CONFIRMATION OF A SUPERNOVA IN THE GALAXY NGC6946

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Within this intermediate use case you learn about supernovae (see also use case 8) and determine the celestial coordinates of a just discovered candidate supernova (see also use case 1) on an image (provided) that has no coordinate systems. This use case provides a glimpse of an activity that is representative of the practical tasks that astronomers have to perform when they analyze data.

This use case is meant to be of help to amateur astronomers who may be often in the situation of the use case. In the classroom this use case is technically of intermediate level (no mathematics required), but its content may require an expert teacher to make it appealing for pupils.

1 Introduction

Suddenly a star runs out its nuclear fuel. Its life as a normal star ends with a catastrophic event. The explosion is so violent that the star outshines even its host galaxy. This type of luminous object is called supernova and can be seen far away.

We can see a supernova by naked eye if it explodes in our galaxy: like those described by Tycho Brahe and Keplero in 1572 A.D. and 1604 A.D. respectively.

Today, astronomers discover more than 200 supernovae every year, and to date they have registered more than 5000 supernovae in galaxies distant up to 13 billions light years.

In the supernova research field amateur astronomers can give a substantial contribution to professional projects. Amateur astronomers all over the world take thousands images of the brightest galaxies every night with the aim to discover a supernova: they compare the new images with older ones and look for new stars.

In this tutorial we show how an amateur astronomer can take advantage in using Aladin to verify a supernova discovery. We start from an image of the galaxy ngc6946 (distant 22 million light years) observed with the telescope of the Col Drusciè Observatory on February 7th, 2008. In this image we think we can see a supernova. You can download the image ngc6946.fit with the supernova (fig. 1),

from *http://vo-for-education.oats.inaf.it/ download/ngc6946.fits* and follow the tutorial to verify if it is really a new star or not.
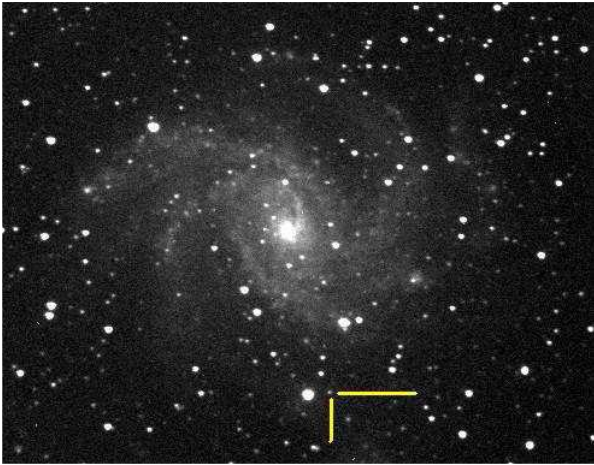

Fig. 1: Image of the host galaxy ngc6946 with the supernova (pointed by the two yellow lines).

2 Supernovae

Before we begin to use Aladin and the observations, let us introduce supernovae. Supernovae are stellar objects with the largest brightness variations. In a few days their brightness may rise more than 20 magnitudes, corresponding to a luminosity increase of a factor of a hundred million.

After the maximum, there is a slow decline lasting several months.

The supernovae are exploding stars. When a star runs out its nuclear fuel, it can not counterbalance gravity any longer and it starts contracting, increasing its temperature. At this time the future of the star depends on its mass. If the nucleus is massive enough the star can become unstable and explodes becoming a supernova, otherwise it can become a black hole, a neutron star or a white dwarf. In the supernova explosion, a gas shell expands with a velocity around 10.000 km/s and can remain visible for thousands of years (for example, we still observe the supernova remnant of the Crab Nebula - M1, exploded in 1054 A.D.). In our galaxy (the Milky Way) we can observe a few tens of such supernova remnants.

In 1941 Rudolph Minkowski was the first to recognise that at least 2 different types of supernovae exist: those that show hydrogen (H) in their spectra (*Type II*), and those that do not (*Type I*). In the 1980s, as the rate of supernovae discoveries increased and data quality improved, Type I supernovae were further subdivided based on the presence of silicon (*Type Ia*) and helium (*Type Ib*) in their spectra, or the lack of these elements (*Type Ic*). It was also discovered that while Type Ia supernovae can be found in any part of any type of galaxy, Type Ib and Type Ic supernovae occur primarily in the nuclei of spiral galaxies.

We now know that Type II, Type Ib and Type Ic supernovae result from the core-collapse of massive stars, while Type Ia supernovae are the thermonuclear explosions of white dwarfs, one of the possible final steps of stellar evolution.

Type Ia supernovae are particularly important since they have all the same peak luminosity, so they can be used like distance indicators. Supernovae allow accurate measurements of cosmic distances to very large scales.

3 Aladin

Aladin is an interactive sky atlas developed and maintained by the Centre de Donnèes astronomiques de Strasbourg (CDS) for the identification of astronomical sources through visual analysis of reference sky images. It is available for download here:
https://aladin.u-strasbg.fr/java/Aladin9.0.jar.
Aladin allows the user to visualize digitized images of any part of the sky, to

superimpose entries from the CDS astronomical catalogues and tables, and to interactively access related data and information from various data servers (like SIMBAD, NED, VizieR). In this tutorial we use the standalone version of Aladin, because this is the only version allowing us to load a local astronomical image. In this usecase we use Aladin in the *undergraduate* mode (developed in the framework of the EuroVO-AIDA European project).

4 Load the local image

Our aim is to check if there is a supernova in the image of the galaxy ngc6946 taken by the Col Druscviè Remote Observatory Supernovae Search (CROSS) program.
The first step is to get the image of ngc6946. Download the image on your PC and start Aladin. Switch to the undergraduate mode from the menu:

edit -> user preferences -> profile -> undergraduate.

Restart Aladin in order to validate the new configuration.
Now load the image of ngc6946 in Aladin from the menu

File -> Open local file.
The display of ngc6946 is not very clear. To improve it, modify the distribution of intensities. Open the *pixel mapping* window ("pixel" button on the right of the image)

 (fig. 2)
and check "sqrt". (fig. 2)

Note that you can always use the buttons "zoom" and "pan" to enlarge the image

and move it, in particular if it is larger than the window of Aladin.

5 Astrometric calibration

Our image has no astrometric calibration, it means that in the image of ngc6946 there is no information on the celestial coordinates. In order to set the coordinate system we compare our image with a calibrated image and identify the same objects (3 or 4 stars) in both images, matching them. We set the coordinate system of our image by imposing the coordinates of the stars in the calibrated image to their counterparts in the image ngc6946.ft.

First of all we have to load a calibrated image. Open the server selector:

File -> Load astronomical image
-> Aladin image server.
Enter "ngc6946" in the field "target".

NOTE: In this tutorial when you find the mouse icon it means you have to click the button next to it.
Select "POSS II F 13'x13' (Optical R)" image.

POSS is the acronyms of Palomar Observatory Sky Survey: it is a collection of digitalized photographic plates covering all the sky accessible from the Northern hemisphere (from a declination of +90 to -27 degrees), taken at the Palomar Observatory. All these images are astrometrically calibrated.
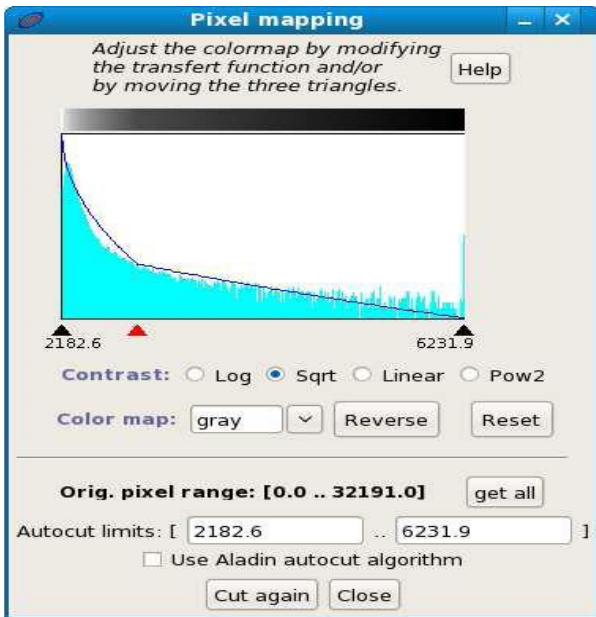
Fig. 2: The pixel mapping window.

Then we load a catalog: we choose the 2MASS Point Sources Catalog that contains data of the most important stars visible in our image. In the server selector window (fig. 3) (in the right column)
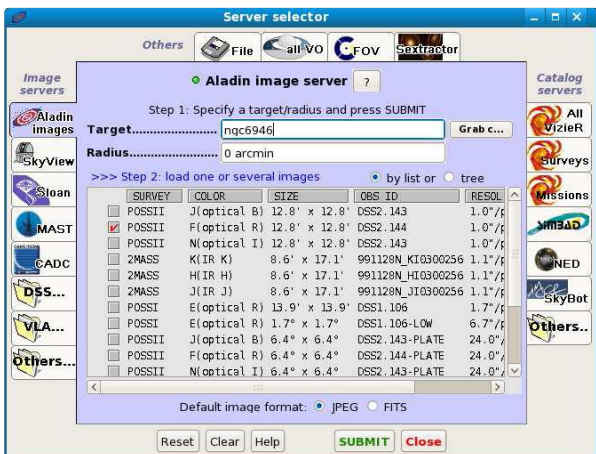

Select "2MASS".

Fig. 3: The Aladin catalog and image server selector.

We can now perform the calibration, selecting the same stars in both images. Right-click on the plane of our image (ngc6946.fit) and select "properties".
In the astrometrical reduction method section

Switch to the "by matching stars" tab. In the cells of the left column pick up the coordinates (x,y) of three or four stars of our image: select the first "x y position" cell and click on a star easy to be recognized on the ngc6946 image. The x and y coordinates of the star appear in the cell. In the cells of the right column pick up the coordinates (RA, Dec) of the corresponding three or four stars of the POSS II image: select the first cell on the right and click on the same star found before, this time on the POSS II image. Do the same for two or three more stars.
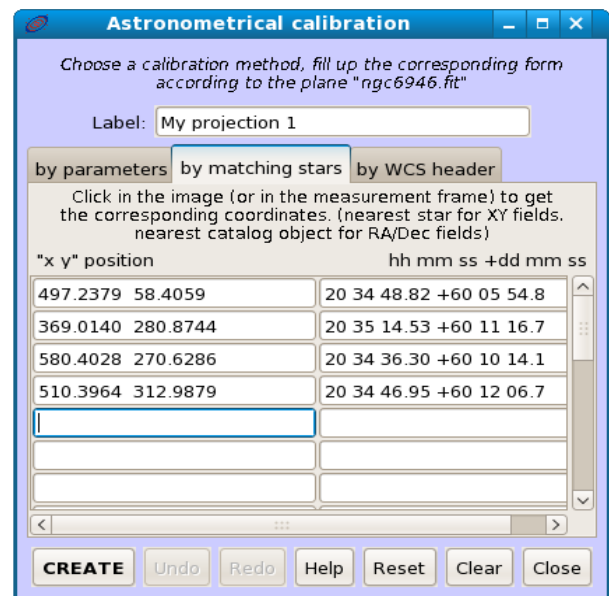
 (fig. 4)

Fig. 4: Star matching windows with the coordinates of four stars of our image and of the same stars in the POSS II calibrated image.

Now our image is calibrated. In the next session we overlay it on the POSS II image and make a comparison.

6 Comparison with POSS II images

A supernova looks like a new star in our image, so we have to compare the image of ngc6946 with an image of the same galaxy taken some time before. The most useful archive of such images available on the web are POSS II images.

Since the star progenitor of the supernova was very faint before the explosion, the new star in our image should not appear in the POSS II image of the same region of the sky. In fact POSS II images were taken in the 1980s. We start comparing our image with the POSS II RED image loaded before. Select the plane ngc6946.fit. Point the cursor on the icon of the plane POSS II and modify its transparency level (move to the right the little cursor on the bottom left corner of the plane icon - fig. 5) to show both images overlaid. It is clear that the apparent supernova does not appear in the POSS II image.

Fig. 5: The cursor to modify the transparency level of the image.

To confirm that the apparent supernova is really a supernova we also have to check that it does not appear in images taken in other wavelengths. We will check POSS

II IR and BLUE. Open the image server selector and select POSS II J (optical B) and POSS II N (optical I). The two new POSS II images are loaded in the Aladin plane stack, repeat the same procedure as before in order to compare our image with them.
Note that the supernova does not appear in any of these images, so it could be really a supernova!

Alternative procedure

The comparison between the two images can be done also by blinking them. Press the "assoc" button

and select ngc6946 in the first field (1) and the POSS II image in the second one (2).

and look at the animation.
On the top right corner of the window there are the controls (play, pause, previous image, next image, etc.). If necessary modify the distribution of intensities of the 2 images with the button "pixel".
Move on the apparent supernova and read the value of the field "pixel" (on the upper side of the Aladin window). Then open the pixel distribution window of the image ngc6946.fit and insert the value of the field "pixel", for example "2500", as maximum of the pixel histogram. Finally cut the minimum value of the histogram moving the left pointer of the plot to the right to remove most of the background noise.
Select "Pow2".

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7 Compute the coordinates and the offset

At this point we are quite confident that our new star is really a supernova. In order to advise the international community of scientists, that will confirm the discovery, we have to accurately compute the position of the supernova (its equatorial coordinates) and its offset from the nucleus of the host galaxy.

It is very simple to compute positions in Aladin: move the cursor on the star and click on it. In the "command" field we have the coordinates of the supernova: 20:34:45.45, +60:05:56.5.

The offset from the nucleus of ngc6946 can be computed directly from the coordinates or by tracing a distance vector in the Aladin window. Press the button "dist"

and trace with the mouse a vector between the supernova and the nucleus of the host galaxy.

In the lower part of the window (fig 6) you have the following information:

Dist = 3.33' (RA=53.778". Dec=3.2')
PA = 195.7 deg,

i.e. the distance between the two objects (3.33') and the projection along the RA and Dec components (53.778", 3.2').
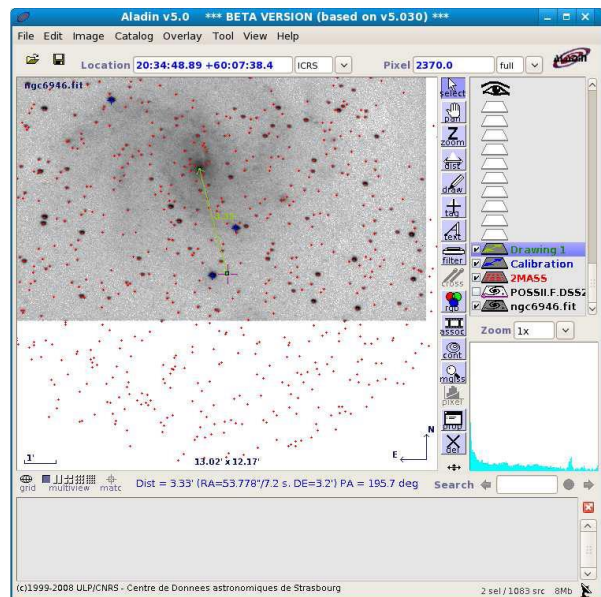

Fig. 6: The distance vector between the supernova and the nucleus of the galaxy.

8 Other supernovae in the same galaxy

Aladin has many useful features to improve our analysis. Suppose we want to visualize all the other supernovae exploded in ngc6946: to do so we have to apply a filter to the SIMBAD catalog.

Select the SIMBAD database in the server selector window, select "-no filter-" in the field "Display filter" (fig. 7).
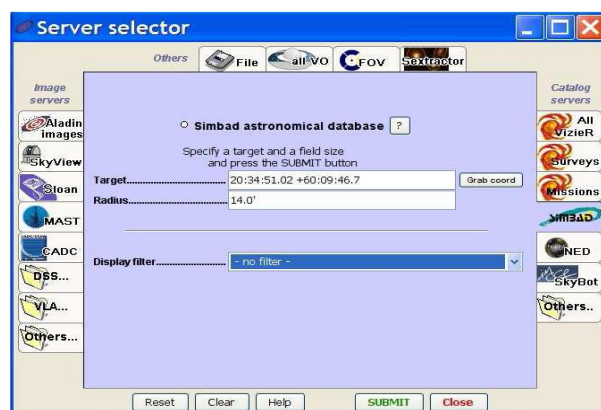

Fig. 7: SIMBAD database in the server selector window.

In Aladin select the newly loaded SIMBAD plane and click the "filter" button.

filtro

Select the "advanced mode", enter the following string in the field "your own filter definition":

$[src.class]="SN" {draw red square}

Apply

All the 9 supernovae exploded in this galaxy are visualized in the filter with red squares (fig. 8).
If you select a supernova its data appear in the measurement window. If you click on its name you open a window in your web browser with the SIMBAD page of the supernova, containing information, references, etc.
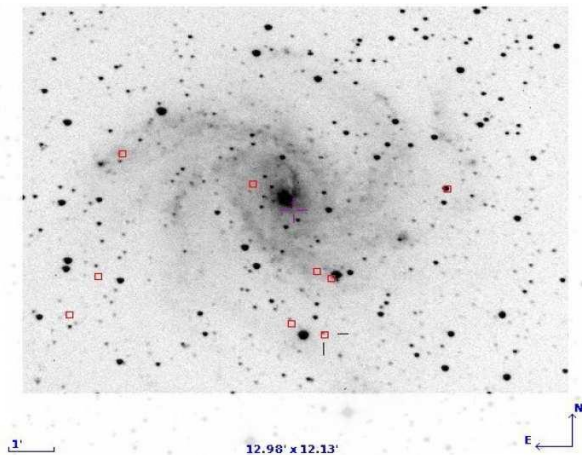

Fig. 8: All the supernovae (red squares) exploded so far in the galaxy ngc6946.

9 Save your work

In Aladin there are many options to save the work: you can save or print the current view, export each plane, save the original image with the astrometrical calibration, etc. The most useful option is perhaps the *stack backup*, that allows you to work offline or continue your work later without going through all the steps again. Go to the menu

File -> Backup the Stack

and choose a name for your Aladin file. The format of the file is .aj, that is an Aladin format. In the .aj file are saved all the planes with all their objects (images, catalogues, calibrations, etc). To load the .aj file into a new later session of Aladin go to the

File -> Load local file

menu and select it.