

The APUS Supernova Search Program: A Scientific Leadership and Research Opportunity for Graduate and Undergraduate Students

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ABSTRACT

Providing hands-on learning experiences for students in space-related education programs is a challenge and particularly so for programs that are offered 100% online. The American Public University System (APUS) offers Bachelor of Science and Master of Science degree programs in Space Studies that are delivered completely online. To date, 559 graduate students and 405 undergraduate students from around the globe have completed degrees since the inception of our program. The unique aspect of our program is its emphasis on the use of astronomical observations to provide opportunities for students to participate in authentic research opportunities and to develop instrumentation for their research. APUS operates a 24-inch Planewave robotic telescope fitted with an SBIG STX-16803 charge-couple device camera, located in Charles Town, West Virginia. This instrument is an integral component of the undergraduate and graduate education in space studies that we provide. Currently, we use this instrument in a supernova search program where students process images of several dozen galaxies obtained from a periodic survey of the sky and then compare the observations to reference images using blink-comparison software. This program is an excellent research opportunity for both graduate and undergraduate space studies students. Students in the leadership group research, design, and test components of the supernova search program; under faculty direction, they engage in evaluating software and supervise small groups of students who analyze and study the images as they search for possible supernova events. This opportunity supports their classroom learning and provides a means for all students in the program to participate in

meaningful scientific research. Currently, 177 galaxies in six different regions of the sky are regularly observed in this program.

Keywords: supernova, online education, graduate research

El programa de búsqueda de supernovas de APUS: un liderazgo científico y una oportunidad de investigación para estudiantes de posgrado y pregrado

RESUMEN

Proporcionar experiencias prácticas de aprendizaje a los estudiantes en los programas de educación relacionados con el espacio es un desafío y especialmente para los programas que se ofrecen 100% en línea. El Sistema Universitario Público Estadounidense (APUS) ofrece programas de licenciatura y maestría en estudios espaciales que se imparten completamente en línea. Hasta la fecha, 559 estudiantes graduados y 405 estudiantes universitarios de todo el mundo han completado sus títulos desde el inicio de nuestro programa. El aspecto único de nuestro programa es su énfasis en el uso de observaciones astronómicas para brindar oportunidades para que los estudiantes participen en oportunidades de investigación auténticas y para desarrollar instrumentación para su investigación. APUS opera un telescopio robótico Planewave de 24 pulgadas equipado con una cámara de dispositivo de carga-par SBIG STX-16803, ubicado en Charles Town, Virginia Occidental. Este instrumento es un componente integral de la educación de pregrado y posgrado en estudios espaciales que brindamos. Actualmente usamos este instrumento en un programa de búsqueda de supernovas donde los estudiantes procesan imágenes de varias docenas de galaxias obtenidas de un estudio periódico del cielo y luego comparan las observaciones con imágenes de referencia utilizando un software de comparación de parpadeos. Este programa es una excelente oportunidad de investigación para estudiantes de estudios espaciales de posgrado y pregrado. Los estudiantes del grupo de liderazgo investigan, diseñan y prueban componentes del programa de búsqueda de supernovas; bajo la dirección de la facultad, se involucran en la evaluación de software y supervisan a pequeños grupos de estudiantes que analizan y estudian las imágenes mientras buscan posibles eventos de supernovas. Esta oportunidad apoya su aprendizaje en el aula y proporciona un medio para que todos los estudiantes del programa participen en una investigación

científica significativa. Actualmente, 177 galaxias en seis regiones diferentes del cielo se observan regularmente en este programa.

Palabras clave: supernova, educación en línea, investigación de posgrado

美国公立大学系统（APUS）超新星搜索项目：一项 针对研究生和本科生的科学领导力及研究机遇

摘要

为太空相关教育专业的学生提供实践学习体验是具有挑战性的，对那些完全提供线上教学的专业而言尤为如此。美国公立大学系统（APUS）为太空研究专业的本科生及研究生提供全线上教学。自该专业成立以来，全球已有559名研究生和405名本科生获得了相关学位。该专业的独特点在于其聚焦于使用宇航观察来为学生提供机遇，参与真实项目并为其研究提供一系列工具。APUS操作一个24英寸的Planewave机器望远镜，搭配一个SBIG STX-16803型号的CCD相机，该设备位于西弗吉尼亚州查尔斯镇。该设备是我们所提供的太空研究本科专业及研究生专业的一部分。目前我们在一项超新星搜索项目中使用该设备，其中学生对从关于太空的周期性检验中获得的几十个星系图像进行处理，随后使用闪视比较软件（blink-comparison software）将观察发现与参考图像进行比较。该项目对太空专业本科生及研究生而言是一次绝佳的研究机遇。领导力小组中的学生对超新星搜索项目的各部分进行研究、设计和测试；在教师的指导下，他们参与评价软件并监督学生小组，后者一边搜索可能的超新星事件，一边分析和研究图像。这一机遇促进了学生的课堂学习，并为该专业的所有学生提供途径参与有意义的科学研究。目前，该项目对太空中6个不同区域里的177个星系进行定期观察。

关键词：超新星，网络教育，研究生研究

Acronyms/Abbreviations

The following acronyms/abbreviations are used in this paper: Corrected Dall-Kirkham 24 inch (CDK24) telescope; charge-coupled device (CCD) camera; American Public University System (APUS); the Panoramic Survey Telescope and Rapid Response system (Pan-STARRS1); the Public ESO Spectroscopic Survey of Transient Objects (PESSTO); Backyard observatory supernova search (BOSS); American Public University System Search for Supernovae (APUS SSN); Puckett Observatory Supernova Search (POSS); Chilean Automatic Supernova Search (CHASE); Lick Observatory Nearby Galaxy Supernova Search (NGSS); Luminous – red – green – blue (LRGB) filters; European Space Agency (ESA); Data Verification Analyst (DVA).

1. Objective

To discuss the unique aspects of the APUS SSN program with an emphasis on the student run aspects of the program. To describe the successes of the program to date, and to suggest areas of improvement for the future.

2. Introduction

The purpose of this research program is two-fold: first and foremost, the purpose is to provide APUS space studies students with the opportunity to develop leadership skills and gain relevant observational experience by creating and supervising a complex research program. The secondary purpose of the program is to document new supernova events throughout the universe to advance scientific knowledge in the community.

2.1 Student Leadership

It is common practice for graduate, and often even undergraduate, students to engage in formal research as part of their education. This is typically achieved by working with a faculty mentor. What is lacking in many STEM education programs, however, is the opportunity for students to take a lead role in the design of the research itself. Learning what is necessary to implement a successful research program is an invaluable experience that can set students apart from their peers in the field. This experience also directly translates to important career skills, better preparing students to be successful in future job opportunities.

2.1.1 Hands-On Learning Opportunities

Hands on learning activities have been shown to increase student interest and mastery in the sciences. Bloom's taxon-

omy defines the highest level of thinking as that of “creation,” which is the ability to “produce new or original work” [1]. Students who participate in original research programs at both the undergraduate and the graduate level thus have an opportunity to participate in the highest level of thinking/ learning.

2.1.2 Supervisory Role

Scientific research today is often performed as part of a group. Learning to navigate and lead in a group research project is a vital skill that will be increasingly important for science students looking to be competitive in the field. Students need to know how to work together to achieve meaningful results in research. The ability to organize group participation in a program, to motivate consistent and timely participation, to troubleshoot and resolve problems that arise, and to monitor results are invaluable skills in the scientific job market.

2.2 Supernova Science

Supernovae are highly violent events that release an enormous amount of energy over a very short period of time (astronomically speaking). There are two main types of supernovae; thermonuclear supernovae (Type I) are produced when material is accreted onto a white dwarf star from a companion star. When the mass of the white dwarf exceeds the Chandrasehkar limit, a supernova is the result. Core collapse supernovae are produced at the end of the life of a massive star and result from the implosion of the star's iron core. These include Type II, which keep their H-rich envelopes prior to the explosion;

Type Ib, which lose their outer layers but retained their He-rich envelopes; and Type Ic, which lose both their H and He layers. Both types of supernovae produce roughly the same amount of energy over the same time period. Type I supernova have peak luminosities of about ten billion solar luminosities over a time period of a few weeks, while Type II supernovae peak at about one billion solar luminosities, but fade much more slowly [2]. The light curves and spectra differ for each type of supernova and represent an important identification tool after the initial detection is made. This study will search for both types of supernova without regard to the conditions that led to the event.

2.2.1 Distance Measurements

Supernovae are of interest in the astronomical community because their high luminosities make them easily to detect in even very distant galaxies. Because their peak luminosities and luminosity profiles are very well known, observations of distant supernovae can be used to very accurately determine the distances to their host galaxies. Thus, they are effective standard candles. Detecting and analyzing new supernovae events is thus highly important for the astronomical community.

2.2.2 Discovery Statistics

In a galaxy about the size of the Milky Way, it is estimated that one supernova explosion occurs roughly every 50 years [3]. If there are approximately 100 - 200 billion galaxies in the observable universe [4], this corresponds to roughly ten billion observable super-

nova per year in the universe, or one per second.

2.3 Current Programs

There are currently several supernova search programs in existence in the astronomical community. These range from large scale, professionally funded efforts to small group studies to individuals, and even amateur astronomers. This paper will briefly describe the Supernova Hunters program, the Boss Team, CHASE, and the Lick Observatory NGSS, as well as the work of a few individuals to give an overview of the current state of the field.

2.3.1 The Supernova Hunters Program

The Supernova Hunters program is a citizen science supernova identification program [5]. This program uses the Zooniverse platform to search data from the Pan-STARRS1 all sky search database. Pan-STARRS1 scans the sky several times each month searching for transient objects (which includes supernovae). Zooniverse provides an interface for users to access and analyze this data; each observation is viewed and classified by multiple users before being flagged for further observation; this minimizes the statistical probability of erroneous “detections” from the Zooniverse user community, which consists almost entirely of untrained participants. Possible supernova candidates are further evaluated by the PESS-TO team. Thus, the Supernova Hunters program represents a partnership between professional astronomers and the public in the search for supernova can-

didates. To date, over 1 million classifications of transient objects (potential supernova candidates) have been made by nearly 6000 citizens. The program has identified 450 supernova candidates and 2 confirmed supernovae [6]. The program is currently paused while improvements to the analysis system are being made.

2.3.2 The Boss Team

The Boss Team is an Australia/New Zealand based group of amateur astronomers who work together to identify supernova candidates using personal telescopes. They supply data to the Central Bureau of Astronomical Telegrams, which is operated by the Harvard-Smithsonian Center for Astrophysics, for further observation and classification by professional astronomers. To date the BOSS team has identified nearly 200 potential supernova candidates, and has discovered more than 50 confirmed supernovae. [7]

2.3.3 CHASE

CHASE is a supernova search project that targets supernovae observations visible in the southern hemisphere. They use a group of 5 robotic 40 cm telescopes located on Cerro Tololo to observe 6,300 nearby galaxies on a regular basis (roughly 250 a night) using an 80 second exposure. [15] An automated calibration and comparison scheme allows the program to process the data nearly in real time. In their first four years of operation, they discovered 130 confirmed supernovae events. [15]

2.3.4 Lick NGSS

The Lick NGSS program was one of the first programs to use CCD imaging and image-subtraction techniques to regularly observe a large sample of galaxies. NGSS observed a total of 14, 882 galaxies over a period of 11 years, totaling millions of observations of galaxies and resulting in more than one thousand confirmed supernovae, spanning all supernovae types. [16]

2.3.5 POSS

POSS is a group of 18 amateur astronomers under the direction of founder Tim Puckett, an award-winning amateur astronomer and astro-photographer [8]. Team members are located around the world and work together to discover and verify supernova candidates. Since 1994, the POSS team has discovered over 270 supernovae.

2.3.6 Individual Astronomers

In addition to the programs described above, there are a number of individual astronomers, both professional and amateur, who also conduct supernova search programs. This paper will describe only one of particular note whose unique abilities have made him especially prominent in the field; however, there are many others. The most legendary supernova hunter is Australian amateur astronomer Robert Evens. In the 40 years he has been observing, Evens has discovered a total of 42 supernovae in his career using only a backyard telescope, paper, and a near perfect photographic memory of galactic star fields. He holds the record for visual discoveries of supernovae. [9]

2.4 APUS SSN

While there are many programs and individuals searching for supernovas, the APUS SSN program is unique in that it is performed entirely by graduate and undergraduate students (under faculty direction). Students in the leadership group design and oversee the working of the program, and both graduate and undergraduate students participate in the potential supernova candidate identification. This program thus represents a unique opportunity for students to participate in formal astronomical research. It also provides a means for students to develop valuable leadership skills in a scientific setting.

3. Material and Methods

The methods described in this paper were originally developed through the work of APUS master's students Cary Hatch and Bradley Pellington, who each fulfilled the role of "project lead graduate student." The method has been updated and streamlined through the work of the current project leadership team, which consists of APUS students Christopher Colvin, Jason Cushard, and Terry Trevino, as well as Melanie Crowson, Director of Education at the PARI Research Institute and former project lead graduate student at APUS. Jason and Terry are the current project lead researchers; Christopher is our Data Verification Analyst (DVA), and Melanie provides observational support and follow up observations for any transients identified. These individuals will hereafter be referred to as the "leadership team."

3.1 The APUS Telescope

APUS owns and operates a research grade telescope for faculty and student use. The telescope is housed in a fully automated 22.5' hemisphere dome on top of the Information Technology building on the APUS campus in Charles Town, WV, elevation 170 m. The telescope is a planewave CDK24, with an aperture of 24 inches and focal length of 155.98 inches. The focal ratio is $f/6.5$. It is paired with a 16.8-megapixel SBIG STX-16803 CCD camera; the array size is 4096 x 4096. It is also equipped with an SBIG FW-7 LRGB filter wheel. The telescope is fully robotic, able to be operated completely remotely, and can incorporate autonomous scripts.

3.2 Galaxies Observed

The galaxies observed in this project were chosen from 6 different regions of the sky. The chosen regions are designed to rise successively over the course of the night. This maximizes the amount of observing time as well as making efficient use of the telescope resources. The galaxies include a range of type and viewing angle; all are 11th magnitude or brighter. A total of one hundred and seventy-seven galaxies can be observed nightly. Specifically, twenty-six galaxies are observed from the Pegasus region, sixteen from the Camelopardus/Eridanus region, thirty-seven from the Ursa Major region, twenty from the Leo/Hydra region, forty-two from the Virgo region, and thirty-six from the Coma Berenices/Canes Venatici region (see Appendix A for more details). The telescope is automated using the Orchestrate software in order to transition

smoothly between observational regions over the course of the night.

3.3 Observations

The observations are 60 second exposures using a standard L filter. The data is then calibrated by subtracting dark frames, flat fields, and bias frames; this processing compensates for irregularities in the CCD itself. The short length of the exposure is sufficient to provide a reasonably good quality image of the host galaxy and can easily capture any supernova events due to their high luminosities. The methods have been tested and proven capable of detecting transient events with brightness as low as 16th magnitude in a 60 second exposure. Typical supernovae brightness is well above this limit, even several weeks after the occurrence of the initial event.

3.4 Data Analysis

Once the data has been obtained and calibrated, it is analyzed by students in the Space Studies program using a procedure developed by the leadership team. The basic procedure involves comparing the obtained galaxy images with reference images of each galaxy which have been observed using the APUS telescope with the same observational parameters. The comparison allows the students to determine if any transient events exist. Such events constitute potential supernova candidates and are flagged for further analysis.

3.4.1 Blink Comparison Process

The images are analyzed using the Aladin Software program. Each image is loaded into the program, along with the

reference galaxy images. The observer then selects 5-6 stars in the data image and marks the same stars in the reference image. Aladin uses these reference points to properly align the images. A visual comparison is performed using a blink comparison method. Aladin generates a composite, animated image that “blinks” back and forth between the reference and observed images. Because they are so bright, supernova can be easily seen as the images blink. Space Studies students work in teams under the guidance of the lead researchers to perform this part of the process, which affords them the opportunity to work with real data, perform visual data analysis, and potentially be part of the discovery process. Students log transient objects for further study; these logs are monitored by the team leaders, and potential supernova candidates are recorded for review and further observations.

3.4.2 Further Analysis

Once a transient object has been identified and confirmed, the team leader reports to the DVA for further study. There are several possibilities that must be ruled out before a supernova discovery can be confirmed. These include CCD effects such as hot pixels, photon leaking from previous images, and changes in seeing. CCD effects can be easily eliminated by follow up observations of the galaxy. False positives can also result from observational effects such as cosmic rays, asteroids in the foreground of the observation, and detection of a variable star. These possibilities must be evaluated through the use of Astrometrica (for asteroid verifi-

cation) and variable star catalogs before the detection can be confirmed. Finally, a potential supernova discovery must be double checked to ensure that the observation is not a previously discovered supernova event. Once these possibilities have been eliminated, the DVA reports the detection to the community for confirmation, and further observations can be made to determine the properties of the supernova.

3.5 Faculty/Student Roles

Faculty perform an important supporting role in the program. The faculty provide the reference images for the galaxy comparisons and create the scripting that allows automated observing of the different sky regions. All observations are made under faculty supervision, with the leadership team assisting. Faculty also perform further study of supernova candidates to confirm the discovery and collect data on the supernova event.

The leadership group participates actively in the design and operation of the project. Cary Hatch (M.S. 3/2019) designed the original evaluation process for the data—the programs and instructions for aligning the data files and for blinking the images. Bradley Pellington (M.S. 10/2019), built on Hatch’s work by extending the instruction manual students use to participate in the program and by designing and implementing the interface that allows students to work with the images and provides accountability (see section 3.5.1). Pellington also completed beta testing of the program and initiated the research phase. The current leadership

team has streamlined the analysis procedure by piloting the use of Aladin to combine the alignment and comparison stages of analysis (which were formally completed as part of a two-step process). The new procedure uses a single step to both align and compare the images, which has resulted in a significant increase in the speed and efficiency of the analysis process. The leadership team has also created an autonomous, self-paced training procedure for new member onboarding and has developed a formal procedure for analysis of potential transient detections.

The current leadership group has also pioneered the use of a team structure in the research project. Members of the leadership team each recruit, train, and supervise a small team of students as they work to analyze the observations. The teams report directly to the lead researchers, who monitor results and help troubleshoot any problems that arise during the analysis.

3.5.1 Program Accountability

In any research program that involves multiple participants, a key factor is accountability. Data must be processed quickly, and results communicated in a short time frame, in order to confirm and further study supernova candidates before they fade below detection limits.

In the APUS SSN program, accountability is the sole responsibility of the leadership team. These students are responsible for communicating with both faculty and student program participants to ensure that all images are processed in an orderly and timely fashion and that no data is overlooked. The

leadership team monitors the progress of data through the analysis process and is the point of contact for any technical issues that arise. The leadership team must also communicate regularly with the faculty to ensure that potential supernova candidates are reported for future study.

To manage this process, the team designed an observatory Google Drive account to provide organization and easy access to the data. The drive includes separate folders for each stage of the process as well as a check-out sheet where students can record which data they are analysing and any transient objects in the data. The simplicity of the system is its greatest asset; it is user friendly and effective, easily monitored, and fairly maintenance free. This system has been an important factor in creating a program that runs smoothly and efficiently.

4. Theory and Calculation

It is important to establish the feasibility of a long-term research program such as the APUS SSN. Two factors are of primary concern here: the probability of detection and the time-frame of detection. Both are pivotal in determining the projected success rate of the program.

4.1 Probability of Detection

The probability of detection relates to the likelihood that the current program will observe a supernova when it occurs. This probability depends on a balance between two key factors: the rate of supernovae in the Universe and the

sample size of the galaxies observed in the program.

4.1.1 Supernova Rate

The number of supernovae which occur yearly in the Universe has been studied by many groups; it varies by supernova type as well as by galaxy type, mass, and even the wavelength of observation and the inclination of the observed galaxy. These rates have been established fairly accurately in recent years; here, we will rely on the measurements by the Lick NGSS program, which computed rates for samples of nearby (local) galaxies based on CCD imaging and modern imaging subtraction techniques for a sample of 1000 supernovae spanning Types Ia, Ibc, and II. [14]

The supernova rate in the Milky Way galaxy is a well-established rate. The Lick observatory NGSS program estimates this rate at 2.84 ± 0.60 SNe per century [14], a number which is consistent with published supernovae rates from other groups using a variety of techniques. They then calculated rates as a function of galaxy mass and supernova type for nearby galaxies. For our purposes, the volumetric rate averaged over early and late type galaxies is sufficient. They report volume rates of 0.301 (Type Ia), 0.258 (Type Ib,c) and 0.447 (Type II) in units of (10^{-4} SN Mpc³ yr⁻¹). [14] Our sample comprises a radius of approximately 19.8; assuming a spherical distribution, this gives a volume of roughly 32.5×10^4 Mpc³. Thus, we can expect rates of 0.98 yr⁻¹ (Type Ia); 0.83 yr⁻¹ (Type Ib,c); 1.45 yr⁻¹ (Type II), or roughly 3 per year. Note that this

assumes complete sampling of the galaxies in the volume, however.

In addition, a supernova event does not necessarily mean a detection. A more useful indication of potential success for our study is perhaps given by established detection rates from similar studies, normalized by the number of observers (telescopes used) and detection capability. Based on observational rates, an estimate of a 2-3 detections per year is reasonable [12]. For comparison, the POSS group reports roughly 15 – 20 supernova detections per year using two telescopes, while the BOSS team reports 9 – 15 detections an average per year using 6 telescopes. [7, 8]

4.1.2 Sample Probability

The number of galaxies regularly observed in the research program directly relates to the probability of detection; the larger the sample size, the more likely a detection will be made. The APUS SSN sample contains 177 galaxies in multiple regions of the sky. Assuming a conservative one observable event per year in given the sample volume, this implies roughly 4200 observations per detection. Observational success rates of similar programs report approximately 1 supernova detection per one thousand observations. [7] [8]

4.2 Observational Timeframe

Supernova peak very quickly and decay over a period of a few weeks to a few months, depending on the type of the supernova (see Fig. 1).

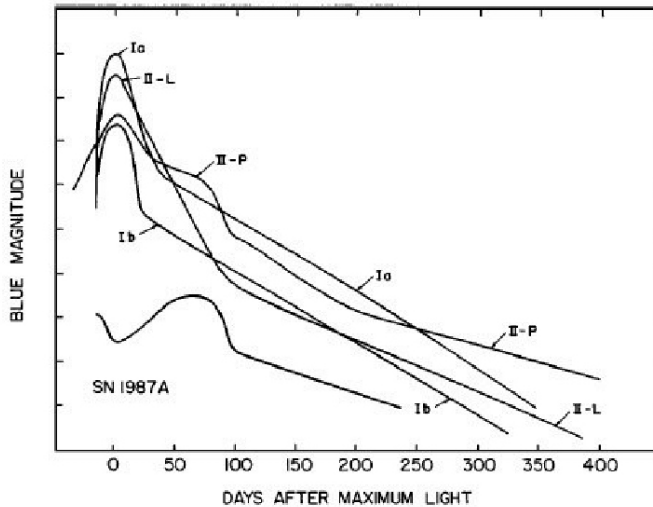


Fig. 1. Supernova lightcurves as a function of time. Image credit: Nadyozhin [13]

For galaxies of 11th magnitude or brighter, the APUS telescope is capable of detecting the light from a typical supernova for approximately 20 - 30 days. This means that each galaxy should be observed a minimum of twice a month in order to ensure that the event is still visible. Weekly observations are preferable in order to detect a supernova as quickly as possible after the event.

5. Results

The APUS SSN program has now completed the testing phase and is currently in operation.

5.1 Testing Phase

Under the direction of (then) lead graduate student Bradley Pellington, a group of two APUS Space Studies students participated in the testing phase of the SSN program from July 27, 2019 through August 4, 2019. The students analyzed 15 images using the process

outlined in section 2. The testing revealed that adjustments were needed in the instruction manual as well as an additional column for comments in the spreadsheet.

5.2 Research Phase

The SSN project is currently fully operational. Approximately 30 APUS Space Studies students are working under the supervision of the leadership team to analyze galaxy images and identify transient objects. Collectively, the students have analyzed hundreds of images at the time of this writing. Figures 2 and 3 show typical galaxy images from the SSN program. Both face-on and edge-on galaxy candidates are included in the galaxy sample.

A number of minor variations due to cosmic rays have been noted, and some photon leakage due to an exceptionally bright star in one of the images was reported. The group has confirmed detection of several transient

events, including several asteroids and the identification of some known variable stars (Figure 4) as well as the detection of the previously reported May 6, 2020 supernova in M61, designation 2020jfo (Figure 5).

While not the supernovae discoveries hoped for, these detections indicate that the process is working. To date, no potential new supernovae candidates have been found, but progress is hopeful and on track for the future.



Fig. 2. NGC 628, Pegasus Region, APUS Observatory, June 2019. Image credit: K. Miller



Fig. 3. NGC 891, Pegasus Region, APUS Observatory, June 2019. Image credit: K. Miller

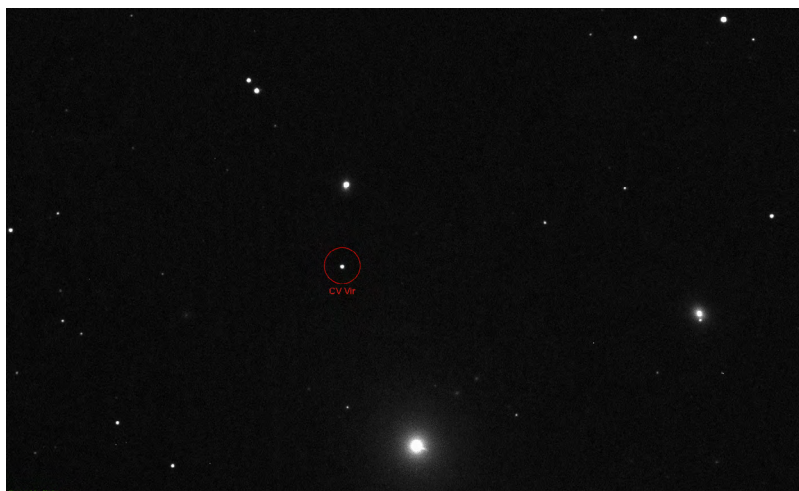


Figure 4: Detection of known variable star CV Vir. APUS Observatory, April 2020.
Image credit: K. Miller



Figure 5: Detection of supernova 2020jfo in M61, APUS Observatory, May 2020.
Image credit: K. Miller

6. Discussion

The main value of this program lies in the research opportunities afforded to both graduate and undergraduate students. Six APUS space studies students, from both the undergraduate and graduate programs, have gained the experience of developing a research program. The first lead student pioneered the development of

programs that would work effectively in the APUS online environment. This work allowed the program to function remotely and smoothly. The second lead student completed testing of the program and developed the interface that allows students to participate in the program. The supervisory nature of his position provides a unique research experience. Both lead students also gained observational experience through the

use of the APUS telescope to observe the galaxies in the program. The current leadership team has streamlined and improved the analysis procedure, developed an effective training program for students who join the research initiative, implemented a successful team-based approach, formalized the detection procedure, and supervised the transition from the testing to the research phase of the program. The combination of authentic observational and program management experience gives these students a unique advantage in future academic studies and also distinguishes them in the job market.

Space Studies students who choose to participate in the program also benefit greatly. Students have the opportunity to work with real observational data in fits format (the standard for astronomical imaging). They learn to analyze the images and detect transient features, which gives them experience

in data interpretation. The hands-on nature of this experience is invaluable and particularly unique for students in an online university program.

7. Conclusion

This paper details the creation of a student run, faculty supported, supernova search research program using the APUS 24-inch Plane-wave telescope. The program has been developed, tested, and successfully implemented by APUS Space Studies students, who direct both graduate and undergraduate students in analyzing the data. This program has the potential to contribute significantly to the scientific community through the detection of new supernova events. It also provides meaningful leadership opportunities for APUS graduate students, and authentic research experience for undergraduates.

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Limitations and Bias

This study is limited in the number of galaxies surveyed. The galaxy group represents an intentional bias towards nearby galaxies (high Z galaxies are excluded), primarily due to observational constraints.

Appendix A (List of Galaxies Observed)

Region	Galaxy	RA	Dec	Mag.
Pegasus	NGC 7217	22 ^h 07 ^m	31°21'	11
Pegasus	NGC 7331	22 ^h 37 ^m	34°24'	10.4
Pegasus	NGC 7479	23 ^h 04 ^m	12°19'	11.6
Pegasus	NGC 7640	23 ^h 22 ^m	40°50'	11.1
Pegasus	NGC 224	00 ^h 42 ^m	41°16'	3.44
Pegasus	NGC 488	01 ^h 21 ^m	15°24'	10.4
Pegasus	NGC 598	01 ^h 33 ^m	30°39'	5.72
Pegasus	NGC 628	01 ^h 36 ^m	15°47'	10
Pegasus	NGC 672	01 ^h 47 ^m	27°25'	11.5
Pegasus	NGC 772	01 ^h 59 ^m	19°00'	10.3
Pegasus	NGC 891	02 ^h 22 ^m	42°21'	10.8
Pegasus	NGC 925	02 ^h 27 ^m	33°34'	10.7
Pegasus	NGC 7606	23 ^h 19 ^m	-08°29'	10.8
Pegasus	NGC 7727	23 ^h 39 ^m	-12°17'	11.5
Pegasus	NGC 45	00 ^h 14 ^m	-23°10'	10.4
Pegasus	NGC 157	00 ^h 34 ^m	-08°23'	10.4
Pegasus	NGC 247	00 ^h 47 ^m	-20°45'	9.9
Pegasus	NGC 253	00 ^h 47 ^m	-25°17'	8
Pegasus	NGC 578	01 ^h 30 ^m	-22°40'	10.63
Pegasus	NGC 720	01 ^h 53 ^m	-13°44'	10.2
Pegasus	NGC 908	02 ^h 23 ^m	-21°14'	10.4
Pegasus	NGC 936	02 ^h 27 ^m	-01°09'	10.2
Pegasus	NGC 1055	02 ^h 41 ^m	00°26'	11.4
Pegasus	NGC 1068	02 ^h 42 ^m	00°00'	9.61
Pegasus	NGC 1073	02 ^h 43 ^m	01°22'	10.8
Pegasus	NGC 1087	02 ^h 46 ^m	-00°29'	11.4
Cam/Eri	IC 342	03 ^h 46 ^m	68°05'	9.1
Cam/Eri	NGC 1961	05 ^h 42 ^m	69°22'	10.9
Cam/Eri	NGC 2146	06 ^h 18 ^m	78°21'	11.38
Cam/Eri	NGC 2336	07 ^h 27 ^m	80°10'	10.3
Cam/Eri	NGC 2403	07 ^h 36 ^m	65°36'	8.9
Cam/Eri	NGC 2655	08 ^h 55 ^m	78°13'	10.1
Cam/Eri	NGC 2683	08 ^h 52 ^m	33°25'	10.6

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Cam/Eri	NGC 1187	03 ^h 02 ^m	-22°52'	11.4
Cam/Eri	NGC 1232	03 ^h 09 ^m	-20°34'	10.9
Cam/Eri	NGC 1300	03 ^h 19 ^m	-19°24'	11.4
Cam/Eri	NGC 1332	03 ^h 26 ^m	-21°20'	7.05
Cam/Eri	NGC 1395	03 ^h 38 ^m	-23°01'	9.8
Cam/Eri	NGC 1398	03 ^h 38 ^m	-26°20'	10.63
Cam/Eri	NGC 1637	04 ^h 41 ^m	-20°51'	11.5
Cam/Eri	NGC 1964	05 ^h 33 ^m	-21°56'	10.8
Ursa Maj	NGC 2681	08 ^h 53 ^m	51°18'	11.1
Ursa Maj	NGC 2841	09 ^h 22 ^m	50°58'	10.1
Ursa Maj	NGC 2976	09 ^h 47 ^m	67°54'	10.8
Ursa Maj	NGC 2985	09 ^h 50 ^m	72°16'	10.4
Ursa Maj	NGC 3031	09 ^h 55 ^m	69°03'	6.94
Ursa Maj	NGC 3034	09 ^h 55 ^m	69°40'	8.41
Ursa Maj	NGC 3077	10 ^h 03 ^m	68°44'	10.6
Ursa Maj	NGC 3184	10 ^h 18 ^m	41°25'	10.4
Ursa Maj	NGC 3198	10 ^h 19 ^m	45°32'	10.3
Ursa Maj	NGC 3310	10 ^h 38 ^m	53°30'	11.2
Ursa Maj	NGC 3319	10 ^h 39 ^m	41°41'	11.07
Ursa Maj	NGC 3359	10 ^h 46 ^m	63°13'	10.57
Ursa Maj	NGC 3368	10 ^h 46 ^m	11°49'	10.1
Ursa Maj	NGC 3556	11 ^h 11 ^m	55°40'	10.7
Ursa Maj	NGC 3631	11 ^h 21 ^m	53°10'	10.1
Ursa Maj	NGC 3675	11 ^h 26 ^m	43°35'	10
Ursa Maj	NGC 3718	11 ^h 32 ^m	53°04'	10.61
Ursa Maj	NGC 3726	11 ^h 33 ^m	47°01'	10.2
Ursa Maj	NGC 3810	11 ^h 40 ^m	11°28'	10.6
Ursa Maj	NGC 3893	11 ^h 48 ^m	48°42'	10.2
Ursa Maj	NGC 3898	11 ^h 49 ^m	56°05'	11.7
Ursa Maj	NGC 3938	11 ^h 52 ^m	44°07'	10.9
Ursa Maj	NGC 3941	11 ^h 52 ^m	36°59'	10.3
Ursa Maj	NGC 3953	11 ^h 53 ^m	52°19'	10.8
Ursa Maj	NGC 3992	11 ^h 57 ^m	53°22'	10.6
Ursa Maj	NGC 4051	12 ^h 03 ^m	44°31'	12.92
Ursa Maj	NGC 4088	12 ^h 05 ^m	50°32'	11.2
Ursa Maj	NGC 4125	12 ^h 08 ^m	65°10'	10.7

Ursa Maj	NGC 4605	12 ^h 39 ^m	61°36'	10.9
Ursa Maj	NGC 5322	13 ^h 49 ^m	60°11'	10.1
Ursa Maj	NGC 5457	14 ^h 03 ^m	54°20'	7.86
Ursa Maj	NGC 5474	14 ^h 05 ^m	53°39'	11.3
Ursa Maj	NGC 5585	14 ^h 19 ^m	56°43'	11.2
Ursa Maj	NGC 5866	15 ^h 06 ^m	55°45'	10.7
Ursa Maj	NGC 5907	15 ^h 15 ^m	56°19'	11.1
Ursa Maj	NGC 6503	17 ^h 49 ^m	70°09'	10.2
Ursa Maj	NGC 6946	20 ^h 34 ^m	60°09'	9.6
Leo/Hyd	NGC 2775	09 ^h 10 ^m	07°02'	11.03
Leo/Hyd	NGC 2903	09 ^h 32 ^m	21°30'	9.7
Leo/Hyd	NGC 3115	10 ^h 05 ^m	-07°43'	9.9
Leo/Hyd	NGC 3166	10 ^h 14 ^m	03°27'	7.21
Leo/Hyd	NGC 3338	10 ^h 42 ^m	13°44'	12.1
Leo/Hyd	NGC 3344	10 ^h 43 ^m	24°55'	10.5
Leo/Hyd	NGC 3351	10 ^h 43 ^m	11°42'	11.4
Leo/Hyd	NGC 3377	10 ^h 47 ^m	13°59'	10.2
Leo/Hyd	NGC 3379	10 ^h 47 ^m	12°34'	10.2
Leo/Hyd	NGC 3486	11 ^h 00 ^m	28°58'	10.5
Leo/Hyd	NGC 3489	11 ^h 00 ^m	13°54'	10.2
Leo/Hyd	NGC 3521	11 ^h 05 ^m	-00°02'	11
Leo/Hyd	NGC 3627	11 ^h 20 ^m	12°59'	8.9
Leo/Hyd	NGC 3628	11 ^h 20 ^m	13°36'	6.07
Leo/Hyd	NGC 2613	08 ^h 33 ^m	-22°58'	11.6
Leo/Hyd	NGC 2835	09 ^h 17 ^m	-22°21'	10.3
Leo/Hyd	NGC 3109	10 ^h 03 ^m	-26°09'	10.4
Leo/Hyd	NGC 3923	11 ^h 51 ^m	-28°48'	9.6
Leo/Hyd	NGC 4038	12 ^h 01 ^m	-18°52'	11.2
Leo/Hyd	NGC 5236	13 ^h 37 ^m	-29°51'	7.54
Virgo	NGC 4030	12 ^h 00 ^m	-01°05'	10.6
Virgo	NGC 4216	12 ^h 15 ^m	13°08'	11
Virgo	NGC 4261	12 ^h 19 ^m	05°49'	11.4
Virgo	NGC 4303	12 ^h 21 ^m	04°28'	10.18
Virgo	NGC 4365	12 ^h 24 ^m	07°19'	6.64
Virgo	NGC 4374	12 ^h 25 ^m	12°53'	10.1
Virgo	NGC 4429	12 ^h 27 ^m	11°06'	11.02

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Virgo	NGC 4438	12 ^h 27 ^m	13°00′	10
Virgo	NGC 4442	12 ^h 15 ^m	13°08′	11.2
Virgo	NGC 4472	12 ^h 29 ^m	08°00′	9.4
Virgo	NGC 4477	12 ^h 30 ^m	13°38′	11.38
Virgo	NGC 4486	12 ^h 30 ^m	12°23′	9.59
Virgo	NGC 4517	12 ^h 32 ^m	00°06′	10.6
Virgo	NGC 4526	12 ^h 34 ^m	07°41′	10.7
Virgo	NGC 4527	12 ^h 34 ^m	02°39′	11.4
Virgo	NGC 4535	12 ^h 34 ^m	08°11′	7.38
Virgo	NGC 4536	12 ^h 34 ^m	02°11′	11.1
Virgo	NGC 4552	12 ^h 35 ^m	12°33′	10.73
Virgo	NGC 4569	12 ^h 36 ^m	13°09′	10.26
Virgo	NGC 4579	12 ^h 54 ^m	-10°14′	10.5
Virgo	NGC 4594	12 ^h 39 ^m	-11°37′	8.98
Virgo	NGC 4621	12 ^h 42 ^m	11°38′	10.6
Virgo	NGC 4636	12 ^h 42 ^m	02°41′	9.4
Virgo	NGC 4649	12 ^h 43 ^m	11°33′	9.8
Virgo	NGC 4654	12 ^h 43 ^m	13°07′	12
Virgo	NGC 4665	12 ^h 45 ^m	03°03′	10.3
Virgo	NGC 4666	12 ^h 42 ^m	-00°11′	10.8
Virgo	NGC 4697	12 ^h 48 ^m	-05°48′	9.2
Virgo	NGC 4699	12 ^h 49 ^m	-08°39′	9.6
Virgo	NGC 4731	12 ^h 48 ^m	-06°23′	10.5
Virgo	NGC 4753	12 ^h 52 ^m	-01°11′	10.85
Virgo	NGC 4762	12 ^h 52 ^m	11°13′	11.12
Virgo	NGC 4856	12 ^h 54 ^m	-10°14′	10.72
Virgo	NGC 4939	13 ^h 04 ^m	-10°20′	11.3
Virgo	NGC 5054	13 ^h 16 ^m	-16°38′	10.36
Virgo	NGC 5068	13 ^h 18 ^m	-21°02′	10.5
Virgo	NGC 5247	13 ^h 38 ^m	-17°53′	10.5
Virgo	NGC 5248	13 ^h 37 ^m	08°53′	10.97
Virgo	NGC 5364	13 ^h 56 ^m	05°00′	11.2
Virgo	NGC 5566	14 ^h 20 ^m	03°56′	11.1
Virgo	NGC 5746	14 ^h 44 ^m	01°57′	11
Virgo	NGC 5846	15 ^h 06 ^m	01°36′	10.1
CB/CV	NGC 4192	12 ^h 13 ^m	14°54′	11

CB/CV	NGC 4254	12 ^h 18 ^m	14°24'	10.4
CB/CV	NGC 4274	12 ^h 29 ^m	29°36'	10.4
CB/CV	NGC 4293	12 ^h 21 ^m	18°22'	10.4
CB/CV	NGC 4314	12 ^h 22 ^m	29°53'	11.4
CB/CV	NGC 4321	12 ^h 22 ^m	15°49'	9.5
CB/CV	NGC 4382	12 ^h 25 ^m	18°11'	10
CB/CV	NGC 4414	12 ^h 26 ^m	31°13'	11
CB/CV	NGC 4450	12 ^h 28 ^m	17°05'	10.9
CB/CV	NGC 4459	12 ^h 29 ^m	13°58'	11.32
CB/CV	NGC 4494	12 ^h 31 ^m	25°46'	9.7
CB/CV	NGC 4501	12 ^h 31 ^m	14°25'	10.4
CB/CV	NGC 4548	12 ^h 35 ^m	14°29'	11
CB/CV	NGC 4559	12 ^h 35 ^m	27°57'	10.4
CB/CV	NGC 4565	12 ^h 36 ^m	25°59'	10.42
CB/CV	NGC 4725	12 ^h 50 ^m	25°30'	10.1
CB/CV	NGC 4826	12 ^h 56 ^m	21°40'	9.36
CB/CV	NGC 4145	12 ^h 10 ^m	39°53'	11.3
CB/CV	NGC 4151	12 ^h 10 ^m	39°24'	11.5
CB/CV	NGC 4214	12 ^h 15 ^m	36°19'	10.2
CB/CV	NGC 4236	12 ^h 16 ^m	69°27'	10.5
CB/CV	NGC 4242	12 ^h 17 ^m	45°37'	11.37
CB/CV	NGC 4244	12 ^h 17 ^m	37°48'	7.72
CB/CV	NGC 4258	12 ^h 19 ^m	47°18'	8.4
CB/CV	NGC 4395	12 ^h 25 ^m	33°32'	10.6
CB/CV	NGC 4395	12 ^h 25 ^m	33°32'	10.6
CB/CV	NGC 4449	12 ^h 28 ^m	44°05'	10
CB/CV	NGC 4490	12 ^h 30 ^m	41°38'	9.8
CB/CV	NGC 4618	12 ^h 41 ^m	41°09'	11.2
CB/CV	NGC 4656	12 ^h 43 ^m	32°10'	11
CB/CV	NGC 4736	12 ^h 50 ^m	41°07'	8.99
CB/CV	NGC 5005	13 ^h 10 ^m	37°03'	10.6
CB/CV	NGC 5033	13 ^h 13 ^m	36°35'	10.8
CB/CV	NGC 5055	13 ^h 15 ^m	42°01'	9.3
CB/CV	NGC 5194	13 ^h 29 ^m	47°11'	8.4
CB/CV	NGC 5371	13 ^h 55 ^m	40°27'	11.3

*Region refers to the area of the sky as defined in the program

* RA = right ascension

*Dec = Declination

*Cam/Eri = Camelopardus/Eridanus

*Ursa Maj = Ursa Major

*Leo/Hyd = Leo/Hydra

*CB/CV = Coma Berenices/Canes Venatici

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Conflicts of Interest

Preliminary reports of this project were made at the AAS Meeting 233 in January 8, 2019 and presented at the 70th International Astronautical Congress, 21-25 October 2019, Washington, D.C., United States. A preliminary report of the project was published in the IAC proceedings, reference number IAC-19, E1,3,11,x54118