# SPIRITS

The Search for Born Again Giants

Joseph Faella

**Abstract**

This UROP project gauges the viability of using a ground-based telescope to find and study Born Again Giants, which are stars that appears to explode into a supernova, then reappear again as a red giant. After an unknown period of time, the star will again erupt and reform. Our results show that our current telescope and image reduction methods are not sufficient for these purposes.

## 1 Introduction

The University of Minnesota SPitzer InfraRed Intensive Transient Survey(SPIRITS) research team[1] is working with the larger SPIRITS program, led by Dr. Mansi Kasliwal at the Carnegie Institution of Washington to find extragalactic transient supernovae. SPIRITS aims to be the "definitive study to ascertain the rate and origin of two new classes of red gap transients, quantify the contribution of classical novae to galactic chemical evolution and uncover supernovae buried in starbursts.[2]" Born Again Giants have been observed in the Milky Way, and SPIRITS is attempting to be the first survey to discover extragalactic transient supernova. Originally, the project was looking for two types of infrared transients: Luminous Red Novae (LRN) and Intermediate Luminosity Red Transients (ILRT). Over the course of the study, the team may have found a new type of transient, tentatively named IFRITs (InFraRed Intermediate-luminosity Transients). All of these transients appear in mid-infrared wavelength bands. Dr. Kasliwal's team makes use of the Spitzer Space

[1]See Acknowledgements for a list of team members.
[2]Kasliwal et al.

Telescope to take observations.

The University of Minnesota SPIRITS team is led by Dr. Robert Gehrz. The team's goal is to find extragalactic infrared transient supernovae using a ground-based infrared telescope instead of a space-based telescope. We use a ground-based telescope to take many pictures of galaxies and analyze these images to find the limiting magnitudes for an event to be detectable. An advantage to using a ground-based telescopes is that our team can take data more frequently than Dr. Kasliwal's team. The main SPIRITS team can access the Spitzer space telescope several times per year, while the UMN team can use a ground-based telescope every month. Since these events only last for a short period of time, it is important to take new data as often as possible for comparisons.

## 2 Data Collection

Data was collected using the Mt. Lemmon Observational Facility. It is located atop Mt Lemmon, in the Coronado National Forest north of Tucson, Arizona. This facility was originally a Cold War listening station, and was bought in 1970 by teams at the University of Minnesota and the University of California at San Diego[3]. Today, the facility is also used and maintained by the University of Arizona at Tucson. The telescope, known as the Minnesota 60", is a reflecting IR telescope with a 60-inch primary mirror. It observes in the J, H, and Ks wavelength bands (or filters). The telescope itself is controlled by a computer using software originally developed in 1977 for use at the Wyoming Infrared Observatory[4]. The telescope's camera is controlled by Astrocam, a program designed for this purpose.

Each month, two or three team members travel to MLOF to take data. Over a period of 4-7 days, a team takes images of 6-15 galaxies. These galaxies are chosen from a list of nearby galaxies containing possible transient events, which is provided by Dr Kasliwal. 720 images are taken of each galaxy, 360 images with the galaxy in the frame of view, and 360

[3] Gehrz.
[4] Forth.

images of nearby empty sky (used for background subtraction). Images are taken in sets of 90, alternating on-galaxy and off-galaxy images for each set. Each image has a 10 second exposure time, and the camera randomly shifts, or jogs, a small amount every four images to help reduce false positives due to problems in the image, such as bad pixels. Figure 1 shows one of the preliminary images of a galaxy (NGC0891), before analysis and reduction. Images are stored as FITS files, a file type that is designed for storing and representing complex image data in a compact form. In December, we discovered an error in the telescope software: When the telescope was given a target, it would point several hundred arcminutes away from the target galaxy. We were able to fix this issue by comparing our field of view to galaxy images found in the SIMBAD[5] database in order to manually fix the telescope offset.

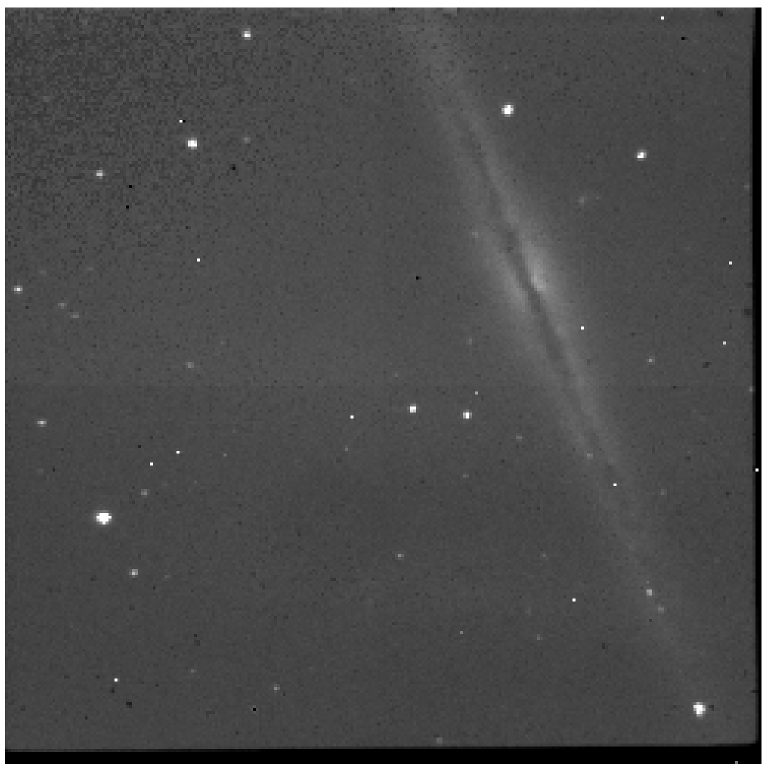

Figure 1: NGC0891, preliminary J band image. Original figure.

[5] Wenger et al.

## 3 Data Analysis

In order to find transients in a galaxy, the images of the galaxy must be coadded together. This method adds all of the images of a galaxy together and reduces the 360 initial images to one final image for each filter[6]. This method enhances similar features of the images and discourages noise. Coadding allows us to string many images together into a single long-exposure image. We cannot normally use long-exposure photography due to the motion of the earth as well as random interference from the sky. Figure 2 shows a the final J-band image of NGC0891, after the reduction process. The steps of the reduction process, as well as the Python scripts used, were developed primarily by Dinesh Shenoy.

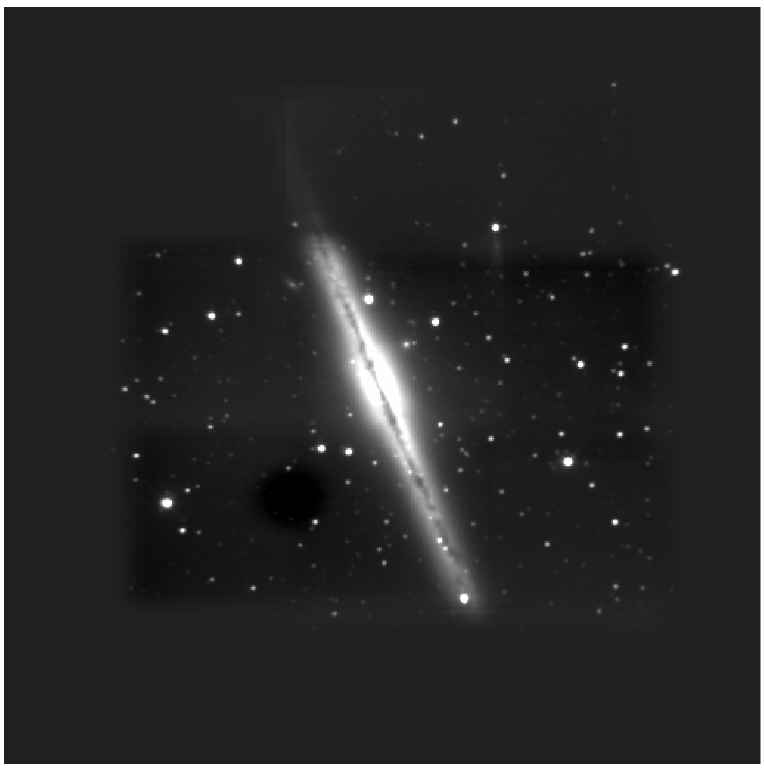

Figure 2: NGC0891, J band after image reduction. Original figure.

Each image contains three smaller images, one for each wavelength band. The first step in reducing a galaxy is to separate the each image into three images. Bad pixels are removed

[6]Shenoy.

from the images. A bad pixel is marked by a sudden bright spot in the image, which is removed by replacing the pixel with the average brightness value of the surrounding pixels. We manually checked the images for errors and removed images of poor quality. These include oversaturated images (which results in a distinctive jailbar pattern across the galaxy), or images where an aircraft passed directly above the telescope resulting in a strikingly bright line across the galaxy. We also removed images where the jogging process resulted in the galaxy appearing out of the image. An advantage of coadding short-exposure images rather than taking longer exposures is that we can remove images with these errors without much impact on the final result. A background image is made for each filter of the galaxy to filter out noise. This is done by applying a mask to each image that will cover any bright stars found in the background images, then using IRAF to coadd the images to a single average image.

Each on-galaxy image in each set of 90 images is divided by the average image created for that particular image set. This reduces the chance of false positives due to background noise in the images, and is done using IRAF. The images are then aligned using custom scripts. This process centers the galaxy in the frame of the image by adding an amount of black space at each edge. Alignment is usually performed automatically, the scripts find the bulge of the galaxy by analyzing the brightness of the bulge compared to a selected section of background space. If necessary, alignment can be performed manually as well. It is important for the images to be aligned for the coadding process to work properly, as misaligned images will result in a blurred final image. A final check is performed to remove any oversaturated or misaligned images. The remaining images are then coadded together. Of 360 beginning images, roughly 300 are generally used for the final step.

We then find the limiting magnitude for transient events in the galaxy. In order for a point source such as a star or transient supernova to be visible, it must be five times brighter than the background of the image. We used IMEXAM, an IRAF program, to find the brightness of the background and convert this to an apparent magnitude. IMEXAM measures brightness by giving us a number of "counts" found in a given section of the image. This number of counts corresponds to the values of selected pixels in the image. The limiting brightness is five times the average number of counts measured in the background area, times the circular size of the visible point sources (in pixels) in the image. We use Astrometry.net to attach known coordinates and magnitude information to the stars in each image. Since we can compare the known magnitudes of specific stars to the number of counts found in the image, the limiting magnitude for the image can be found using Equation 1:

$$m_{lim} = m_{star} - 2.5log_{10}(\frac{limiting\ brightness}{star\ brightness}) \quad (1)$$

The limiting magnitude for an image is found by taking the average result of Equation 1 for 3-5 stars in the image. Limiting magnitudes for NGC0891 are 14.8±.2, 14.3±.2, and 14.0±.3 for the J, H, and Ks filters respectively. A transient event in this galaxy would likely have an apparent magnitude of 18-20, much dimmer than what we can detect.

## 4 Conclusion

In conclusion, the Minnesota 60" at MLOF is unfortunately inadequate for finding transient supernovae. Our telescope can distinguish events as dim as 15.5 magnitudes from the the background but the events we are searching for are generally dimmer, around 18-20 magnitudes.

## 5 Acknowledgments

Data collection was performed with the assistance of Joseph Barnes and Samuel Amodeo. The University of Minnesota SPIRITS team is led by Dr. Robert Gehrz and consists of Samuel Amodeo, Joseph Barnes, Aliza Beverage, Robert Carlon, Alexander Cass, David Corgan, Modi Hammarsted, and Dinesh Shenoy, in addition to the author. This research would be impossible without the Mt Lemmon caretakers and operators, led by Jim Grantham and Joseph Hoscheidt. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

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