

SUPERNOVA LIGHT CURVES – What type of supernova?

ImageJ

In the spring of 1994 several high school students were studying M51, the spiral galaxy also known as the Whirlpool Galaxy. Various images had been requested throughout February and March, and in early April, two girls at Oil City High School in Pennsylvania received an important phone call. They had serendipitously obtained the first images of a supernova in M51.

A supernova is the violent process that a very massive star undergoes when it dies. Many people think of supernovae as explosions, and in some cases this is true, but some stars implode rather than explode when they die. In either case, the brightness of the star increases dramatically during a supernova and then fades off continually until it is no longer visible. The rate at which the brightness increases and then fades is one indicator of which type of supernova has occurred and what type of star is involved. In the *Supernova Light Curve Unit* you will use images taken by students to create and study a plot of the brightness of a supernova as it changes over several weeks. This plot is called a light curve.

In order to measure the brightness variation of the supernova itself, you must eliminate effects caused by changing observing conditions. This is done through the use of a reference star. Since the reference star and the supernova are within the same image, the observing conditions are identical for both objects. The reference star should have constant luminosity which means if the observing conditions remain constant from one night to the next, the Counts of the reference star will remain the same. In general, observing conditions do change, so the number of Counts measured for the reference star will increase or decrease depending how much light the atmosphere lets through on a given night.

If the luminosity of the supernova candidate were to remain constant from image to image even though the observing conditions change, the ratio of Counts for the supernova and the reference star would also remain constant – then the candidate is not a supernova. However, for a supernova that grows brighter and then fades, the brightness ratio changes accordingly. By measuring this ratio for each image, you can plot the true light curve for the supernova.

Supernovas were originally classified on the basis of their optical properties. [Type II supernovas](#) show conspicuous evidence for hydrogen in the expanding debris ejected in the explosion; [Type Ia](#) explosions do not. Recent research has led to a refinement of these types, and a classification in terms of the types of stars that give rise to supernovas. A Type II, as well as Type Ib and Type Ic explosion, is produced by the catastrophic collapse of the core of a massive star. A Type Ia supernova is produced by a sudden thermonuclear explosion that disintegrates a [white dwarf](#) star.

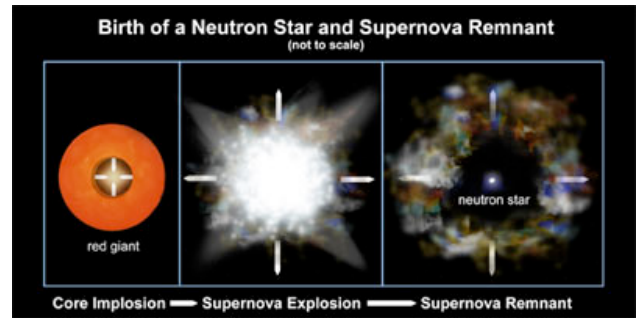
Type II supernovas occur in regions with lots of bright, young stars, such as the spiral arms of galaxies. They apparently do not occur in elliptical galaxies, which are dominated by old, low-mass stars. Since bright young stars are typically stars with masses greater than about 10 times the mass of the sun, this and other evidence led

to the conclusion that Type II supernovae are produced by massive stars.

Some Type I supernovas show many of the characteristics of Type II supernovas. These supernovas, called Type Ib and Type Ic, apparently differ from Type II because they lost their outer hydrogen envelope prior to the explosion. The hydrogen envelope could have been lost by a vigorous outflow of matter prior to the explosion, or because it was pulled away by a companion star.

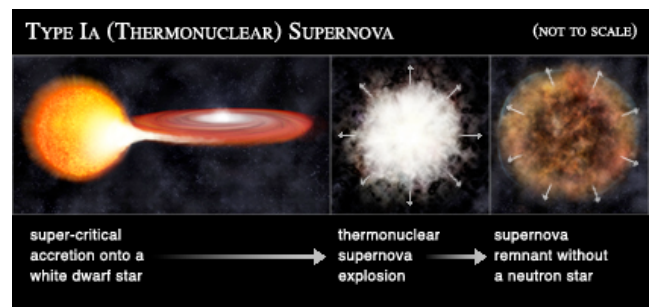
Core-collapse Supernovas

These all have the same type of graph. The general picture for Type II, Type Ib and Type Ic supernovas - also called core-collapse supernovas - goes something like this. When the nuclear power source at the center or core of a star is exhausted, the core collapses. In less than a second, a [neutron star](#) (or a [black hole](#), if the star is extremely massive) is formed. The formation of a neutron star releases an enormous amount of energy in the form of neutrinos and heat, which reverses the implosion. All but the central neutron star is blown away at speeds in excess of 50 million kilometers per hour as a thermonuclear shock wave races through the now expanding stellar debris, fusing lighter elements into heavier ones and producing a brilliant visual outburst that can be as intense as the light of several billion Suns.



Thermonuclear Supernovas

Type Ia supernovas, in contrast, are observed in all kinds of galaxies, and are produced by white dwarf stars, the condensed remnant of what used to be sun-like stars. A white dwarf star, a dense ball primarily composed of carbon and oxygen atoms, is intrinsically the most stable of stars, as long as its mass remains below the so-called Chandrasekhar limit of 1.4 solar masses.



If, however, accretion of matter from a companion star or the merger with another white dwarf, pushes a white dwarf star over the Chandrasekhar limit, it will collapse, heat up and explode like a thermonuclear bomb, leaving nothing behind. The expanding cloud of ejecta glows brightly for many weeks as radioactive nickel produced in the explosion decays into cobalt and then iron.

Because Type Ia supernovas all occur in a star that has a mass of about 1.4 solar masses, they produce about the same amount of light. This property makes them extremely useful as a distance indicator - if one Type Ia supernova is dimmer than another one, it must be further away by an amount that can be calculated. In recent years Type Ia supernova have been used in this way to determine the rate of expansion of the universe. This research has led to the astounding discovery that the expansion of the universe is accelerating, possibly because the universe is filled with a mysterious substance called dark energy.

SUPERNOVAE LIGHT CURVES UNIT

Activity I: Look What We Found!

Open up images: *M51img1* and *M51img2*

Images on class website at the top: Fits Images: Supernova

These are two images of M51, the whirlpool galaxy. The first, *M51img1*, was requested by Scott Miller, a high school student at Oil City PA, on February 12, 1994. The core of the galaxy is the bright spot near the bottom of the image. The bright spot near the top is a companion galaxy. The second, *M51img2*, was requested on March 31, 1994 by Heather Tartara and Melody Spence, Scott's classmates, to further study the galaxy. Heather and Melody received some surprising news soon after obtaining their image.

- Use **Log Scaling** and adjust the **Brightness/Contrast** on both images to see more detail within the region of the core of M51 and try to find what all the excitement was about. It may not be easily seen and you may have to open up the additional images listed below.

Open up images: *M51img1*, *M51img2*, and *M51img3*

The image *M51img3* was requested by Vincent Prosapio, a student at Alan B. Shepard High School in Palos Heights, IL, on April 7, 1994.

- Use **Log Scaling** and adjust the **Brightness/Contrast** to see the galaxy.

1. Use drawings and words to compare the three images.

2. Approximately how many times brighter than the Sun is the supernova?

The core of M51 (the bright spot in the center) is about as bright as a million Suns. Use **Aperture Photometry tool** to compare the brightness of the supernova to the core of the galaxy. You might want to change the radius.

3. Use a new image of M51 requested by your class or a recent image of the galaxy from the Skynet or MicroObservatory database. You can also use the image on our webpage (*m51march52000.fits*) but it is from 2000. Compare whichever new image you choose to work with, to the images from Spring of 1994. Describe your findings.

Activity II: Plotting the Light Curve of SN1994i

Open up images: *SNimg1* through *SNimg12*. It is probably easiest to use one image at a time and repeat the procedure below for each one

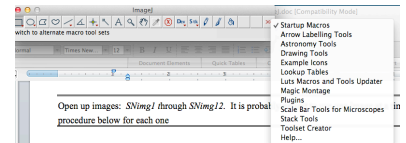
These twelve images of the supernova were taken in April and early May of 1994. The date of observation and other information are listed under **Show Info**. To create a light curve you must use only images taken through the same filter. All these images were taken through the I filter, which lets through infra-red light. The images you examined in Activity I used the V filter (letting through mostly yellow light) so they cannot be used together with these images to create the light curve.

4. Find the night number and measure the light from the supernova and reference star.

- Find the night number by counting the number of days between the observation date and March 31, 1994 which was the first night it was seen. Find the observation date in the *Image Info*, in the Image menu. Dates are listed as day first, then month, then year [

- Use the bright star at approximately 45° to the lower left of the galaxy core as a reference star. Use the **Aperture Photometry tool**.

To access the Photometry tool on the toolbar, click on the arrows and choose *Astronomy Tools*. Then double click the Aperture tool (a bull's eye) and make sure the following box is checked:



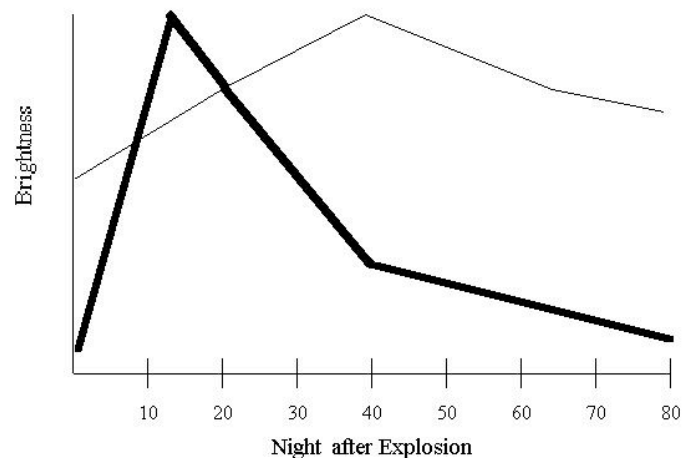
Use the clicked position, do not reposition

You can also use the **Multiple Aperture Photometry tool** which will calculate a ratio of the supernova and the reference star for you, but you will have to set the number of apertures it will measure at 2. You will also have to measure the supernova before the reference star.

- Divide the Counts for the supernova by the Counts of the reference star to get the Count ratio for each night. (B_{SN}/B_R as a measure of brightness changes.)

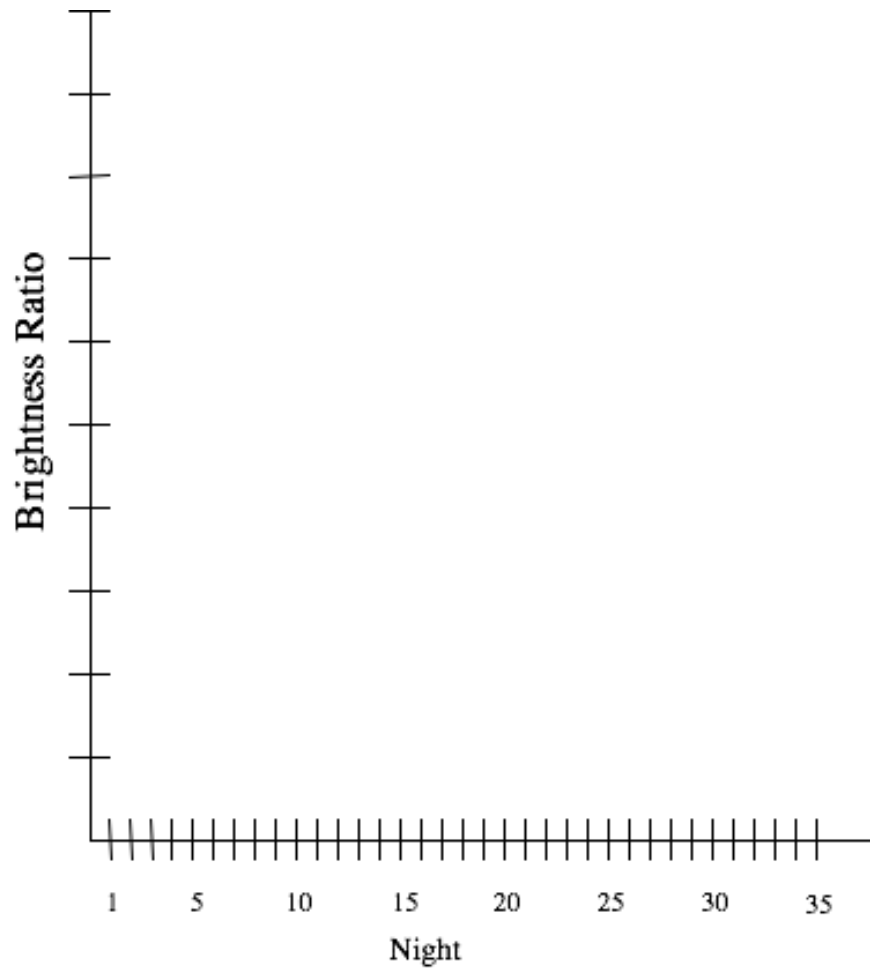
5. Make a light curve for SN1994i by plotting the Count ratio versus night number.

6. Compare your light curve with those shown below and infer the type supernova for SN1994i. Type I SN is a Type Ia SN. Explain your reasoning.



Type I SN ———
Type II SN ———

5.



6. What type of Supernova is SN1994I? What kind of object blew up? Explain your reasoning.