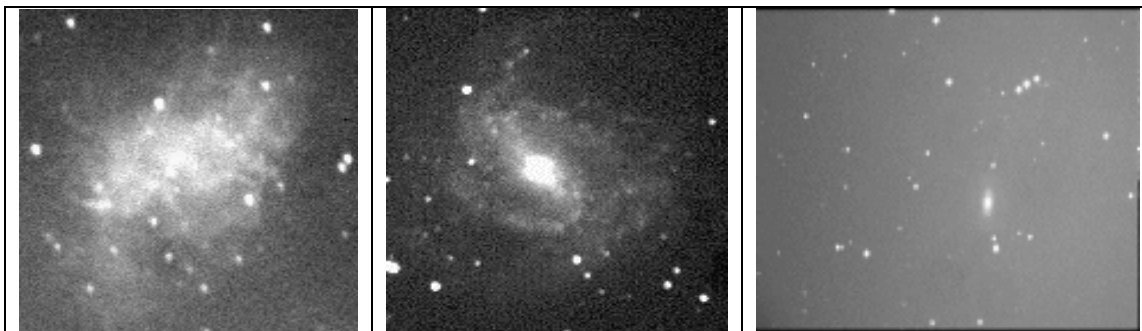### Finding Light Curves of Supernovas using RAAP CCD Images

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Images for this lab can be downloaded from the RAAP home page:
http://www.deepspace.ucsb.edu.

This is a "Generic Supernova Light Curve Lab". We provide general guidelines for downloading supernova data sets from the RAAP homepage, preparing the images for comparison with finder charts, finding the variation in magnitude with the photometry feature provided by IMAGE32, and graphing the light curve. Some general references on supernovae are provided for the interested student.

Background:

       Supernovae have fascinated people even before the first well-documented supernova dazzled observers in 1054 AD; its remnant is still observed today as the Crab Nebula (M1) in Taurus, seen in the first image at the top of this page. According to records from the Sung Dynasty in China, this supernova was visible as a "guest star", which gradually faded after a full year. (See Burnham's Celestial Handbook, volume III, p. 1846.) More recently, Supernovae 1987A in the Large Magellanic Cloud and 1993J in M81, have provided astronomers with a wealth of information with which to test their models of stellar evolution and supernova genesis.

       It is estimated that supernovae occur at the rate of 1 per galaxy per century, which means that if you observe a single galaxy every night for 100 years, or 100 galaxies every night for one year, you may be lucky enough to discover a supernova! Rich galaxy clusters such as those in Virgo, Hercules, and Coma Bernices are good places to look for supernovae, and many amateur and research astronomers spend countless hours combing the sky, hoping to make the discovery. In fact, many supernovae ARE discovered each year, but most are in very distant galaxies. Supernovae are named according to the year in which they were discovered, and the order in which they occurred, for example: SN1987A was the first supernova discovered in 1987, and SN1993J was the tenth supernova discovered in1993.

Supernovae fall into two general categories: Type I and Type II, distinguished by the presence of hydrogen lines in their spectra. Type I supernovae do not show hydrogen lines in their spectra, while Type II do. These two main classes are further subdivided based on their light curves and other elements visible in their spectra. Determining the light curve of a supernova can help determine what type of supernova it is, and shed light on what type of star it could have come from.

Using the RAAP telescope to search for supernovae is one way in which you as a student can make a significant contribution to astronomy, if indeed you can find a supernova and then generate a light curve for it! (In fact, SN1993J was first discovered by an amateur astronomer in Madrid, Spain.)

First, however, you should practice finding supernovae with existing data sets (it is not always as easy as it sounds), doing the photometry, and graphing the light curves. In this exercise you can select any data set from the RAAP home page to work with, as you follow the steps in this activity. --

Step 1. Downloading the data set.

You can get any of our variable star data sets from the following public website: http://www.deepspace.ucsb.edu/images/datasets/index.htm . Each data set is a zipped file consisting of several images in .FTS format, that are readable by our software. Download the files and unzip with Winzip.

Step 2. Positioning the images so they align with finder charts.

When you look at reference charts, such as those available in Burnham's Celestial Handbook, or from the American Association of Variable Star Observers (AAVSO), the charts are usually oriented with North at the top of the page. When you look through a telescope, however, images are inverted (upside-down) and left-to-right flipped. So, if you try to compare an image taken with the RAAP telescope to a finder chart, you will notice that every star in the image is upside down and right-to-left flipped with respect to the finder chart! No, the finder chart is not wrong; it is set up to match what your EYE would see, but since the telescope inverts and flips the image, you have to invert and flip the other way to make the image as seen through the telescope match the image as would be seen by your eyes (that is, if they could collect enough light!).

For example:

Here is a raw image taken with the RAAP telescope. The galaxy in the image is NGC2962, a 12th magnitude spiral galaxy in Hydra. Somewhere in this image is lurking a supernova, SN1995D.

To make this image line up with the finder charts, it must be flipped vertically, then rotated by 90°. BE CAREFUL: THE ORDER IN WHICH YOU DO THE ROTATIONS MATTERS! **Vertical flip followed by 90° rotation is NOT the same as 90° rotation followed by vertical flip!**   The corrected image should look like this:

Step 3. Looking for the star with the variable light output.

Bring a bunch of the images onto your screen. You may need to histogram-limit them for the best contrast. You should be able to see which one varied!

Step 4. Finding magnitudes with the photometry function.

Photometry is the process of attempting to measure the total light reaching the detector (eye, camera, or CCD) from a star, not including the light from the background sky, atmosphere, heat of the electronics near the detector, or any other spurious signals. This can be quite a challenging process! Some idea of the light level of the background sky must be obtained, and there must be a reference star within the field of view whose magnitude is known independently**.**
Before the advent of electronic CCD imaging techniques, the magnitudes of stars had to be determined by measuring their diameters on photographic plates very carefully. The diameter of the image on a photographic plate is related to the magnitude of a star because of the way in which the grains in the emulsion absorb light and are blackened.
In a digital image taken with a CCD, the brighter stars also make larger spots on the image, however we can also read the maximum intensities of the pixels which form the star image, and in that way determine the actual flux of starlight hitting the CCD. It is possible to measure the magnitude directly by isolating the star from the background, subtracting the background sky from the image produced by the star, and then relating the intensity of the star to that of a reference star of known magnitude.

Now that you have determined which star is the supernova, find the date that the image was taken from the header by clicking on "View Header". The date should be in the header. (In fact, it may be convenient for you to rename each image according to either the date it was taken or its sequential number.)

UCSBImage32 will perform "sky-subtracted aperture photometry" automatically, as will most image processing programs. In process B we simply take the default values, however these may not be accurate enough for certain applications, such as if you are trying to verify some published results, and need accurate magnitudes. Before actually going to the Photometry option, you need to do the following:
Look at the **HISTOGRAM** of the image. Find your best estimate of the optimal value for the sky background. You can also do this with the ZOOM window. The starlight you are trying to measure is a combination of the star as well as the sky, and the program will subtract out the value for the average sky background when it performs photometry. In order to check that the program correctly estimates the sky background to subtract, you should check it yourself first. Write down your estimate of the average sky background level.

1. Set your star radius to include all of the star.
2. In the Options menu, se the inner sky annulus to be just a bit bigger than the star, and the outer sky annulus to be at least twice as big as the inner, depending on the density of the star field. (If it's too dense, you want to be careful not to include other stars.)
3. Click on the box Use Mean. This tells the program to use the mean value between the inner and outer radii in computing the sky value.
4. Position your cursor over a reference star, and click on Set Ref. Either it is a star for which you know the magnitude, in which case use the actual magnitude, or just make something up that is reasonable, and use this in all the images. The program will calculate

a magnitude for your variable star which is referenced to this one. If you don't use a real value, you will simply get a magnitude variation from "normal" – but that may be ok.

5. Do this for each image.

Step 5. Graphing the Light Curve.

You should now have the magnitude of the supernova for each day of observation. Your data table should be organized like this:

DATE	DAY #	MAGNITUDE	Error

The first date is day 1. Count up from that date, and number each date with a day, so that the light curve will have the proper shape and not be scrunched up and distorted. For example:

The header will most likely have the dates written in the form day/month/year. Suppose the first date of the observations was March 23, 1995; it will be recorded in the header as 23/3/95. You count this as day 1. Suppose that the next observation was made on 30/3/95; this would be day number 8. Your data table would look something like this:

DATE	DAY #	MAGNITUDE	Error
23/03/95	1	11.5	
30/03/95	8	11.0	
03/04/95	12	10.8	

Notice that the magnitudes are DECREASING, which indicates that the supernova is BRIGHTENING! Calculate the percent error, and you will see that it is never more than around 1% of the calculated magnitude. (These are ideal, fictitious measurements!) This allows you to put error bars into your graph of the light curve. Small error bars indicate to the person who looks at your results that you did a careful job, and your results are credible. (Either that, or you "fudged" your data, but you would *never* do such a thing...)

To make the light curve, you can import your data into EXCEL and make a graph. Use scatter plot, and connect the dots, and show the data markers.

Congratulations! You have plotted a light curve! This technique is good for investigating supernova light curves, light curves for Cepheid variables, or any variable star!