# SUPERNOVAE CLASSIFICATION BY THE OBSERVATION OF LIGHT CURVES

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## Abstract:

Certain stars will end their existence in the form of a supernova explosion. A supernova is classified by its observable characteristics, namely, its spectrum and light curve. Each specific type of supernova will exhibit a unique light curve as it decays in brightness. The features of these light curves are dependent on the composition of matter that make up the progenitor stars. How this matter absorbs and reemits the huge energy release that is a supernova explosion will dictate the shape these curves. If a newly observable supernova is methodically imaged, photometry techniques can be used to formulate its light curve. The type of the supernova can then be determined by comparing its light curve to standard models. This is the basis of this research. Using the equipment at the Fort Lewis Observatory, several supernovae were imaged, photometry techniques were implemented on each and with varying degrees of success the resulting light curves yielded information on the types of supernovae at hand.


## Experimental Procedure:

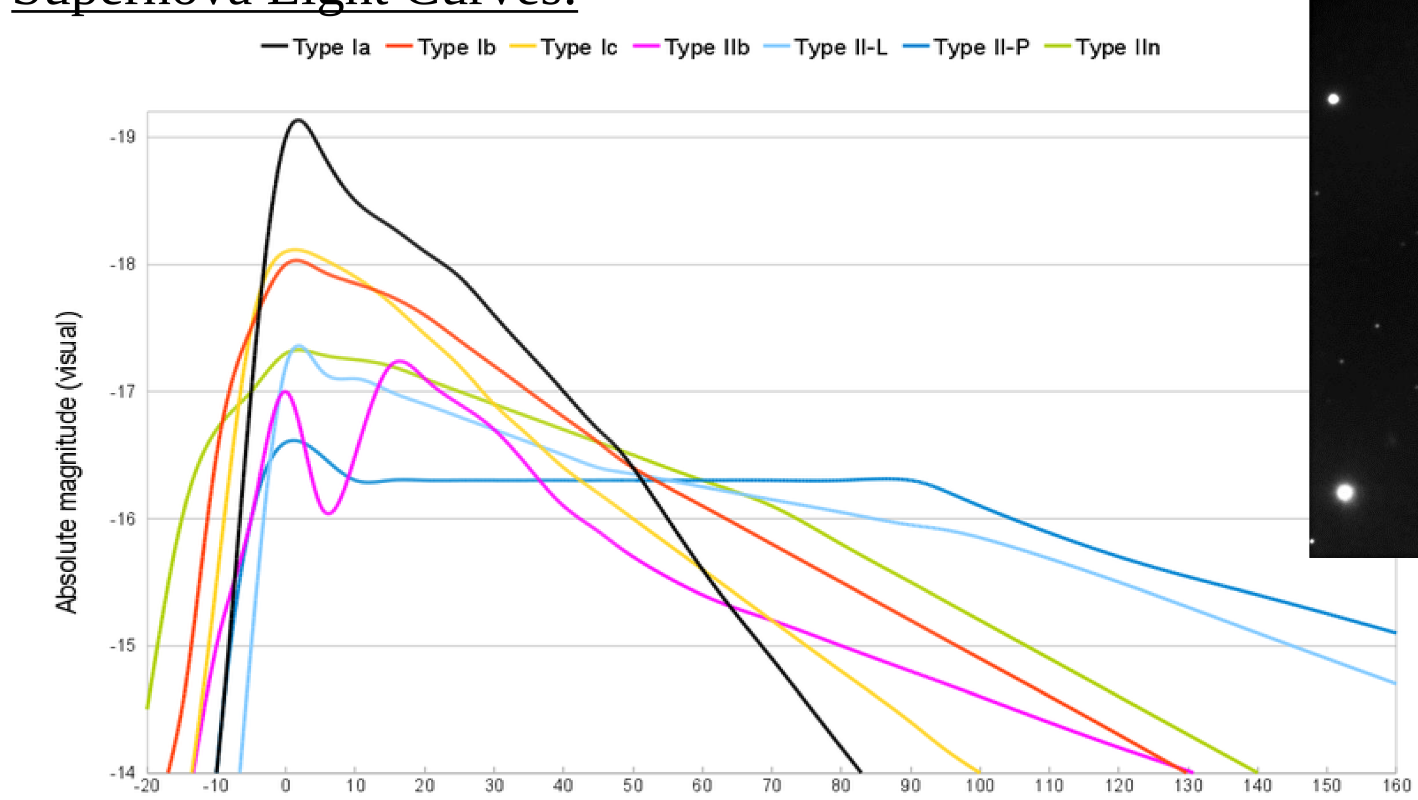
- † An image taken with a CCD camera carries precise information about differential photon flux between each object in the image.
- † With current databases of stellar objects, most stars have a cataloged magnitude of brightness.
- † Using astronomical image processing software, the measurement of an object's brightness as a function of time is possible. This procedure is known as photometry.
- † With a reference star of cataloged magnitude, $m_r$ , the magnitude of a supernova, $m_s$ , can be calculated using the equation:

$$m_s = -2.5\log(F_s/F_r) + m_r \, , \qquad (1)$$

where $F$ is each objects' respective photon flux.

- † This is done with several reference stars to get an average magnitude for the supernova. Then a light curve can be formulated with each data point representing a single night of observation.
- † With proper data, the type of supernova at hand can then be deduced based on the features of this light curve.

## Supernova Light Curves:



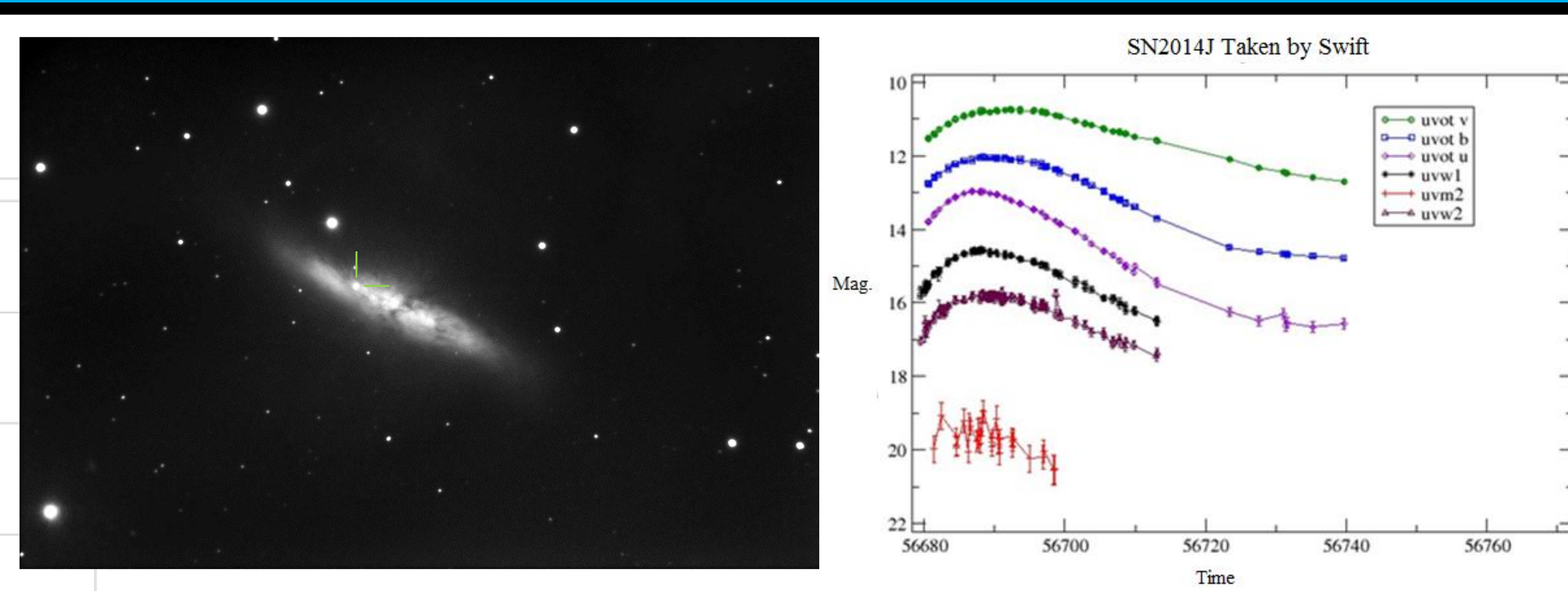




Figure 4: M 82 with the type Ia supernova SN2014J on the left. The image to the right is a plot of light curves for SN2014J taken with various filters. These were taken by NASA's spacecraft Swift.

Figure 3: Examples of different supernovae and their characteristic light curves. For example, a type Ia supernova (black) happens when a white dwarf star accretes matter from a companion star until its oxygen carbon core reaches the Chandrasekhar mass of 1.44 solar masses and thermonuclear runaway obliterates the star. The first steep part of the curve relates to radioactive nickel 56 decaying to also radioactive cobalt 56. The second part of this curve relates to this cobalt 56 decaying to stable iron 56. Both of these reactions are positron decay. The rest of the supernovae shown occur when supermassive stars collapse, and based on the composition of the stars' outer layers, the energy of the explosion will be absorbed and reemitted in similar nuclear reactions, but in ways unique to the type. (Wikipedia image)

## Photometry Methods:

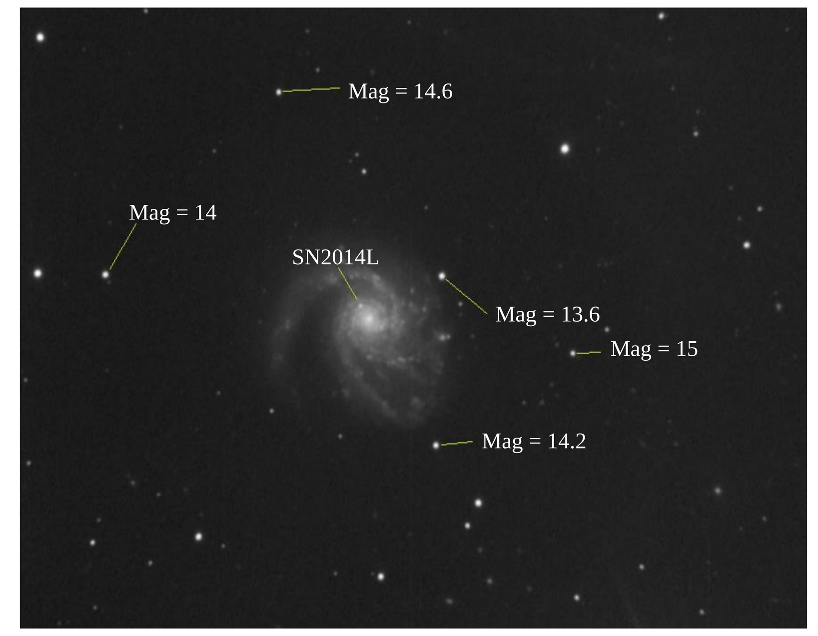



Figure 1: The magnitude of a supernova is determined by comparing its measured intensity to the respective intensity of several cataloged reference stars. Shown here is SN2014L in galaxy M 99, along with the stars used for differential magnitude calculations.

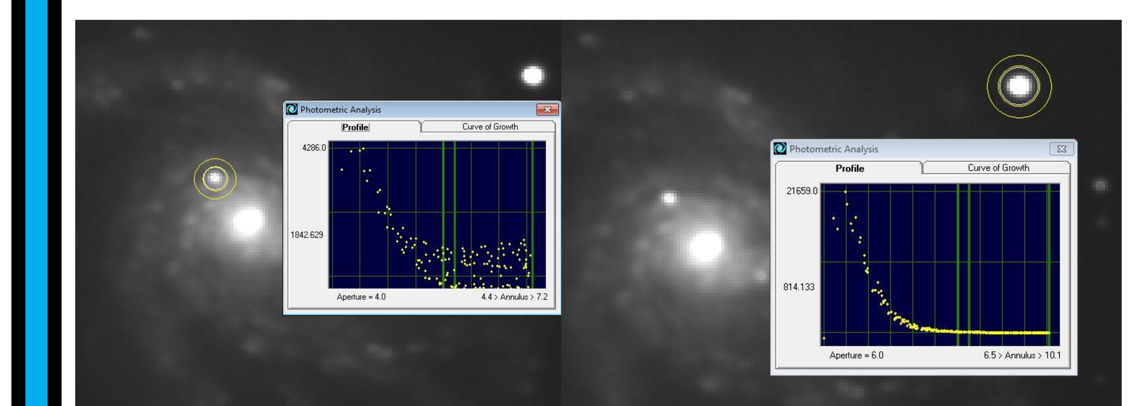


Figure 2: AIP4WIN's aperture/annulus method of photometry subtracts the sky's background light from the light of a star to calculate the total photon flux for that star. Then equation 1 can be used. This method is very accurate for stars, but not so accurate for a supernova embedded in a galaxy. Notice the ill behaved distribution of light for SN2014L, verses the well behaved distribution of light for the reference star.

## Experimental Results:

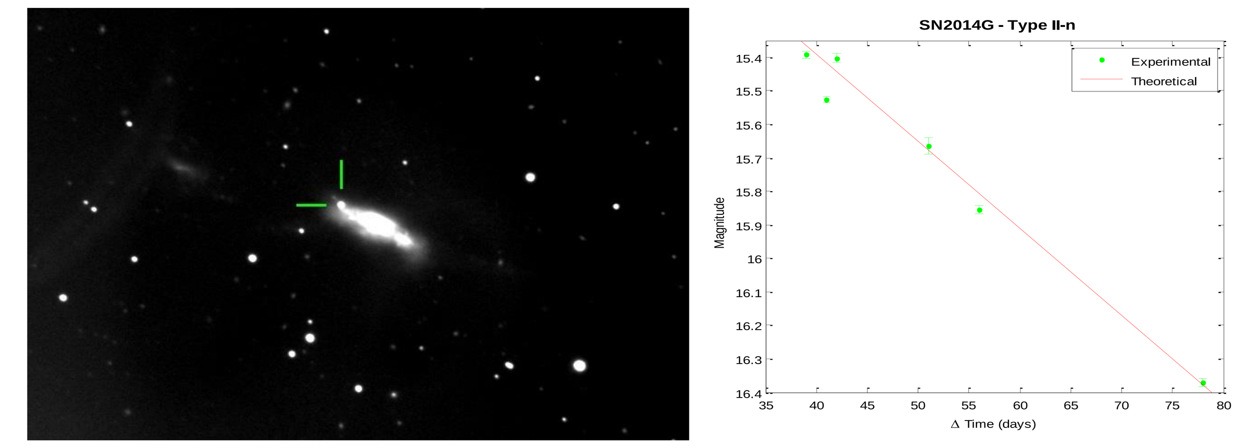



Figure 5: SN2014G of galaxy NGC 3448 shown with experimental data points along with a linear fit standard for a type II-n supernova. This supernova gave the most well behaved and informative data of the experiment, as the background light from the galaxy is minimal and well distributed.

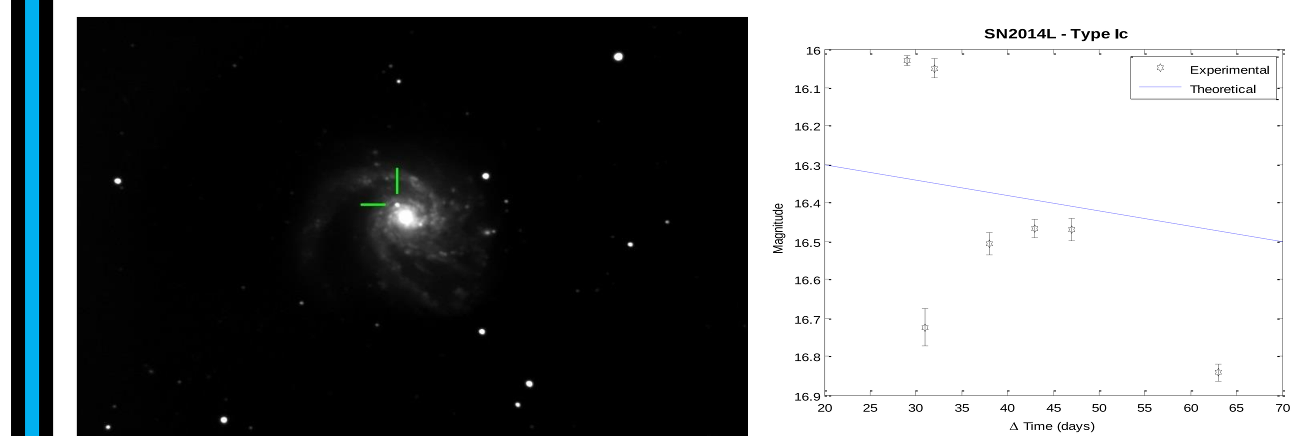



Figure 6: SN2014L of galaxy M 99 gave perhaps the most ill behaved data, in part because of how close it is to the nucleus of M 99. This makes accurate magnitude calculations difficult as there is irregularly distributed background light, which skews the data.

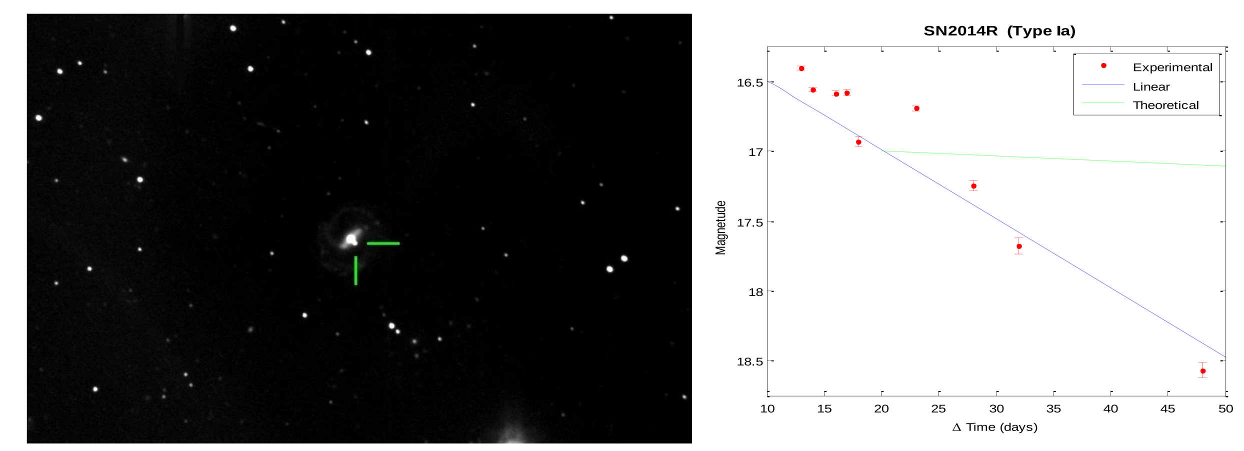



Figure 7: SN2014R of galaxy UGC 5055. Despite being classified as a type Ia by spectral analysis, the resulting data showed a near linear nature, corresponding to the decay rate of radioactive $^{56}$Ni. I have no explanation for this.

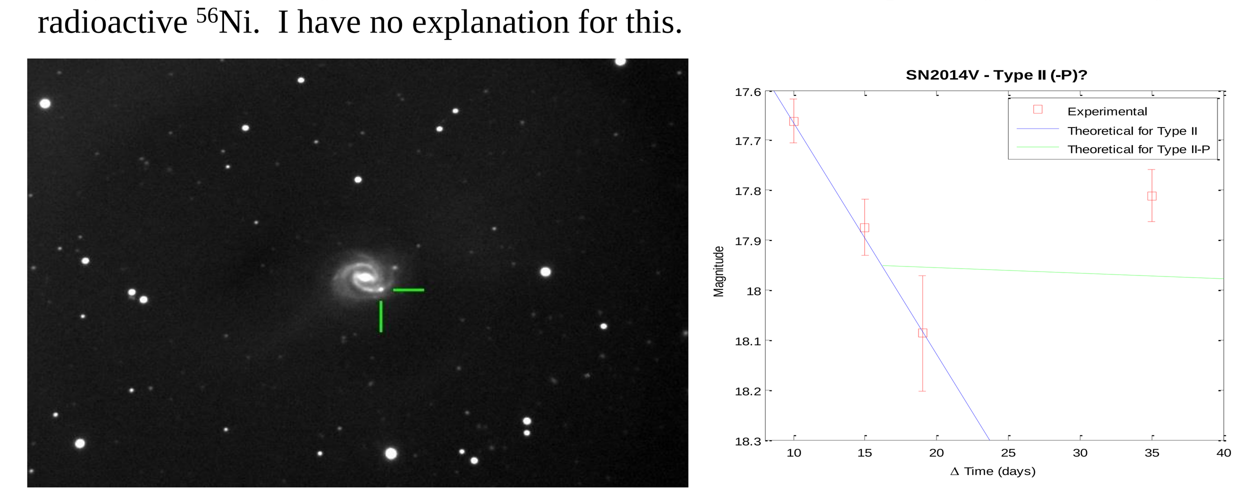



Figure 8: SN2014V of galaxy NGC 3905 lacked data points because imaging on it began late in the project. Categorized only as type II by CBAT, the last data point raised question to if it could be a type II-P, whose light curve has a characteristic plateau due to large amounts of exited hydrogen. This being said, this point is likely just a bad data point.

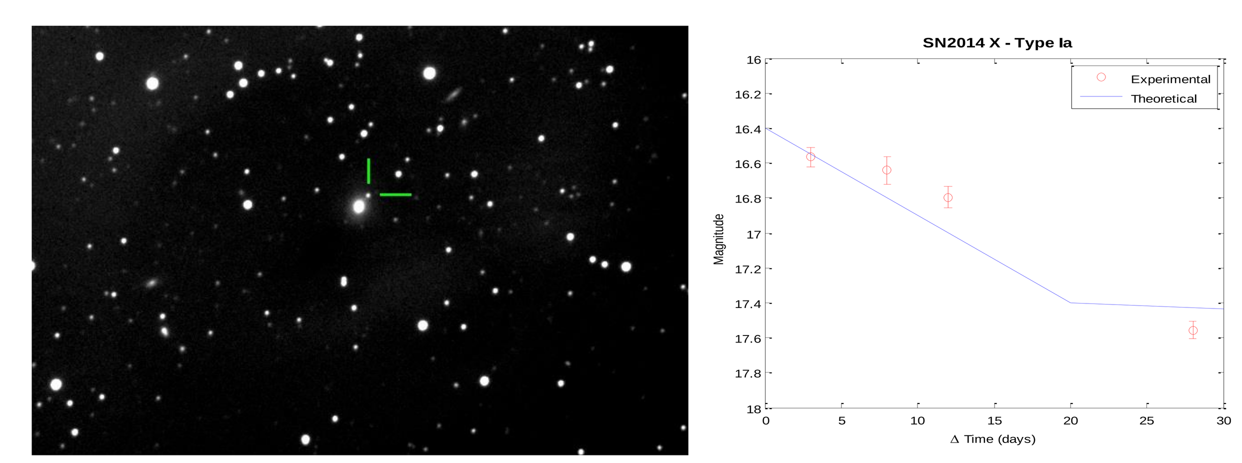



Figure 9: SN2014X of galaxy ESO 379-G31. Although again lacking data points, this target was the closest I got to observing a supernova at peak brightness. This supernova is perfect for magnitude calculations as there is little background light surrounding it. From the look of the points, if imaged more frequently and for a longer period of time, this supernovae would have produced a type Ia light curve much like those of figure 4.

## Conclusions:

- † Spectral analysis is typically a more efficient way to classify supernovae, unless light curves appear as those in figure 4.
- † Due to the background light of galaxies, the aperture/annulus method of photometry doesn't always produce measurements of photon flux accurately representative of a supernova's brightness.
- † Astronomers that are serious about making supernova light curves have archived images of galaxies such as M 99, so when a supernova happens to occur in one, they can literally subtract the image of the galaxy without the supernova from the image of the galaxy with the supernova. This leaves only the supernova's light, and is a much more accurate way to measure and compare its photon flux.
- † Hazy or moonlit nights added to the discrepancy of my data.

## References: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"SN2014J UVOT Light Curves" http://people.physics.tamu.edu/pbrown/SwiftSN/SN2014J_lightcurve.jpg (Image 4)


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