Searching for Supernovae Over the Internet

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Abstract

The Sloan Digital Sky Survey II (SDSS-II) is a 3 year extension of a five year project to survey approximately a quarter of the sky for astronomical objects. SDSS-II has three main components; (i) completion of the five year survey, (ii) mapping structure and stellar makeup of the Milky Way Galaxy and (iii) detect and measure light curves for a large sample of supernovae (SNe). With repeat imaging of a strip of sky (about 2.5 deg wide by 110 deg long) over the course of three 3-month campaigns (Sept-Nov. 2005-7), the search is intended to gather multi-band light curves for 200 Type Ia supernovae in the redshift range z=0.1-0.3. Software has been developed for rapid processing of images that will identify astronomical objects as possible supernovae candidates by subtracting new images from template images. Further evaluation by the human eye of the subtracted images is necessary, as all objects detected by this process will not be supernovae. This paper will acquaint the reader with the web page we created so that collaborators from anywhere in the world, with Internet access, will be able to participate in selecting interesting candidates for follow-up observation. The web page will display the template, search and subtracted images in g, r and i filters along with additional information to assist in this determination. This method was used in an engineering run performed in the fall of 2004 which yielded 254 candidates and 41 confirmed SNe of various types and 16 type Ia's.

1 Introduction

The mission of Fermi National Accelerator Laboratory is to conduct research to advance the understanding of the fundamental nature of matter and energy. Long term planning of Fermilab is to expand its leadership role in Particle Astrophysics, which provides probes of fundamental physics that complement accelerator experiments. [1]

1.1 Particle Astrophysics at Fermilab

In 2004, partial implementation of this plan began with the formation of the Fermilab Particle Astrophysics Center. This center incorporates the following: Theoretical Astrophysics Group, Pierre Auger Observatory, Cyogenic Dark Matter Search, Supernova/Acceleration Probe, Dark Energy Survey and the Sloan Digital Sky Survey.

1.1.1 Theoretical Astrophysics Group

Founded in 1983, the Fermilab Theoretical Astrophysics Group performs research at the confluence of astrophysics, cosmology, and particle physics. The main enterprise is theoretical cosmology. Work are on topics ranging from early universe string theory to numerical simulations of structure formation [4].

determine the expansion history of the universe over the last 10 billion years. SNAP will also use gravitational lensing, the distortions of distant galaxies by foreground matter in other galaxies and clusters, as another measure of distances and growth of universal structure [3].

1.1.5 Dark Energy Survey

The Dark Energy Survey (DES), which will make precision measurments of dark energy using four independent astronomical techniques. The DES will use the world's biggest CCD camera mounted on a four-meter telescope at the Cerro Tololo Inter-American Observatory in Chile to measure the history of the expansion rate of the universe [3].

1.1.6 Sloan Digital Sky Survey

This astronomical survey is systematically mapping one quarter of the sky. When completed, it will provide scientists with a three-dimensional picture of the sky through a volume one hundred times larger than that explored to date. The survey will measure positions, absolute brightnesses of and distances to millions of celestial objects and galaxies [3].

1.2 Sloan Digital Sky Survey

The Sloan Digital Sky Survey (SDSS) has been operation since June 8, 1998. The SDSS will obtain high-resolution pictures of one quarter of the entire sky in five different colors. From these pictures, advanced image processing software will measure the shape, brightness, and color of hundreds of millions of astronomical objects including stars, galaxies, quasars (compact but very bright objects thought to be powered by material falling into giant black holes), and an array of other celestial exotica. Selected galaxies, quasars, and stars will be observed using an instrument called a spectrograph to determine accurate distances to a million galaxies and 100,000 quasars, and to provide a wealth of information about the individual objects [5].

1.2.1 Location and Instruments

The SDSS telescopes are located at Apache Point Observatory (APO) in Sunspot, New Mexico.(See Fig 1.) The main telescope has a 2.5-meter primary mirror reflecting to 1.08-meter secondary mirror. (see Figs. 2, 3).

1.3 Sloan Digital Sky Survey II

The SDSS five year plan has been completed and additional funding was granted to continue this venture in SDSS-II. This new undertaking will run through the summer of 2008 and has three main components; LEGACY, SEGUE and a supernovae survey.

2 Supernovae Survey

Every fall during 2005-2007, the SDSS 2.5m telescope will continuously scan 200 square degrees of the sky near the south Galactic pole. This "movie of the sky" will reveal asteroids, comets, galactic variable stars, extragalactic supernovae and bursts from active galactic nuclei. Supernovae are of special interest. The SDSS-II survey will find explosions in the "supernova desert": a distance range ($0.1 < z < 0.3$) that has seen very few supernova discoveries.(See Fig. 4) But SDSS-II has the unique ability to detect very faint events over a large search area and expects find about 200 type Ia supernovae in the desert.

2.1 What is a supernova?

They are giganitic thermonuclear explosions that signify the end life of certain stars that reach a critical mass. These occur when the star's nuclear fuel is exhausted and the equilibrium between the gravitational inward force is no longer supported by the release of nuclear energy. If the star is particularly massive, then its core will collapse and in so doing will release a huge amount of energy explosively. The resulting explosion can outshine a nearby galaxy of millions of stars!

2.1.1 Type Ia Supernovae

Type Ia Supernovae are of particular interest since their light curves, graph of luminosity as a function of time after the explosion, are all similar in shape for all known type Ia's observed. The interesting part is that type Ia's share uniform energy flux at maximum luminosity. This property has led their use as a standard candle. In 1998, the study of type Ia's led to the discovery that the expansion rate of the universe is accelerating.

2.1.2 What can we study from Type Ia's?

1) Use the supernova light curves to measure the properties of dark energy that is accelerating the expansion of the universe. 2) Study the diversity of supernovae and use that information to make them better distance indicators and more reliable cosmological probes. 3) Compare supernova characteristics with properties of their host galaxies including metallicity, star formation rate and star formation history.

3 Supernovae Search Program

The search method for the SDSS II is automated. Software compares search images with template images (using high-quality SDSS data from previous years). A computer cluster at the observatory will automatically processes the data: producing corrected frames with the

4 Manual Scan 2004

For the 2004 engineering test run, a GUI interface was written to manually scan all objects detected by subtraction software. The GUI enviornment was written in TK with tcl embedded for control of data, output and accessing mySQL database.The interface had three main boxes; image display, information on displayed object and any history about the position of the object.(see Fig. 10) The image display was another software package, DS9, which displayed FITS images. The infomation about object was queried from mySQL database and organized to help in determining if object is a candidate for further inspection. This box held options for querying mySQL; by search run, template run, etc. The history of the position is a necessary aid to the user to be able to determine if object is static. If it was not static, then object could be classified as a transient. Once the scanner makes a determination of the object, it would be catergorized by the options available such as AGN, dipole, etc., or a SNe candidate. This classification is then entered into the database.

5 Manual Scan 2005

To use the software developed for manual scanning in 2004, it was necessary to log on to one of the Fermilabs networks to access database, retrieve images and run DS9. Speed was dependent on connection, especially the downloading of the large FITS image files.

The objective of creating a webpage is to be able to have any collaborator participate in the classification of objects detected and perform this task quickly and effeciently. To do this, we utilize the Internet.

5.1 Initialization Page

Manual scan has basically 3 different pages;initializaling page, manual scanning page and a guide page. Upon entering URL, the first page is the initialization page(See Fig. 11). Here the user would select their user name in a drop down menu and enter search and template run numbers, with some additional criteria to access appropriate observation data and images. Hit enter.

5.2 Manual Scanning Page

This brings you to the manual scanning page. This interface is similar to the one written for the engineering run. The page is divided into 4 frames;image display, current object information, history of position of object and the update frame.(See Fig. 12)

This is the defining frame of the manual scan for objects detected by the subtraction code. Here the user, upon catergorizing object according to selection shown; i.e. transient, variable, SNe GOLD, etc., will hit UPDATE button. This will update database and, if selected as a SNe candidate, follow-up consideration will be determined.

5.3 Guide to Manual Scan

On the information frame there is a link to the Manual Scan Guide (See Fig. 13). This page is for information about the webpages and gives some description of different criteria of selecting and defining objects.

6 Results

Manual Scan was only recently completed and available to collaborators for testing. So no actual statistics can be given on results. There is feedback from users which will be given consideration to further development of pages. One of the testing methods is inserting fake supernovae into testing images to see if scanners will identify them. The testing is being done on images taken last year. Since we know results, we will be able to compare efficacy of our program by the accuracy of reproducing results of last year.

7 Conclusion

Methods of manual scanning were proven in 2004 engineering run. We will be able to compare our testing with those results. New hardware was purchased with additional processors running at higher frequencies so that completion of a nights observation will finish more quickly so that manual scanning can be started faster. We also have the experience from last years, which will enable us to efficiently determine if objects are SNe candidates.

References

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[6] Sloan Digital Sky Survey:A New Survey,2005. http://www.sdss.org/news/released/20050711.sdssII.html

[7] Nuclear Astrophysics. http://www.jinaweb.org/sdss2/html/goals.html

Figure 1: Apache Point Observatory

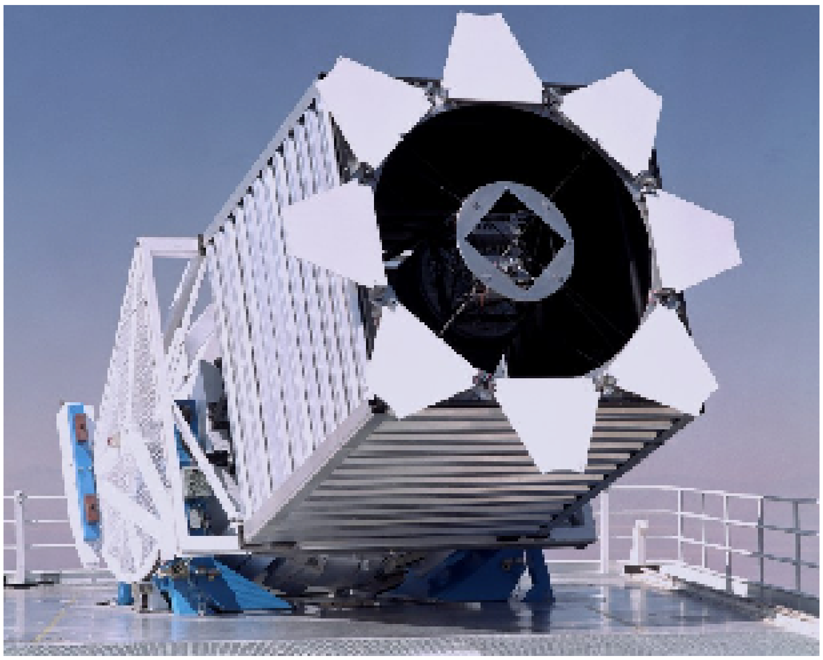

Figure 2: Sloan Telescope

[8] Lerdorf, Rasmus and Kevin Tatroe. Programming PHP. O'Reilly & Associates,2002.

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[11] Vaswani, Vikram. The Complete Reference MySQL. New York:McGraw-Hill,2004

[12] Callihan, Steve. Learn HTML 4 in a weekend. Boston:Premier Press, 2003.

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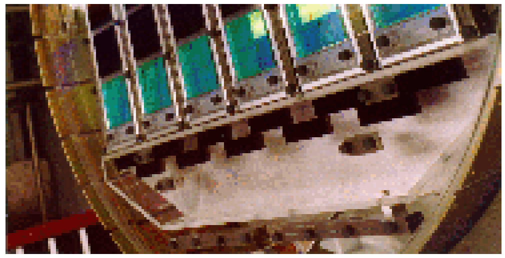

Figure 3: Five Filters, 30 CCD's

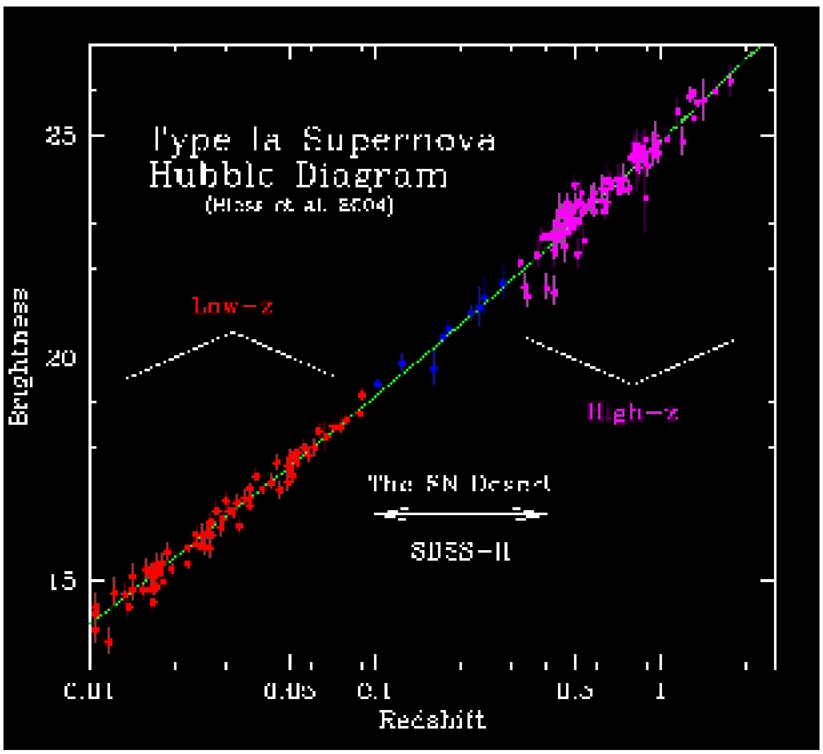

Figure 4: Hubble Diagram of Type Ia: Red Shift Desert shown

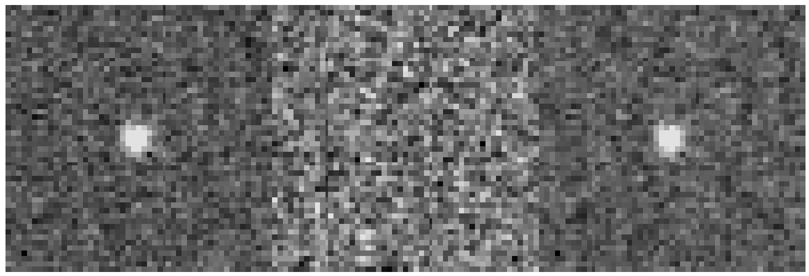

Figure 6: Transient: Search Image, Template Image, Subtracted Image

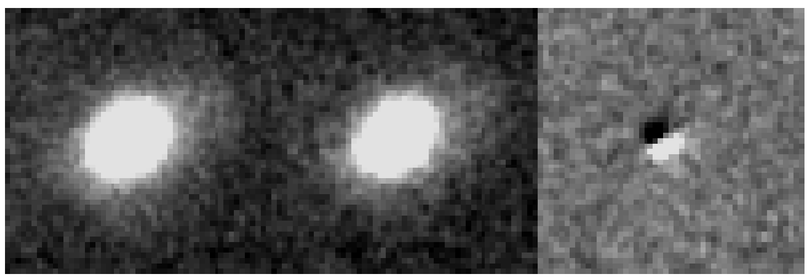

Figure 7: Dipole: Search Image, Template Image, Subtracted Image

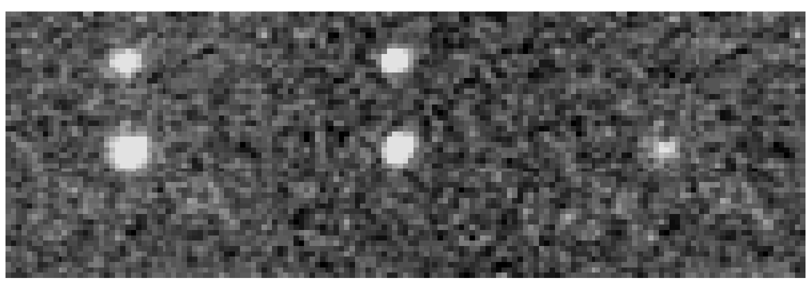

Figure 8: Variable: Search Image, Template Image, Subtracted Image

Figure 9: Artifact: Search Image, Template Image, Subtracted Image

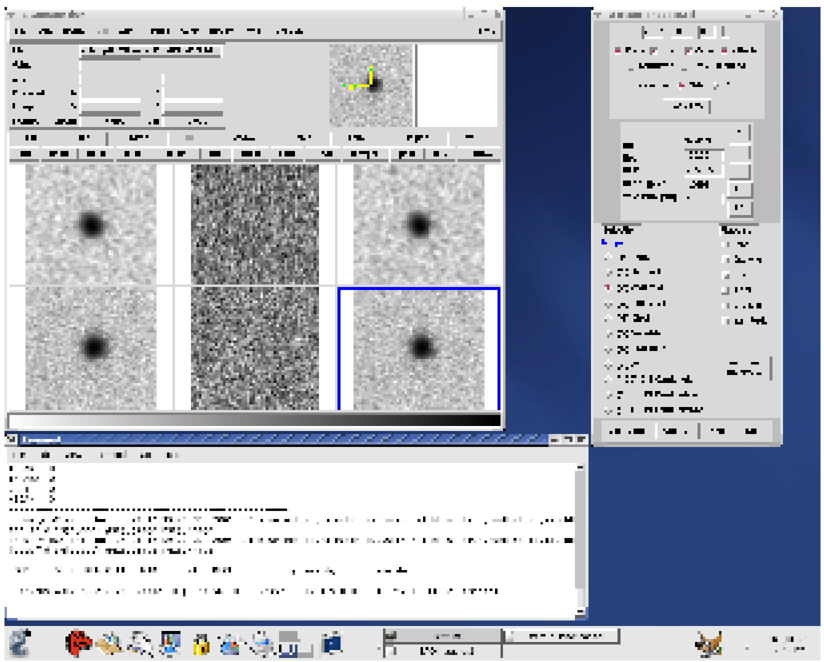

Figure 10: Manual Scan 2004:TK/tcl code

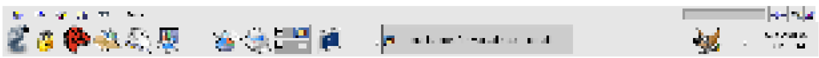

Figure 11: Manual Scan 2005:Initialization Page:HTML & PHP code

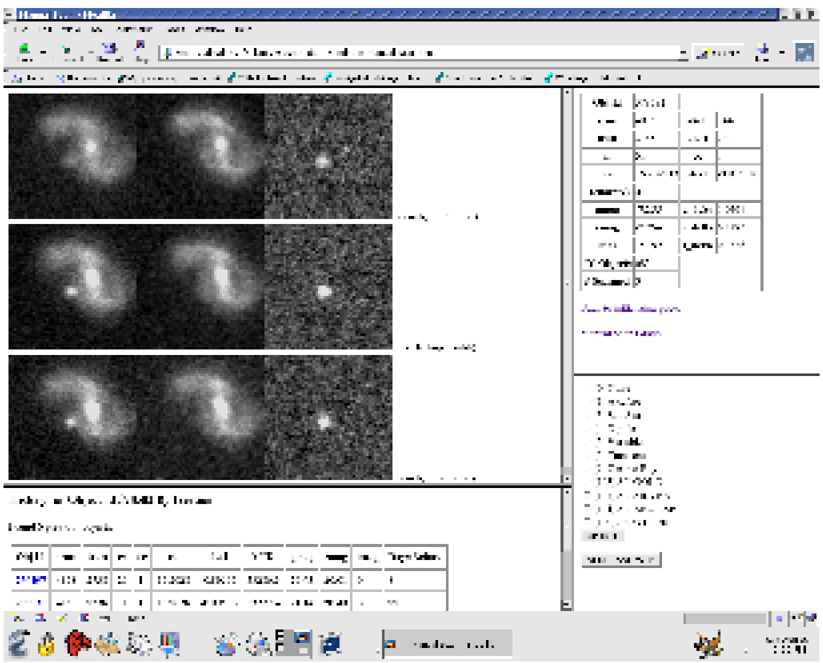

Figure 12: Manual Scan 2005:Manual Scan Page:HTML & PHP code

301424	4869	2738	29	1	16.2028	-0.89597	532863	21.27	20.56	0	-1.9
370661	4975	2738	29	1	16.2028	0.89599	553114.3	21.82	20.89	0	19.9

Figure 13: History Frame

Obj Id	378382		
srun	4892	**sfield**	144
trun	2738	**tfield**	26
rr	51	**cc**	1
ra	16.202913	**decl**	0.895920
Delta(pix)	0		
gmag	7.255	**g_delta**	1.0954
rmag	7.754	**r_delta**	0.7273
imag	7.789	**i_delta**	0.3636
Tel Objects	685		
# Scanned	0		

Back to initializing page.

Manual Scan Guide

Figure 14: Object Info Frame

Figure 15: Update Frame

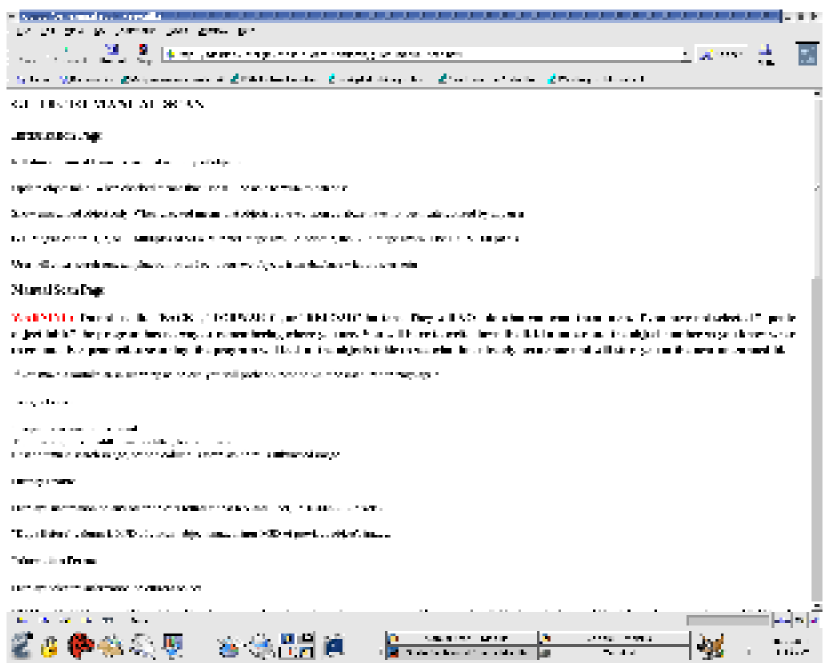

Figure 16: Guide to Manual Scan Page