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Looking for supernovae in the southern sky

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Abstract. We present two supernova searches recently started in Australia. One of them is carried on using the Automated Patrol Telescope (APT) at Siding Spring, and should allow the monitoring of all the galaxies with $cz < 10000$ km/s and Declination $< +20$ degrees. The other one is a bad conditions override program at the Mount Stromlo 50-inch telescope, and should allow the monitoring of all the late-type galaxies with $cz < 4500$ km/s and Declination $< +20$ degrees that are not monitored by the northern-hemisphere based LOTOSS supernova search. Our searches are the only such ones active in the southern hemisphere. They are expected to reach maximum efficiency as soon as a new detector is implemented at the APT, which should allow the monitoring of the whole sky every two or three nights, and as soon as the data reduction pipeline is completed at both telescopes.

Key words. Instrumentation: detectors – Supernovae – Surveys – Techniques: photometric

1. Introduction

Supernova (SN) events give us clues to the final evolutionary phases of certain kinds of stars, the evolution of galaxies and the characteristics of the interstellar medium. Much has been done so far to understand the physics of these objects, and we are now able to describe the overall characteristics and behavior of their various classes and subclasses. However, SN physics is not yet understood in great detail, and this is a limitation to the use of some properties of these objects, such as the use of Type Ia SN (SNIa) as standard candles and the investigation of the relationship between Type Ib/c SN (SNIb/c) and gamma-ray bursts (GRBs).

SNIa have been one of astronomy's premier tools for measuring the extragalactic distances. For example, using SNIa it has been discovered that the Universe is accelerating its expansion (Schmidt et al. (1998)), driven by some sort of "dark energy" such as cosmological constant or *quintessence* (Riess et al. (2000), Perlmutter et al. (1999)). For this purpose, the relations between the intrinsic luminosity and the observed parameters of SNIa must be de-

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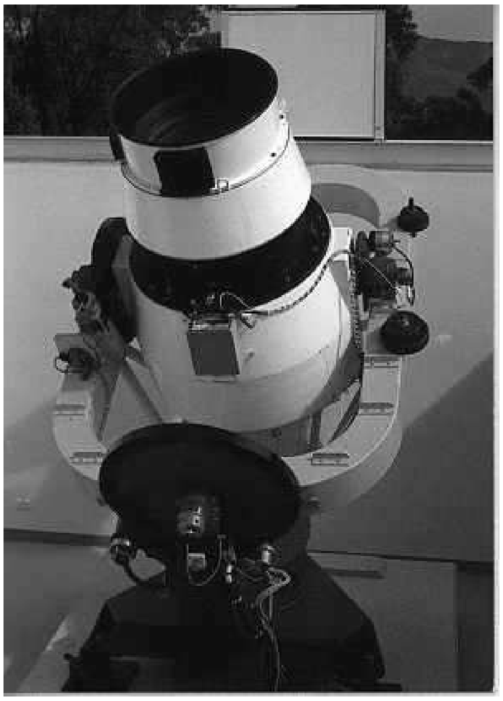

Fig. 1. The UNSW Automated Patrol Telescope.

termined with high precision. The best-known relation is the empirical decline-rate vs.luminosity correction (Phillips et al. (1999)), whose coefficients have varied over the last few years due to a larger sample of objects being available and to more refined estimations of their reddening (Germany et al., A&A in prep.). The SNIa luminosities exhibit a scatter of approximately 0.12 magnitudes around this 1-parameter family. However, there are some deviant objects, and it is clear that a larger sample of well-observed objects is necessary to understand if additional parameters are needed to predict distances for the entire array of SNIa explosions.

At this stage, it is very difficult to define a strategy to explore multi-parameter relations. Most of the ones we have are empirical, and we do not even know whether SNa are evenly distributed in the space of parameters or they form discrete groups. A significant enlargement of the sample of well-studied objects would allow a better check of the relations and a comparison between them and the theoretical models. Our present knowledge about the energetics of SNIa explains the relation between luminosity and light curve shape most easily in terms of ^{56}Ni mass. The greater the amount of synthesed nickel, the higher the luminosity and the temperature (Branch (2001)). But Riess et al. (1999) remark that the models that explain the relations between the rise times of the light curve and the luminosity do not explain the relations between decline times and luminosity of the same objects, so it would appear our theoretical understanding of these objects is still incomplete.

Another hot topic in astrophysics is the nature of GRBs and their possible association with supernovae. The collapsar model (MacFadyen et al. (2001)) of GRBs suggests that an energetic SNIb/c (*hypernova*) should be seen underneath the GRB. Indeed, the SNIc 1998bw has been detected in the error circle of GRB980425 (Galama et al. (1998)), but Price et al. (2002) find that SN underneath GRBs, if actually present, are not always as bright as SN 1998bw, and are consequently difficult to study directly. As a different approach, we propose to study the population of SNIb/c in the local universe to determine what fraction of these events are hypernovae. Uncovering an intermediate population of objects that lies between normal SNIb/c and normal GRBs (such as SN 1998bw), would provide strong evidence of a connection between the two.

2. Our aims

This project is aimed at monitoring the southern sky in order to detect supernovae in nearby galaxies, and in particular to greatly enlarge the current sample of SNIa to use for cosmology. We have embarked on two SN searches, one using the Automated Patrol Telescope (APT, Fig.1) at Siding Spring Observatory, owned and

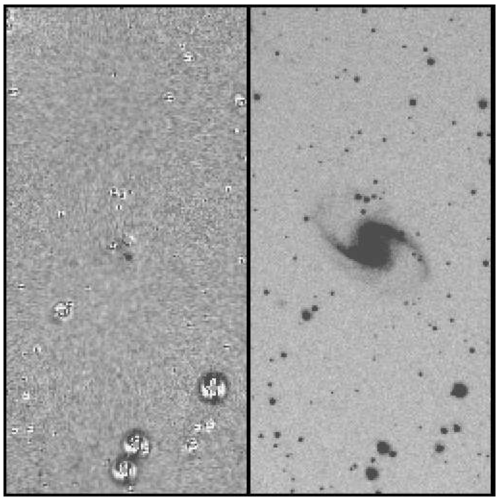

Fig. 2. Right: NGC 1365 with SN 2001du in an APT image taken in August 2001 (see IAUC N. 7690). Left: the SN, below the nucleus of the galaxy, is revealed by subtracting a template of the same field from the image on the right.

operated by the University of New South Wales (UNSW), and one at Mt. Stromlo Observatory (MSO), using the 50-inch telescope with the same setup used a few years ago for the MACHO project.

Based on an estimated rate of 1 SN/(88 square degrees)/year, the expected discovery rate is of more than 100 SN/year (APT) down to V $\sim$ 17 mag, in galaxies at cz $<$ 10000 km/s, and up to 20 SN/year (MSO 50-inch) down to R $\sim$ 18 mag, in late-type galaxies at $cz < 4500$ km/s. We have decided to limit the 50-inch targets to the late-type galaxies because they are the most likely to produce SN of all types. The SN candidates that will be produced by our searches will be confirmed, classified and followed using the 2.3-m telescope at Siding Spring Observatory and, possibly, other telescopes around the world.

This will allow us to obtain an enlarged sample of well-studied SN of all types, and thus provide K-corrections and templates, and will allow to measure peculiar motions in the local universe. From such a sample of objects, the SN rate in the local universe could be obtained with much higher precision than the current rate, and provide important information for the study of galaxy evolution as a function of galaxy type and environment. Our program also aims to determine the first bin in the equation of state for choosing Cosmology with SNIa, and contribute to answer the question as to whether the dark energy of the universe is consistent with a cosmological constant or with *quintessence*, a time-evolving spatially inhomogeneous energy component.

This work should discover almost every SN in the search area within a distance of 10000 km/s and it is the only automated search presently ongoing in the southern hemisphere.

3. Instruments and observing strategies

The APT is a fully automated Baker-Nunn camera with a primary mirror of 0.75m and aperture 0.5m, f/1. It has a 5 degrees diameter optically corrected field of view (Carter et al. (1992)). The detector is a Wright Instruments CCD, Peltier cooled, with a 2×3 degrees field of view and a scale of 9.41 arcsec/pixel, which means that we have heavily undersampled images of our targets. We deal with this by "wobbling" the telescope while taking exposures, in order to obtain an artificial point spread function. Our automated data reduction pipeline is formed by a set of programs in C and Perl, sometimes making use of certain IRAF tasks, derived from the High-z SN Search Team routines and adapted for the needs of this search via an additional series of Perl scripts. The pipeline calibrates the three images we take of each field (120 seconds exposure time per image) and combines them, then it subtracts a template of the same field from the combined image. Our subtraction technique is based on the ISIS package (Alard & Lupton (1998), Fig.2). Finally, our pipeline produces a list of SN candidates visible on the subtracted image, after verifying that they are not bad detections, known asteroids or

variable stars. A similar pipeline is being implemented at the MSO 50-inch telescope. Our APT targets are all the galaxies within $cz < 10000$ km/s and Dec $<+20$ degrees listed in the NASA Extragalactic Database, and our purpose is to monitor them at least once, possibly twice a month. Our targets at the 50-inch telescope are all the late-type galaxies at $cz < 4500$ km/s listed in the LEDA database and not monitored by the US-based Lick and Tenagra Observatories Supernova Search (LOTOSS). These are to be monitored every time this fully robotic telescope is not observing its main targets (searching for trans-neptunian objects and GRB follow-up) due to poor conditions: bad seeing, high sky brightness etc.
Spectroscopic confirmation of the candidates discovered by our searches will be provided using the 2.3-m telescope at Siding Spring Observatory, which is currently available for our program for about two nights per month.

4. Present status of the project

1. The APT targets must be monitored at least twice a month in order to discover the SNe before they reach maximum light.
2. A new CCD camera with a smaller pixel-size ($4.28''$/pix vs. $9.41''$/pix of the present one, and FOV>25 sq.deg.) shall soon replace the present one, and that will allow a monitoring of the entire sky in $\sim$2 nights. The telescope computer system is being upgraded accordingly to the needs of the new detector and observing techniques.
3. The group at UNSW has completed the automation of the APT, and the telescope can now be used remotely on a regular basis. An automated data reduction pipeline is being tested to supply reduced data to the observer in real time.
4. A scheduler for observations at the APT and 50-inch telescope has been written and is being refined. Routines to safely operate the APT in fully automated mode have been implemented and are being tested.
5. Observing time at the 2.3-m telescope at Siding Spring has been granted so far for SN follow-up, after the monthly monitoring time at the APT.
6. Contact has been established and will be maintained with the northern hemisphere SN searches in order to obtain maximum coverage of the sky at all times.

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