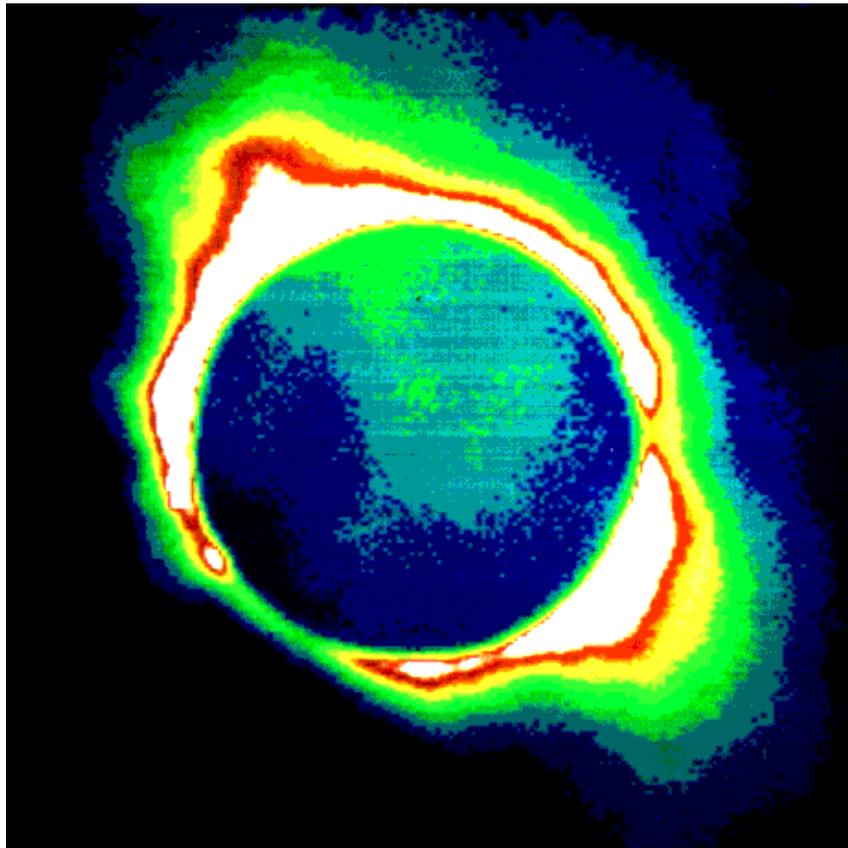


# HANDS-ON UNIVERSE

HIGH SCHOOL SCIENCE AND MATH  
IN THE CONTEXT OF ASTRONOMY  
INVESTIGATIONS

## Searching for Supernovae



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by Lawrence Hall of Science  
University of California, Berkeley  
Lawrence Berkeley National Laboratory  
and TERC of Cambridge, Massachusetts



HOU provides a visual and analytic way of exploring the universe.

Use HOU images from professional telescopes, along with HOU image processing software, to pursue investigations of astronomical objects, phenomena, and concepts. Opportunities available to HOU students can lead to accessing professional-grade telescopes via the World-Wide Web for observations as part of research projects such as searching for supernovae and asteroids.

- HOU has been developed and operated by staff at Lawrence Berkeley National Laboratory and Space Science Laboratories at the University of California at Berkeley, California, with generous support from the National Science Foundation (grant # ESI-9252915) and the US Department of Energy. The HOU curriculum was developed by TERC with contributions from the Berkeley staff and teachers. The educational center for HOU currently resides at Lawrence Hall of Science, University of California, Berkeley.
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# Searching for Supernovae

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**HANDS-ON UNIVERSE™**  
**DISCUSSION SHEET**  
**SEARCHING FOR SUPERNOVAE**

Both amateur and professional astronomers actively search for supernovae, and they are being discovered more and more frequently. Using the same basic strategy, they look for the appearance of a new star. An exciting recent discovery, SN1994I, was based on images taken by HOU students at Oil City High School in Pennsylvania. Using HOU, you have the same tools professional astronomers use to search for supernovae by comparing images of the same patch of sky taken at different times.

Sometimes a supernova is so bright it can be spotted by eye by just looking at two images taken at different times. In fact, there is an amateur astronomer in Australia, a minister named Bob Evans, who can spot supernovae by looking stereoscopically at two images at once. Often, however, two images do not match very well, and it is necessary to use image processing tools in order to detect the presence of a supernova. One reason the images may not match is because the telescope does not line up on the object exactly the same each night, so the images appear off-center with respect to one another. Another reason is that observing conditions, such as cloudiness or background light, can change from night to night. The image processing software through processes called shifting and normalization can deal with each of these. After the images are properly shifted and normalized, you can subtract one image from the other to examine the difference. If a significant variation has occurred, such as a supernova, it will be apparent in the subtracted image.

## Shifting Files

In order to align two images so they are ready for subtraction you need to use the **Axes** option in **Data Tools** and the **Shift** option in **Manipulation**. What happens when you shift a file? Below is a small section of an image file with brightness values given for the pixel locations to illustrate the result when the image processor shifts a file "to the right by 2":

Original File						Shifted Right by 2				
107	108	50	100	102		0	0	107	108	50
106	108	60	90	100	--> 2	0	0	106	108	60
106	108	52	52	55		0	0	106	108	52

In this case as the image was shifted to the right, the new columns created on the left were filled in with zeroes. There is an option in the software to select a "fill value" so that you can have new columns or rows filled in with a value that matches the background sky.

## Subtracting Files

When using the image processor, it is important to understand the difference between an image and its data file. The data file consists of numbers that the image processor uses to find the brightness for each pixel in order to display the image on the screen. You can manipulate the image, but this does not change the data file. The image processor cannot modify a data file. You can create new data files, however, by Saving an image under a new file name after making changes using image processing tools such as **Data Tools** and **Manipulation**.

Once two images are aligned, you can subtract one from the other to see if there is a difference between them, such as the occurrence of a supernova. What happens when you use this tool for subtracting one data file from another? You can think of each file as an array of numbers. For example:

0	0	0	0	0	0	0	0	0
0	0	0	80	90	75	0	0	0
0	0	50	108	132	100	66	0	0
0	64	112	109	130	166	120	50	0
0	0	106	113	52	112	116	0	0
0	0	0	0	0	0	0	0	0

Each number corresponds to the brightness of a part of the sky in the image. By subtracting one file from another, you create a third file where each number in the array is the difference in brightness at that pixel. For example:

File to Subtract From (a part of a data file might look like this; the whole file would be a much larger array)

```

0  0  0  0  0  0  0  0  0
0  0  0  80 90 75 0  0  0
0  0  50 108 132 100 66 0  0
0  64 112 109 130 166 120 50 0
0  0  106 113 52 112 116 0  0
0  0  0  0  0  0  0  0  0

```

– File to Subtract (a part of a reference data file might look like this)

```

0  0  0  0  0  0  0  0  0
0  0  0  80 90 75 0  0  0
0  0  50 108 132 100 66 0  0
0  64 112 109 130 106 60 50 0
0  0  106 113 52 52 56 0  0
0  0  0  0  0  0  0  0  0

```

= Difference File (then the difference file would look like this)

```

0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0
0  0  0  0  0  60 60 0  0
0  0  0  0  0  60 60 0  0
0  0  0  0  0  0  0  0  0

```

In this example the 60s in the Difference File are new brightness in the top file that did not exist in the reference data file.

# HANDS-ON UNIVERSE™

## TECHNIQUES FOR FINDING A SUPERNOVA

### UNIT

#### Activity I: Comparing Images By Subtracting

In this first example *m51nor* is an image of galaxy M51 as it normally appears. *m51fake1* includes a supernova that has been added or pasted into the *m51nor* image. To find the supernova, find the difference between these two files by subtracting one from another. Then you can locate the supernova in the Difference File. Fake supernovae are used in these first exercises to make it easier to learn to use the image processor tools.

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Screen Setup: *m51nor* and *m51fake1* with the contrast adjusted to show the spirals.

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- With *m51fake1* highlighted, select **Subtract** from the **Manipulation** menu. For what you would like to subtract from it, click on **Displayed Image** and select *m51nor*. Click on **Display Result in New Window** and **OK**.
- With the Difference File window highlighted, get position and brightness data for the supernova using **Auto Aperture** by clicking on the tool Bar icon or selecting **Auto Aperture** the **Data Tools** menu and clicking on the supernova.

1. Record the data.

## Activity II: Aligning The Images Before Subtracting

Images of a patch of sky may be slightly shifted from one night to the next if the telescope has not been aimed exactly to the same set of coordinates each night. In this case, before using the image processing **Subtract** tool, one of the images must be shifted so the two "match". For this you use a second faked image.

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Screen Setup: *m51nor* and *m51fake2*. Adjust the contrast to show the spirals.

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- First **Subtract** *m51nor* from *m51fake2*, and click on **Display Result in New Window** and **OK**. You will need this image at the end of this activity.
  - Select **Axes** from the **Data Tools** menu, click on **OK** and box a reference star in *m51nor*, (a star that appears in both images). Repeat for *m51fake2*.
2. Record the center (x,y) coordinates of your reference star in each image.
  3. Calculate how much to shift *m51nor* so it matches *m51fake2*.  
right shift =  $x(\text{fake image}) - x(\text{normal image})$   
up shift =  $y(\text{fake image}) - y(\text{normal image})$ .  
A negative value means shift left or shift down.
- Now shift the normal image, with no supernova, so it is aligned with the fake image that has a supernova candidate. Use **Shift** in the **Manipulation** menu, enter your Offset values, and click on **Display Result in New Window** and **OK**.
  - Verify that the shifted image lines up with *m51fake2* by checking that the coordinates of the reference object are the same in both images.
  - **Subtract** the shifted image from the fake image.
4. What is different between the two subtracted images, the one before aligning and the one after aligning?
  5. Can you find the supernova? Record the position and brightness data.

### Activity III: Adjusting for Brightness Differences

Differences in brightness may be due to changes in the background light level, called "sky", such as the amount of moon light. Different exposure times are another cause. Background light is corrected for by subtraction; remaining differences due to factors such as change in exposure time are corrected for by multiplying by a Normalization factor.

In this section you will learn the two operations you must perform to correct for whole image brightness differences:

First subtract the sky value (background light) in each image.

Next multiply one image by the brightness ratio of the reference stars, called the Normalization factor.

Then you can subtract the resulting files to find the supernova.

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Screen Setup: *m51nor* and *m51fake3*. Adjust the contrast to show the spirals.

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- First **Subtract** *m51nor* from *m51fake3*, and click on **Display Result in New Window** and **OK**. You will need this image at the end of this activity.
- Select **Sky** to find the brightness of the background sky.
- **Subtract** sky value from each image, entering the sky values for 'Number of Counts', **Display Result in New Window, OK**.

Adjust brightness (normalization) in the two images.

- First Select **Auto Aperture** in the **Data Tools** menu to get the brightness value for a reference star that appears in both images.
- Calculate the Normalization factor, N, the brightness ratio of the reference star in the two images: no-sky fake/no-sky normal.
- **Multiply** no-sky normal by N, **Display Result in New Window, OK**.
- **Subtract** this normalized image from the no-sky fake image.

6. What is different between the two subtracted images, the one before adjusting for brightness and the one after adjusting for brightness?
7. Can you find the supernova? Record the position and brightness data.

Date: \_\_\_\_\_

Name: \_\_\_\_\_

## Answer Sheet

### Techniques For Finding A Supernova Unit

1. Supernova data for *m51fake1*:
2. Center (x,y) coordinates of my reference star in each image:
3. Shift of *m51nor* to match *m51fake2*:  
right shift =                      up shift =
4. What happens if you do not align before subtracting:
5. Position and brightness data for the supernova in *m51fake2*:
6. What happens if you do not adjust for brightness differences:
7. Position and brightness data for the supernova in *m51fake3*:

**HANDS-ON UNIVERSE™**  
**SUPPLEMENTARY ACTIVITY 2**  
**THE IMAGE MANIPULATION CHALLENGE**

In this game the challenge is to figure out how a file has been manipulated. Working in small groups, each group manipulates *m5Inor* and gives it to another group to "un"-manipulate.

**THE RULES**

1. Begin with *m5Inor*.
2. Any combination of the manipulation tools may be used:  
    shifting, rotating, and/or flipping.
3. No more than three manipulations are allowed per challenge.
4. The answer must specify a sequence of manipulations. For example:  
    right shift 50, rotate 90 degrees clockwise.

## HANDS-ON UNIVERSE™

# DISCOVER A SUPERNOVA UNIT

In this activity you look at a series of images of a galaxy to detect the presence in that galaxy of an exploding star, called a supernova. The supernova is SN1990H, which means it was the 8th one discovered in 1990 (H is the 8th letter of the alphabet). The images were taken at two week intervals in the Spring of 1990.

### **Activity I: What Can You Tell By Looking At A Single Image?**

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Screen Setup: *SNW* with the contrast adjusted using Min/Max to bring out the spiral arms of the galaxy.

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Can you tell if there is a supernova? Supernovae are very bright objects, often brighter than an entire galaxy. In this image, there are five or six very bright objects - are they all supernovae? Not likely. Objects that are also typically very bright include the galaxy core and foreground stars in our own Milky Way galaxy that lie in the same line of sight as the far off galaxy.

Galaxy cores and nearby stars tend to keep on being bright. A supernova, on the other hand, changes brightness over time, initially flaring up and then slowly fading back to become indistinguishable. In the visible light spectrum, the cycle from obscurity to obscurity typically takes anywhere from a couple of weeks to a couple of months. This makes it possible to discover a supernova by comparing images taken at different times to see if a new bright object has appeared in the later image.

1. Make a sketch of the *SNW* image showing the galaxy with its spiral arms, or use **Print** in the **File** menu. Label the five or six bright objects A, B, C ... and put a check by the ones you think are likely candidates to be SN1990H.

## Activity II: What Can You Tell By Looking At Four Images?

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Screen Setup: *SNW*, *X*, *Y* and *Z* with the contrast adjusted to bring out the spiral arms in each galaxy. Use the **Tile** option in the **Window** menu so you can see all four images.

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2. Which bright object is the supernova? (A, B, C ...)
3. The images are out of order, in terms of when each was taken. What do you think is the proper order of *W*, *X*, *Y*, *Z*? (It is ambiguous) Explain your answer.

## Activity III: Subtracting Images To Find a Supernova

You did not need to use more refined tools to discover SN1990H because it stands out when you see all four images. However, that is not always the case. **Data Tools** gives you a way to find a new supernova that is not obvious at first.

The overall idea is to subtract an earlier Reference Image, one where there was no supernova, from a new image to see if there is a difference. Objects that have not changed brightness should cancel each other out, and any bright object remaining should be a new source; i.e., a supernova. Easy to say; somewhat fussy to do. Here is what is involved:

Remove background skylight due to ground lights and moonlight.

Align the images to correct for differences due to telescope aim.

Normalize the images to correct for differing observing conditions due to haze or high thin clouds.

Subtract the Reference Image from the new image.

Identify any new light sources.

In order to make comparisons it is necessary to decide on a reference that everything else will be compared to. In this case, there needs to be both a Reference Image and Reference Star. A Reference Image is one without a supernova. Use *SNX* as the Reference Image. A Reference Star is a steady star; i.e., one with constant brightness. Choose one of the bright objects outside the galaxy that is presumably a foreground star in our Milky Way galaxy as the Reference Star.

## Get Initial Data:

- Use **Sky** to get a median background sky Count for the whole image. This background sky Count will probably differ from the one listed using **Auto Aperture**, which only gives the Count for background sky next to the star.
- To get the location for a Reference Star, use **Axes** and drag a box around the foreground star you have chosen. Do this for the same star in each image.

4. Which star did you choose as your reference star?

## Remove the Skylight:

- Subtract background skylight from the images in order to remove background skylight from ground lights such as city lights and from moonlight. Use **Subtract** in the **Manipulation** menu. Enter for 'Number of Counts' the 'Sky' value listed in the *Results* window. This value is the mode - the most frequent brightness value in the image. After the subtraction the Sky value should be 0 in each image.

## Align the Images:

- Correct for telescope aim using **Shift** in the **Manipulation** menu to match all images to the Reference Image, *SNX*. Enter X and Y Offset values so that your Reference Star's pixel location will be the same as its location in *SNX*. Refer to the *Results* window to get the coordinates of the Reference Star in each image. Enter off sets to two decimal places.

## Normalize the Images:

Correct for differing observing conditions due to haze and high thin clouds that block out light before it reaches the telescope. This should make the brightness of the Reference Star the same in each image. Other objects should also have roughly equal brightness, except for the supernova, which is new.

5. Using the Reference Star, calculate the Normalization Factor for each image:

$$\frac{\text{brightness of reference star in reference image}}{\text{brightness of reference star in new image}}$$

- With the new image highlighted, go to **Multiply** in the **Manipulation** menu. For 'Number of Counts' enter the value of your Normalization Factor.

### **Subtract Images:**

- With the new image window highlighted, subtract the Reference Image from the new image using **Subtract** in the **Manipulation** menu. Click on **Display Result in New Window**. Adjust the contrast — you should be able to bring out a “lumpy” detail of black and white spots. Variations within each image account for why the subtracted image is not all blank except for the supernova.

### **Look for a Supernova:**

- Identify any new sources of light using **Find** in the **Data Tools** menu.

6. Record the brightness of the supernova.

### **Activity IV: Plot a Supernova Light Curve for SN1990H**

Normally you could look under 'Date-Obs' in **Image Info** in the **Data Tools** menu to see when each image was taken. In this case the dates are all listed as 0/0/0, which is the zeroeth day of the zeroeth month in the zeroeth year. That is not correct. The dates for the four images are as follows:

*SNW: 5/2/90;    SNX: 6/2/90;    SNY: 4/19/90;    SNZ: 5/17/90.*

7. Using the brightness Count values you got in Activity III for the supernova in each of the new images, plot the points for brightness in Counts versus week. *SNX* was taken after the supernova had died out. Give it a brightness value equal to 0, which relative to its supernova brightness is a reasonable value. Sketch a curve to connect the points.

Date: \_\_\_\_\_

Name: \_\_\_\_\_

Answer Sheet  
**Discover A Supernova Unit**

**Activity I**

1. *SNW* image showing the galaxy with its spiral arms and five or six bright objects A, B, C... with a check by the ones I think are likely candidates to be SN1990H.

**Activity II**

2. Which bright object is the supernova (A, B, C ...):
3. What I think is the proper order of *SNW*, X, Y & Z and why:

**Activity III**

4. My Reference Star:
5. Normalization factors, using C for Counts.

$$C_X/C_X = \text{_____} / \text{_____} = 1$$

$$C_X/C_Y = \text{_____} / \text{_____} = \text{___}$$

$$C_X/C_W = \text{_____} / \text{_____} = \text{___}$$

$$C_X/C_Z = \text{_____} / \text{_____} = \text{___}$$

6. Brightness of the supernova in each of the images:

Supernova in *SNW*:

Supernova in *SNY*:

Supernova in *SNZ*:

## Activity IV

7. Plot of brightness in Counts versus week.

