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The SWIRT Project at Campo Imperatore

E. Brocato, M. Dolci *

I.N.A.F. - Osservatorio Astronomico di Collurania - Teramo
Via Mentore Maggini s.n.c., 64100 Teramo
e-mail: brocato@te.astro.it

Abstract. The current status of the SWIRT Project is discussed. This project, involving the Observatories from Teramo, Rome and Pulkovo, is presently aimed to the infrared follow-up of supernovae and to the search of them in external galaxies. This is accomplished with the near-infrared camera SWIRCAM, mounted at the focal plane of the 1.1-m telescope AZT24 at Campo Imperatore, L'Aquila, Italy. The first results of the survey program performed on 1448+514 galaxies are described. The infrared follow-up of six supernovae is shown, with a particular attention to the infrared+optical lightcurves of the type-IIn supernova SN1999el, the second of this class of objects ever studied with this detail.
Finally the future perspectives, related mainly to the implementation of the low-resolution spectroscopic mode of the camera SWIRCAM, are outlined.

Key words. NIR astronomy - SNe

1. Introduction

SWIRT (**S**upernova **W**atchdogging **I**nfra**R**ed **T**elescope) is a project involving the Observatories of Teramo, Rome and Pulkovo. It is devoted to the infrared follow-up of all those supernovae whose lightcurve can be acquired extensively and with good accuracy; and to the search of supernova events in a selected sample of nearby spiral galaxies, at near-infrared wavelengths. The project for a Near-Infrared telescope could be traced back to 1994 (Battinelli et al. 1994). In 1995, the official agreement between the three above-mentioned observatories stated that the AZT-24 1.1-m telescope, provided by Pulkovo Obs., should have been installed in the east dome of the Campo Imperatore Station (Rome Obs.) and then equipped with a near-infrared camera provided by Teramo Obs.
The telescope was installed in 1997: in the same year, the Infrared Laboratories delivered the camera which saw its first light in 1998. Finally, in 1999, the SWIRT project started with a rough galaxy sample and the follow-up of the type-IIn supernova SN1999el.

Send offprint requests to: E. Brocato
* on behalf of the S W I R T Collaboration: A. Tornambè, E. Brocato, E. Di Carlo, M. Dolci, G. Valentini, A. Di Paola, A. Arkharov, V. Larionov, Y. Gnedin, I. Netchitailov, F. Massi, A. Caratti o Garatti, G. Licausi
Correspondence to: Via Mentore Maggini s.n.c., 64100 Teramo

Optical design	Ritchey-Chrétien
Corrected FOV	20 arcmin
Primary mirror diameter	1100 mm
Effective Focal Length	7971 mm
Mirrors roughness	$\sim 0.03\lambda$ rms
PSF parameters ($\lambda = 632.8\,nm$)	74% total light energy in 0".52 circle on axis 66% total light energy in 0".52 circle off axis
Mount	Equatorial (German)
Telescope movement and pointing	DC motors+absolute encoders 10 arcsec resolution 15 arcsec s^{-1} speed (exact guidance)

Table 1. AZT-24 Main Data

An important step forward was made in January 2000, with the discovery of the type-Ia supernova SN2000E (Valentini et al. 2000a) and its follow-up. Currently, the SWIRT observations concern a sample of 514 spiral galaxies, out of which 299 have been observed in the period July-November 2001. Moreover, the follow-up of new SNe is in progress or under analysis.

The SWIRT Project benefits of the 75% of the allocated time at the AZT24 telescope. The remaining 25% is devoted to selected projects concerning variable stars, star formation, gamma-ray bursts, X-ray sources, BL Lac objects (see the paper by Nesci *et al.* in this issue) and minor bodies of the Solar System.

In this paper we attempt to give an exhaustive description of the SWIRT Project. A resumé of the technical data of the telescope and the camera is given in the second section, together with a few examples of the images normally acquired. The general characteristics and guidelines of the SWIRT project are described in the third section. Finally, future perpectives are outlined in the fourth section, taking into account mainly the implementation of the spectroscopic mode currently in progress.

2. Technical data

The AZT-24 is a Ritchey-Chrétien telescope whose primary mirror has a diameter of 1.1 m and the secondary one has a diameter of 0.58 m. The overall focal length is 7.97 m, for a focal ratio $f/7.24$. The corrected field-of-view amounts to 20 arcmin, and could be extended up to 84 arcmin by making use of a correcting lens, which is not installed however.

The mount is of equatorial german type. The pointing and movement of the telescope are performed via DC motors and absolute encoders, whose accuracy is 10 arcsec and speed is 75 arcmin s^{-1} in rough guidance mode and 15 arcsec s^{-1} in exact guidance mode.

The complete data concerning the telescope are reported in tab. 1. These specifications are also discussed in another paper by A. Di Paola in this issue. The AZT-24 telescope is installed in the east dome of the Campo Imperatore Observatory. This station was built in the 1950s near the Gran Sasso d'Italia, at an altitude of 2120 m a.s.l. The site is not excellent as to the atmospheric stability, but the sky brightness amounts, as indicative values, to about 15.5, 14.5 and 11.5 mag arcsec^{-2} in the J, H and K bands respectively. Fluctuations related to the amount of atmospheric water vapour show differences even larger than 0.2 mag between the winter, most stable, and the summer.

The FWHM, measured on the first year of SWIRT observations, follows a distribution peaked around 2.1 arcsec and ranging predominantly between 1.8 and 2.8 arcsec, with the best data at 1.6 arcsec. The seeing is better in the winter.

Meteo data recorded in the last 5 years show that at Campo Imperatore the sky is clear for about the 50% of the available time (about 30% during the winter and 70% during the summer).
The AZT24 telescope is equipped with the near-infrared camera SWIRCAM. This camera is a device of the EFOSC type: it is composed by a first wheel hosting a field stop plus three slits for spectroscopy, located on the focal plane of the telescope; by a collimator which creates a paraxial beam; by two other wheels, placed around the pupil, carrying a set of filters and grisms; and by the camera optics, which refocuses the image onto the array. A Lyot stop is placed on the pupil. The camera is capable to perform imaging and low-resolution spectroscopy of point-like and extended sources.
It is provided with a 256 × 256 HgCdTe "PICNIC" array plus a set of broad- and narrow-band filters and grisms for the 1.1-2.5 μm region, reported in detail in tab. 2. The focal plane scale is 1.04 arcsec pix^{-1}, for a pixel size of 40 μm. The overall array, whose area is 10.24^2 mm^2, covers a field of view of more than 4.4 × 4.4 arcmin^2, with a residual distortion amounting to -2.65% which is software-corrected on the images. The main data about the camera performances are summarized in tab. 3. The quantum efficiency is larger than 50%, being maximum in the H band. Dark counts are almost negligible, whereas the reported RON level can be drastically reduced by a Fowler correlated double sampling. The linearity is rather good. The adopted flat fielding is differential, with preferred count levels for the two parent images of 40000—50000 (high) and 500—1000 (low), and should be preferentially performed at dawn or dusk on the sky. The fluctuations over the image are not larger than 40%.
The camera is liquid nitrogen-cooled at 77 K (75 K at 2120 m a.s.l.). The two-stage dewar (capacity of 13 l) has an evaporation rate of 0.26 l/hour and ensures a safe cooling up to 50 hours. Finally, the dewar is evacuated, with a residual pressure of 10^{-6} torr.

A sample of the images acquired with the camera SWIRCAM is reported in fig. 1. Most often active (probably star forming) regions appear in the infrared images, which are almost invisible in the optical range. This is the case, for example, of the galaxy NGC6267, observed in the J, H, K bands and shown in fig. 1.
By assuming the sky brightnesses reported at the beginning of this section, the limiting magnitudes (S/N $\sim$ 3) m_J=17.7, m_H=16.9 and m_K=16.2 can be achieved, by performing 1 min exposure time, with seeing conditions of $\sim$ 2 arcsec FWHM. These performances could be optimized by a better shaping of the Lyot stop, in order to shield the array not only from the spurious radiation coming from the edge of the primary mirror and the mount of the telescope, but also from the one generated by the secondary mirror. This technical work is currently in progress and a significant improvement is expected, as already seen on NICS at TNG (see the paper by Oliva in this issue).

3. The SWIRT project

The scientific aim of the SWIRT Project has been already described in other papers (Battinelli et al. 1994) (Vitali et al. 1996). Here we remind its two main goals:

1. the follow-up of different types of supernovae at near-infrared wavelengths
2. the near-infrared search of extragalactic supernovae in nearby spiral galaxies

In the following a brief description of the current status of the two aspects of the project are summarized.

Broad-band filters	**Narrow-band filters**	**Grisms**	**Other**
J (1.25 μm)	HeI (1.083 μm)	I+J	
H (1.65 μm)	FeII (1.645 μm)	H+K	H+K order sorter
K (2.2 μm)	H2 (2.121 μm)		
K' (2.2 μm, cut at 2.32 μm)	Brγ (2.164 μm)		

Table 2. SWIRCAM Capabilities

	J	H	K
Quantum efficiency	59%	70%	61%
Dark current level	0.00367 ADU s^{-1} pix^{-1}		
Dynamic range	0—55000		
Linearity	5000—50000		
RON	$\sim$ 30 e$^-$		
Gain	5.95 e$^-$/ADU		
Persistence ghosts	negligible		
Electronic ghosts	$\sim$ 2.5% of the source brightness		
Main overheads:			
Detector readout	$\sim$0.36 sec/DIT		
Image transfer	$\sim$9.50 sec/group		
Telescope offset	$\sim$3.30 sec/arcmin *(low speed)*		

Table 3. SWIRCAM Performances

Total selected galaxies	514
Maximum number of galaxies	*600*
Galaxy type	Spiral
Inclination	$60^o \leq i \leq 90^o$ (*edge on*) for the 67% of the sample $0^o \leq i \leq 30^o$ (*face on*) for the 33% of the sample
B absolute magnitude	$\leq$ -17
Angular diameter	$\geq$ 1.5 arcmin to avoid spatial undersampling $\leq$ 4.0 arcmin to fit the field-of-view
Distance modulus	$\leq$ 33.5 for face-on galaxies $\leq$ 32 for edge-on galaxies
Control time	between 20 and 90 days (41 days average), depending upon each star
Other	no stars-poor fields no very bright stars close to the galaxies

Table 4. SWIRT Galaxy Sample Data

3.1. The survey

The SWIRT survey concerns a selected sample of nearby spiral galaxies. At the beginning of the SWIRT Project, a test sample of 1448 galaxies from the RC3 catalogue was chosen more or less uniformly distributed over the sky at declinations higher than -10^o, and with recession velocities lower than 3500 Km s^{-1} (Battinelli et al. 1994).

After the first year of observations, the collected data allowed to refine the sample in order to match some requirements such as a proper spatial and temporal sampling of the galaxies, their visibility, the general meteo conditions and the availability of the human resources. The current sample consists of 514 galaxies, whose characteristics are summarized in tab. 4: a complete

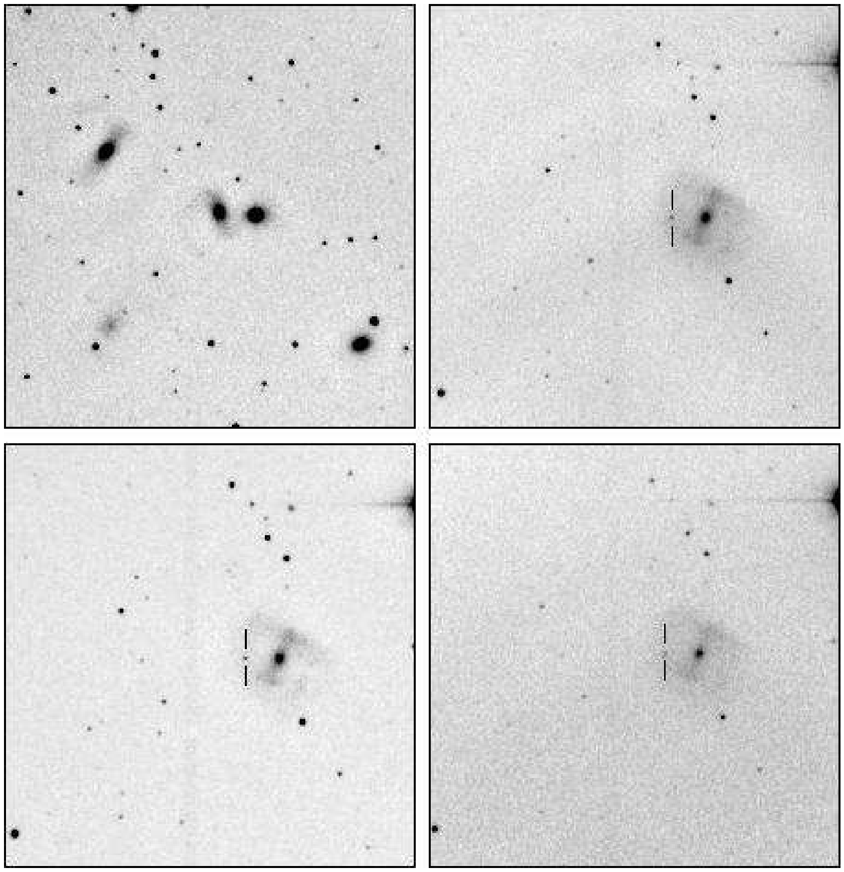

Fig. 1. A sample of the images acquired with the near-infrared camera SWIRCAM. *Top left*: the Stefan's Quintet, observed in the H band with a total exposure time of 3 min. *Top right*: the galaxy NGC6267, observed in the H band with a total exposure time of 6 min. *Bottom*: the same galaxy observed in the J band with a total exposure time of 6 min (*left*) and in the K band with a total exposure time of 12 min (*right*). The dark spot to east of the nucleus, and approximately at its same declination, visible mainly in the H and J images, is an active region not appearing in the optical frames.

description of the new catalogue is given in (Caratti et al. 2001).

A model for the SWIRT galaxies has been developed in order to evaluate the expected number of detected SNe (Caratti et al. 2001). According to these computations at least 3 ± 1 SNe should be detected in one year, with a detection efficiency ranging between 78% and 94% and a significant improvement with respect to the optical observations.

The observations are weekly scheduled by one of us. A typical observation of a galaxy field runs as follows. After the acquisition of each image, the removal of the background and the flat fielding are performed via the automatic routine PREPROCESS (Di Paola 2000). The image is then inserted in an automatic pipeline which derives a list of all the stellar-like objects and compares it with a catalogue created from previous images (if existing). If a new suspected object is found, a new image is acquired and the usual detailed check is performed by using, for example, 2MASS, IRAS, DSS and other public catalogues. Moreover the presence of transient asteroids is investigated by quering the MPC ephemeris on-line service.

The current SWIRT archive includes 1091 frames from the old catalogue, acquired between Oct, 5, 1999 and Jun, 26, 2001 and concerning 404 out of 1448 galaxies, plus 710 frames from the new catalogue, acquired between Jun, 26, 2001 and Nov, 24, 2001 and concerning 299 out of 514 galaxies. An example of the results is shown in fig. 2. No unambigous detection of SN candidates has been recorded yet, but 5 active regions not visible in the optical range have been discovered and 4 known asteroids have been serendipitously observed (SAIt 2001, poster).
The SWIRT data, and their future upgrades, are expected to be accessible online to the public in a website currently in preparation at the Teramo Observatory.

3.2. IR follow-up of SNe

The most important result of the follow-up program has been the determination of the lightcurves for the supernova SN1999el (Cao et al. 1999). This supernova has been observed at the AZT24 telescope in the J, H, and K bands up to 150 days after the B maximum and then at the TNG telescope, after the 200th day, in the J and K bands. Moreover, it has been observed in the optical B, V, R, I bands at the TNT 72-cm telescope of Teramo Observatory. SN1999el is a type-IIn supernova and only another similar object (SN1998S) has been extensively studied in the past (see, for example, Fassia et al. (2000)). Therefore, this work represents a cornerstone in this field and is going to be published (Di Carlo et al. 2001).
Another important result is the discovery and follow-up of SN2000E (Valentini et al. 2000a) whose infrared and optical lightcurves have been also determined (Valentini et al. 2001). SN2000E is a type-Ia supernova, hence particularly relevant as a distance indicator. Moreover, its occurrence in the same galaxy of SN1999el (NGC6951) makes it particularly interesting.
Up to now thw SWIRT Project performed observations of other supernovae in the infrared. SN2000ev (type IIn), SN2001Q (type II), SN2001V (type Ia), SN2001cy (type II) are shown in fig. 3. The analysis of these data is currently in progress.

4. Conclusions and future perspectives

After more than two years, we can report that the activity related to the follow-up of SNe has already produced valuable scientific results and is presently fully operative. On the other hand, the program of SN survey appears to be well established in all its operational steps (scheduling, observations, data analysis). However, the survey activity is facing with the unavoidable difficulties still present for the complete automatization of the telescope and the general meteo conditions which make it very expensive in terms of man power and of observing time. The not optimized operational stability and the unavailability of large human resources have provided a global working discontinuity that clearly affected the relevance and the timescale of the final scientific results of the original survey program. For this reason, the major effort of the SWIRT Project is currently addressed to the SN follow-up in the NIR bands. Possibly, as briefly discussed in the following, by also improving the spectroscopic facilities presently under development.
Preliminary tests show indeed that spectroscopy can be performed between 0.84 and 1.32 μm (I+J region) and between 1.45 and 2.38 μm (H+K region), with a spectral sampling of $\simeq 19$ Å/pix and $\simeq 36$ Å/pix respectively. This is consistent with the predicted resolving power of ~ 270 for both the grisms (Speziali & Vitali 1997).
Limiting magnitudes are expected around

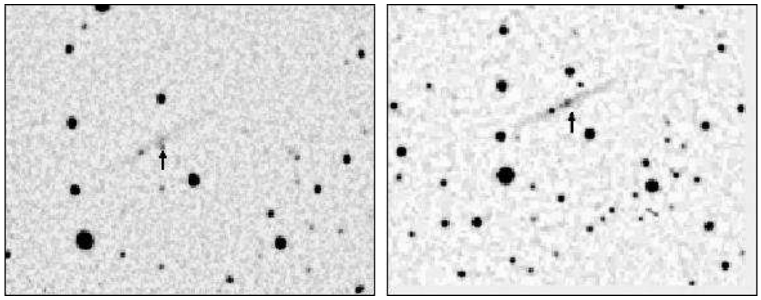

Fig. 2. The left image shows the galaxy UGC3314 (SW0217) observed on Nov 9, 1999. A stellar-like object is present just below the nucleus of the galaxy. The same object is not visible in the DSS-red plate, shown to the right.

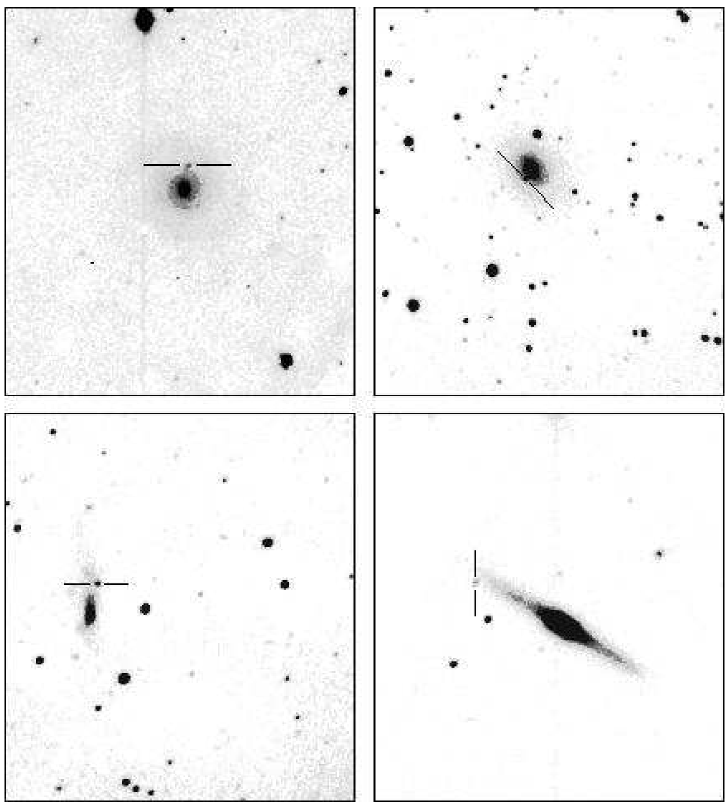

Fig. 3. Some supernovae whose follow-up has been recently performed and whose data analysis is in progress. *Top left*: SN2001Q in UGC6429 (type II). *Top right*: SN2001cy in UGC11927 (type II). *Bottom left*: SN2000ev in UGC3500 (type IIn). *Bottom right*: SN2001V in NGC3987 (type Ia).

14 for an exposure time of 1 min, a seeing figure of 2 arcsec and a signal-to-noise ratio equal to 3, in the worst sky conditions (K band).

With these performances, the spectroscopic follow-up, in addition to the photometric one, should be possible in the early- and intermediate stages of a supernova explosion. As an example, the spectroscopic observations should get more light on the evolution of the gas and dust which are believed to exist around type-IIn supernovae (see, for example, Lentz et al. (2001). More generally, the spectroscopic potential of the camera SWIRCAM will be exploited not only by the SWIRT project, but also by the other projects currently operational at the AZT24 telescope.

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