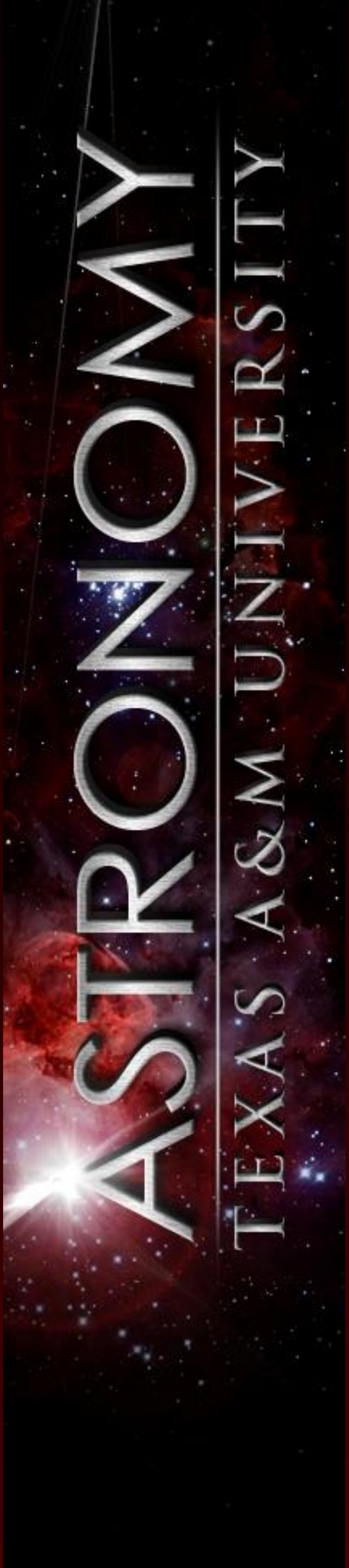

Abstract

Type Ia supernovae (SNe Ia) are often called standard candles, since the explosions of these white dwarf stars have similar magnitudes in optical light. Because of this, they are used to measure cosmological distances. This project was a photometric study in which we analyzed the light curves of many SNe Ia in the ultraviolet range of wavelengths. Using Swift Ultra Violet Optical Telescope (UVOT) data, we were able to compare the light curves and create a template of these supernovae's magnitudes in six ultraviolet and optical filters. To do this, we took several averages of their magnitudes over different times from the peak magnitude, and then fit the template back to the individual light curves to show how varied the light curves are. By doing this, we are able to gain insight on the validity of our use of SNe Ia as standard candles for measuring cosmic distances and how much variation there is at different wavelengths.

Introduction

By observing supernovae, astronomers are able to gain a better understanding of how our universe works. SNe Ia are particularly useful for this, since they have a high optical luminosity which correlates closely with the optical light curve shape and color. Because of this, SNe Ia are called standard candles, or a type of object whose luminosity and observed brightness can be compared to compute distances. The standard way to characterize SNe Ia is through spectroscopy. Generally, SNe Ia will have strong Si II absorption lines, and an absence of a hydrogen absorption line. However, as more SNe are discovered, photometric observations are more readily available than spectroscopic observations. This is purely due to a lack of telescopes with available spectrometers. Instead, more astronomers are starting to classify SNe by their light curves. Typically, SNe Ia will reach a peak brightness, and then it will decline. For example, you can see that in the different light curves of SN2015F.

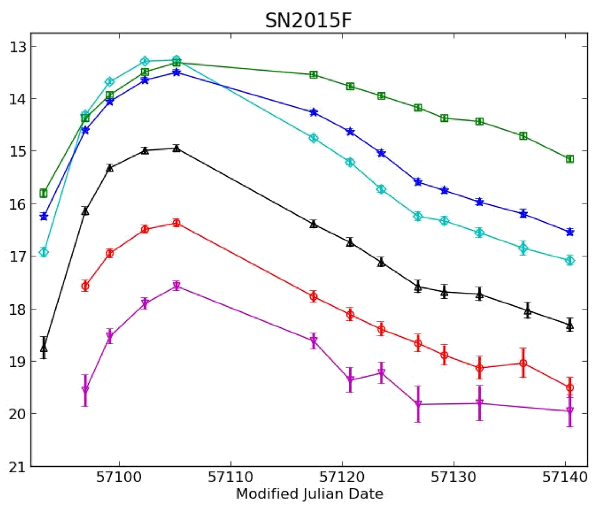

Figure 1. Light curves in six filters of SN2015F.

In order to create these light curves, we first have to do the photometry for each supernova. After doing the photometry and creating the light curves, we generate a three-color image of the supernova and its host galaxy.

Figure 2. Three-color image of SN2015F and its host galaxy NGC 2442.

Swift Telescope

Swift is a multi-wavelength observatory dedicated to detecting gamma-ray bursts. Swift has three instruments: Burst Alert Telescope (BAT), X-ray Telescope (XRT), UV/Optical Telescope (UVOT). The instrument that this data is from is the UVOT instrument. As described in Roming et al. (2005), this instrument observes objects in six filters. Three of these filters are in optical wavelengths (u, b, v), and three are in ultraviolet (w2, m2, w1).

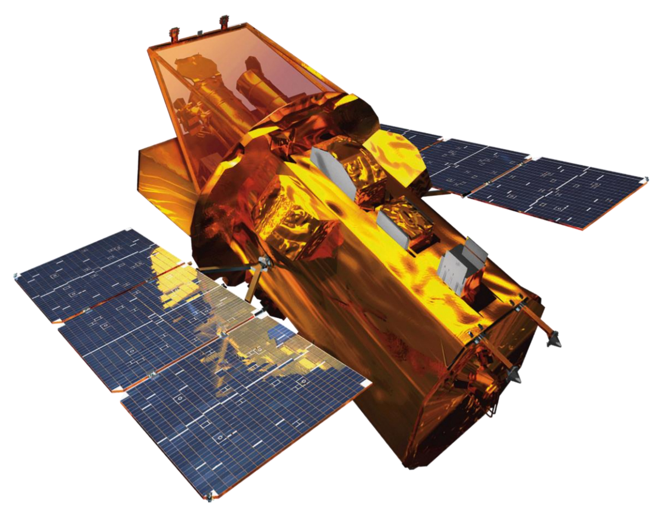

Figure 3. Model showing the Swift Telescope and all of its instrumentation.

Each of these filters are for observing in different ranges of wavelengths. In Figure 4, you can see that these filters cover a different range of wavelengths from uvw2 covering the smallest wavelengths, to v covering the largest for this instrument. In order from smallest wavelength filter to largest, the filters are uvw2, uwm2, uvw1, u, b, v.

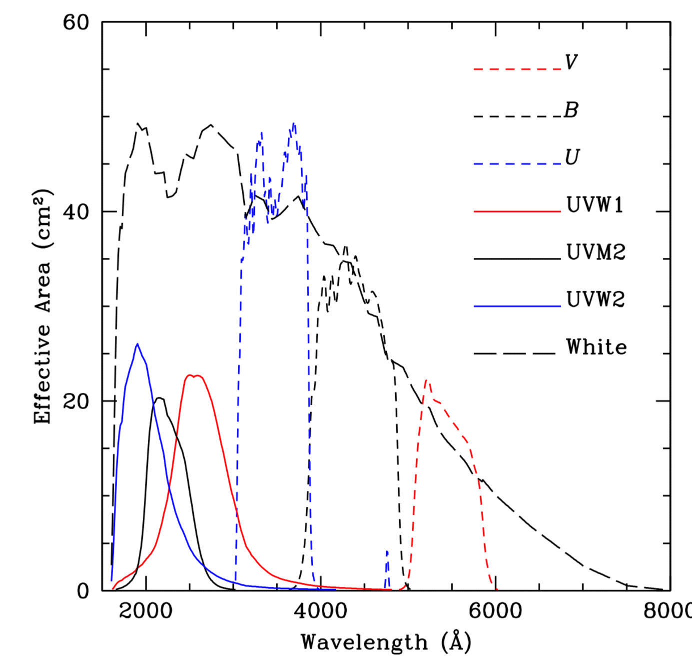

Figure 4. Graph showing which wavelengths each filter covers.

Analysis

We graphed each of the light curves of the same filter on the same display. Then, we lined them up based on the brightest observation on each curve. The black points on each graph represent the average magnitude for each day from 10 days before the peak to 20 days after the peak. These points give us an idea of how closely related each of them are in various filters. From these graphs in Figure 5, we can see that the ultraviolet filters (left column) have more scatter, and the optical filters (right column) have a tighter fit. From the black points, we were able to create a template light curve. This template allows us to check each individual light curve's variation from the average. The Milne et al. (2010) paper created templates in the uvw1 and uvw2 filters, but did not have enough observations in the uvm2 filter.

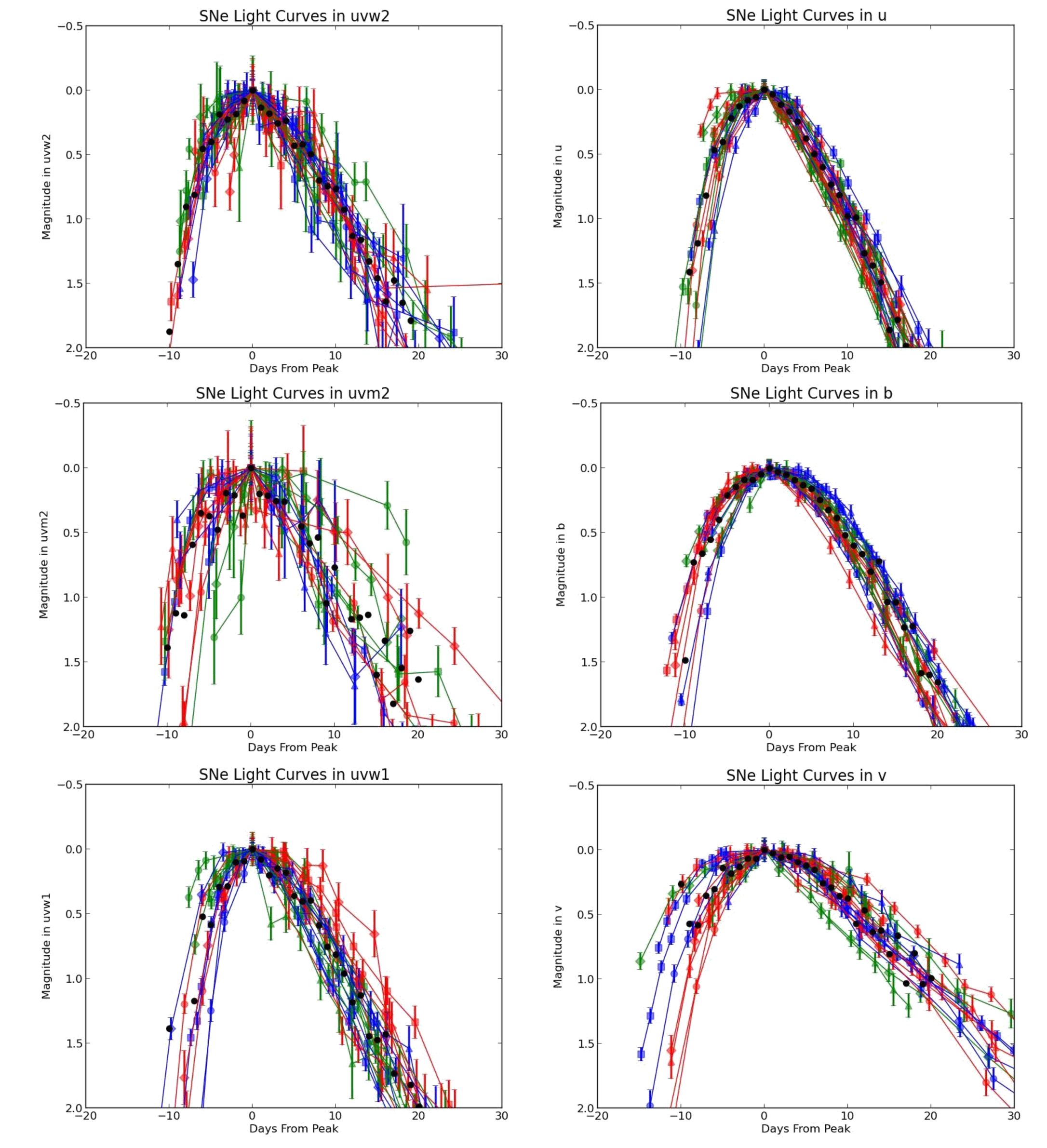

Figure 5. Six graphs showing the light curves of each filter lined up by the brightest point on each light curve. The black dots show a template for each filter.

List of Supernovae

We have looked at a range of Type Ia Supernovae from Brown et al. (2017). The table below provides a list of the supernovae which were analyzed, their host galaxies, and in which filters they were plotted (denoted by an x).

Supernova	Host Galaxy	w2	m2	w1	u	b	v
SN2015F	NGC 2442	x	x	x	x	x	x
SN2013gy	NGC 1418	x	x	x	x		
SN2013gs	UGC 5066	x	x	x	x		
SN2013ex	NGC 1954		x	x			
SN2013eu	UGC 5609		x	x		x	x
SN2013cs	ESO 576-17		x	x	x	x	
SN2012ht	NGC 3447		x	x	x	x	x
SN2012hr	Anon.	x	x		x		x
SN2011im	NGC 7364	x	x	x	x	x	x
SN2011ia	MGC +11-22-23	x		x		x	
SN2011by	NGC 3972	x	x	x		x	x
SN2011ao	IC 2973	x	x		x	x	
SN2011B	NGC 2655	x	x		x	x	
SN2010kg	NGC 1633	x	x	x	x	x	x
SN2010gp	NGC 6240	x	x	x	x		x
SN2010gn	Anon.	x	x	x	x	x	x
SN2010ev	NGC 3244	x	x	x	x	x	x
SN2009cz	NGC 2789	x	x	x	x	x	x
SN2009Y	NGC 5728	x	x	x	x	x	x
SN2008hv	NGC 2765	x	x	x	x	x	x
SN2008ec	NGC 7469	x	x		x	x	x
SN2008Q	NGC 524	x	x	x	x		
SN2007co	MGC +05-43-16	x	x		x	x	x
SN2007af	NGC 5584			x	x	x	x
SN2006ej	NGC 191	x	x	x	x	x	x
SN2006dm	MGC -01-60-21	x	x		x	x	x
SN2005df	NGC 1559	x	x	x	x	x	x
SN2005cf	MCG -01-39-3	x	x		x	x	x

References

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