1 The Vista SuperNova Abell clusters Public Survey (SNAPS)

M. Riello, University of Cambridge, UK
Stefano Benetti, Maria Teresa Botticella, Enrico Cappellaro, Massimo Della Valle, Elisa Di Carlo, Eduardo Gonzales-Solares, Laura Greggio, Filippo Mannucci, Seppo Mattila, Andrea Pastorello, Ferdinando Patat, Stephen Smartt, Amedeo Tornambè, Massimo Turatto, Stefano Valenti, Luca Zampieri, Daniela Bettoni, Giovanni Fasano, Bianca Poggianti

1.1 Abstract:(10 lines max)

The rate of Supernovae (SNe) is an important parameter in astrophysics. It is regulating the chemical evolution of the galaxies, the physics of the ISM and its structure and kinematics, the production of high-energy cosmic rays and also the GRB rate (at least as far as concern long bursts) is tightly connected with it. Unfortunately this quantity is known with remarkable uncertainty. Analysis of optical searches and preliminary indications from pilot surveys carried out in the NIR wavelenghts (Mannucci *et al.* 2003; Mattila *et al.* 2004) have show that SN surveys performed in the optical can miss a significant fraction of SN events (up to 70%). Here, we propose to use VISTA to monitor 30-40 Abell clusters, from which we expect to detect a SN sample 10 times as large as the sample studied by Mannucci *et al.* 2003. The comparison between the number of detected SNe with the number of SNe predicted from the optical surveys (Cappellaro *et al.* 1999) will enable us to measure, for the first time, the correction factor between optical and NIR with an accuracy of the order of 20% or less.

2 Description of the survey: (Text: 3 pages, Figures: 2 pages)

2.1 Scientific rationale:

The **rate of Supernovae** during the evolution of the Universe is a key parameter for astrophysics. The rate of core-collapse (CC) SNe, because of their short-lived progenitors, probes the initial mass function (IMF) of stars, traces the star formation history of the Universe and can be used to test the different scenarios for galaxy formation, monolithic collapse vs. hierarchical clustering (*e.g.* Madau *et al.* 1998). Instead, the rate of Type Ia SNe, which are believed to result from the thermonuclear disruption of a white dwarf in a binary system, can be used to trace the long term star formation history and shed light on the still unknown nature of their progenitors.
While there are many ongoing projects intended to measure the evolution of the SN rate with redshift, some of which already produced interesting results (Cappellaro *et al.* 2005, Dahlen *et al.* 2004, Strolger *et al.* 2004, Barris & Tonry 2006), we are still facing some major uncertainties in these surveys and even in the local rate. Indeed, the current best estimate of the local SN rate still relies on photographic and visual surveys completed in the mid '80s (Cappellaro *et al.* 1999). Work in progress to exploit the results of modern CCD SN searches is expected to greatly improve the event statistics which is crucial to explore the correlation of the different SN types with specific stellar populations. In this respect, especially important is the LOTOSS survey which in the recent years has been monitoring at optical wavelengths a few thousand, nearby ($d \leq 20 - 30$ Mpc) galaxies with a magnitude limit of ~ 19 (unfiltered).
Because all the major surveys of the SN rate have been done in the optical, there is an expected large and very uncertain bias due to extinction in the parent galaxies. This is exemplified in Fig. 1 where we plotted the distribution of SNe in spiral galaxies seen at different inclination. There appear to be a severe bias against SN discoveries in late spirals seen edge-on and for core collapse (II+Ib/c). Additionally one can see that, contrary to common expectations, an extinction bias is seen also for Type Ia SNe.

Based on this evidence, we estimate that 1/2 to 2/3 of CC SNe are lost due to extinction, while for Type Ia SNe this fraction is probably 1/3. Different SN types, being related to different populations, may experience different average extinction and, hence, different biases. Mannucci *et al.* (2005a, 2005b) have shown that Type Ia SNe derive from both young and old stellar populations. Their delay times between progenitor formation and SN explosion must have a wide distribution, between few 10^7 years and 10^9 years. There is also a claim that two populations of Type Ia SNe exist, the "prompt" component exploding after about 10^8 years and the "tardy" one, exploding after a few Gyrs. If this is the case, it is reasonable to expect that SNe exploding soon after the star formation episode have a level of dust extinction much higher than "tardy" SNe and optical searches could be severely biased against certain SN types.

On the other side, the accurate determination of the SN rate in different galaxy types would allow us to quantitatively address many important astrophysical issues, among which we mention the following.

(i) The ratio between the rate of CC SNe and standard indicators of the current star-formation rate (SFR), *e.g.* Hα luminosity, radio emission and UV luminosity, is essentially dependent on the mass range of the CC SN progenitors and on the IMF parameters. Studying the systematic behaviour of this ratio with galaxy type will yield important clues on the IMF variations (if any) among galaxies. These results will impact on the derivation of the cosmic SFR from the cosmic CC SN rate, which are based on this same ratio.

(ii) Due to the wide distribution of their progenitor's lifetime, the rate of Type Ia SNe in a galaxy results from the convolution of the SFR and the distribution function of the delay times over the whole galaxy lifetime. If the distribution function of the delay times is peaked at short delays, relatively young galaxies are more efficient Type Ia SN producers, which results in a correlation between the corresponding rate per unit mass and the parent galaxy colour, as is observed (*e.g.* Mannucci *et al.* 2005a). The slope of the correlation function, though, depends on the shape of the distribution function of the delay times, as shown by Greggio (2005). Figure 4 shows an example of the expected correlation for a variety of models for Type Ia SN progenitors compared to the current observational data. The derivation of accurate Type Ia SN rates in various galaxy types will allow us to better constrain the progenitor's models.

The need for a SN search in nearby clusters with VISTA: To measure an accurate estimate of the SN rate the obvious solution is a survey in the near infra-red (NIR) where absorption is strongly reduced. The wide field capability and sensitivity of Vista make it the ideal instrument to carry out a SN search in the NIR. Vista opens up a new window for discovering low redshift highly extinguished SNe with a reliable signal-to-noise (S/N). To maximise the SN detection rate, the survey will target a number of low redshift ($0.015 \leq z \leq 0.03$) galaxy clusters, the redshift range being a trade-off between the area covered by the cluster and the SN detection limit at that redshift (see section 4). Our goal is to collect a sample of ~ 50 events. Actually, our prediction for the number of events to be discovered is accurate (at best) within a factor two since this is exactly what we want to measure.

A reliable measurement of the extinction bias for current SN rates will have much wider interest than purely among SN specialists. It will give more solid grounds for the link between stellar evolution, SN progenitor scenarios and galaxy chemical evolution and for the use of CC SN rate to measure the star formation history in the universe. Accurate prediction of the number of SN events expected in the local Universe are also required by the very exciting experiments aimed to detect neutrinos and/or gravitational wave from such events.

Supernovae exploding inside dusty regions could dominate, even by a large amount, the number of CC events in the Universe, as most of the star-forming activity is hidden by dust. Events detected in the NIR can be used to study the properties of the SNe in dusty galaxies, and to obtain a complete estimate of the total SN rate at high redshift now under study. For instance, Mannucci *et al.* (2003) monitored a sample of starburst galaxies in K band and found that, in these dusty environments, the SN rate is a factor of 4 larger than expected from optical searches, confirming that the extinction correction can be very high for such environments.

A better understanding of the bias due to extinction is crucial also for high-z SN searches where, at the moment, IR searches are not viable because of the extremely faint magnitude limit required for the detection (K$\simeq 24-25$ mag for $z = 0.8 - 1$). Indeed, the effect of extinction have to be more severe in high redshift searches simply because optical searches probe shorter wavelengths in the galaxy rest frame.
Finally, by studying heavily reddened SNe, we expect to gain more confidence on the dust properties and extinction correction which is currently one of the most severe limitation for the calibration of type Ia SNe and their use as cosmological yardstick (*e.g.* de la Rosa *et al.* 2006).

Complementary science drivers: NIR imaging of nearby galaxy clusters

The study of clusters of galaxies, the largest and most massive collapsed systems in the Universe, is crucial

to understand the formation of cosmological structures and galaxy evolution. In particular, the comparison of cluster contents at low and high redshifts is a useful tool to constraint galaxy formation scenarios. Nowdays, a major effort is devoted to the observation of medium and high redshift clusters both with HST and large ground based telescopes (*e.g.* Giavalisco *et al.* 2004, Daddi *et al.* 2005). This has to be matched by detailed observations of a complete sample of nearby galaxy clusters which have can now be obtained thanks to the development, first in the optical and more recently in the NIR, of wide field, imaging cameras with mosaic digital detectors. As an example, we recall the WINGS project (Fasano *et al.* 2006) which is using different instruments (WFI@MPG of ESO, WFC@INT and WFCAM@UKIRT) to image from optical to NIR a sample of 77 clusters at redshift $0.04 < z < 0.07$. The redshift range was choosen to guarantee the sampling of a large volume given the field of view of available instrumentations. While it is emphasised that both optical and NIR data are required, it has been stressed that the NIR ones are much better tracers of the stellar mass of galaxies (Kodama and Bower 2003; Balogh et al. 2001) since they are less affected by recent star formation and internal and Galactic absorption.
The new generation of panoramic detectors which will soon come in operation will have a factor ~ 4 larger field of view both in the optical (eg. ΩCAM@VST) and in the NIR (VISTA), and can allow to survey a fair sample of clusters at shorter distances ($0.01 < z < 0.03$) with similar efficency and with the advantage of a much better spatial resolution. Indeed, with the proposed strategy for a SN search with VISTA, we will produce very deep J,K imaging of a sample of nearby clusters. Among the most interesting scientific issues for which this data, in combination also with optical monitoring, can be useful are (see *e.g.* Fasano *et al.* 2006; Daddi *et al.* 2004; La Barbera *et al.* 2003 and references therein):

(i) Investigate how the galaxy morphology, current star formation and star formation history vary as a function of the galaxy mass, and how all these properties depend on local galaxy density and global properties of the cluster. K-band data will add a fundamental new dimension to the investigation of nearby clusters, allowing also a more meaningful and straightforward comparison with the theoretical expectations of galaxy formation models for the growth of cosmic structures.
(ii) Measure the NIR galaxy luminosity functions which is relevant for the following issues: a) the LF upturn predicted by CDM theories and observed in the Coma cluster at $M_R \sim$-16 (Mobasher and Trentham, 1998); b) the global star formation efficiency and the ICM to stellar mass ratio as a function of the cluster type; c) the total K-band luminosity of clusters as an estimator of their halo mass (Lin *et al.* , 2003); d) the optical/NIR colors of background galaxies to constrain the intergalactic dust content across the clusters.
(iii) Measure structural properties of cluster galaxies. Since the NIR light distribution traces the underlying stellar mass, in principle the structural parameters of galaxies (Sersic's index n, R_e, R_{Disk}, etc..) should be much better defined in the NIR than in the optical wavebands.

We note that the current plans for extra-galactic public surveys with VISTA seems to adopt two alternative strategies: either they are aiming to shallow, very wide area imaging for studying large volume of the local Universe or instead to very deep, small area surveys to study high redshift galaxies. Our data may allow to explore a different region of the parameter space. In particular we will be able to probe the faint end of the K luminosity down to dwarf cluster galaxies. As a reference for clusters at z=0.02, we expect to be able to detected on the deep stacked images galaxies down to absolute magnitude $K \sim -13$.

While we are ready to discuss the list of targets and the survey depth with any group interested in exploiting the stacked images, for the purpose of the current proposal we decided to emphasise the goal and strategy of a SN search which appears to set the observational constraints. Finally we remark that this observational strategy which allow both the detection of transients and deep imaging of selected fields, has proved to be very effective in some of the most successful modern surveys, eg. GOODS at HST and the LEGACY Survey at the CFHT.

2.2 Immediate objective:

The aim of the survey is twofold:
1 - to perform a SN search in nearby ($0.015 \leq z \leq 0.030$) galaxy clusters and measure the extinction bias;
2 - to provide deep J, K imaging of $\sim 30 - 40$ nearby galaxy clusters.

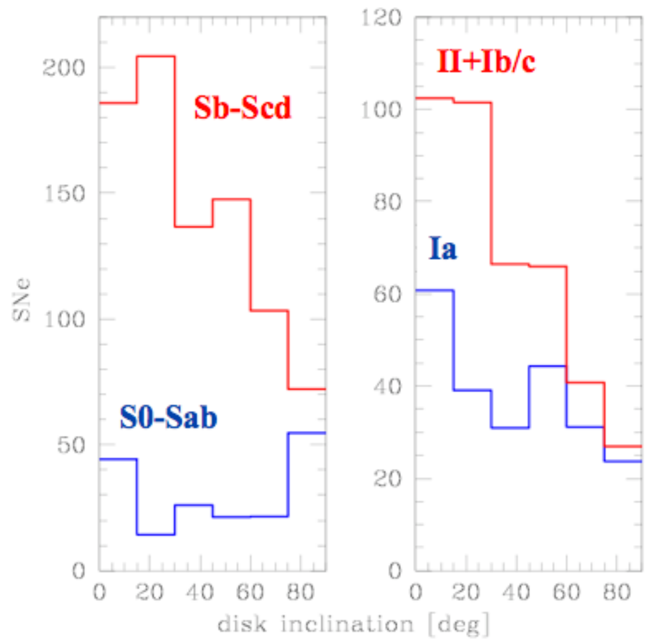

Figure 1: SN counts in spiral galaxies of different inclinations (0 deg is for face-on galaxies) normalised to the fraction of galaxies in each bin of inclination as given in the RC3. In the left panel we show separately early and late type spirals, whereas in the right panel we distinguish core collapse (II+Ib/c) from thermonuclear (Ia) Supernovae. Only the SNe discovered after 1998 have been included.

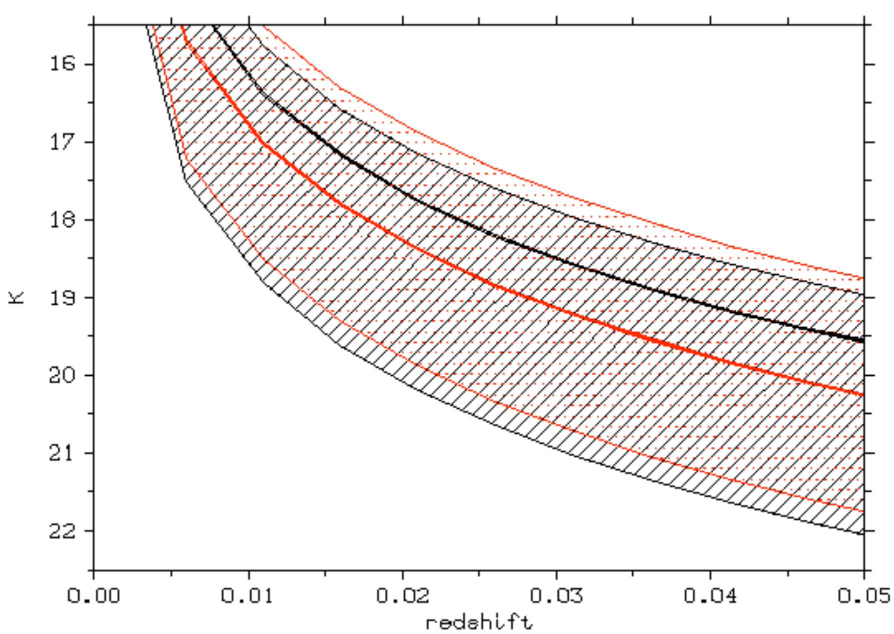

Figure 2: K-band apparent magnitude of Type Ia SN (black) and CC SN (red) with $A_V = 10$ mag of extinction ($A_K \simeq 1$ mag) as a function of redshift. The thick solid lines corresponds to the SN maximum light while the shaded regions show the expected spread due to the intrinsic diversity among each SN category.

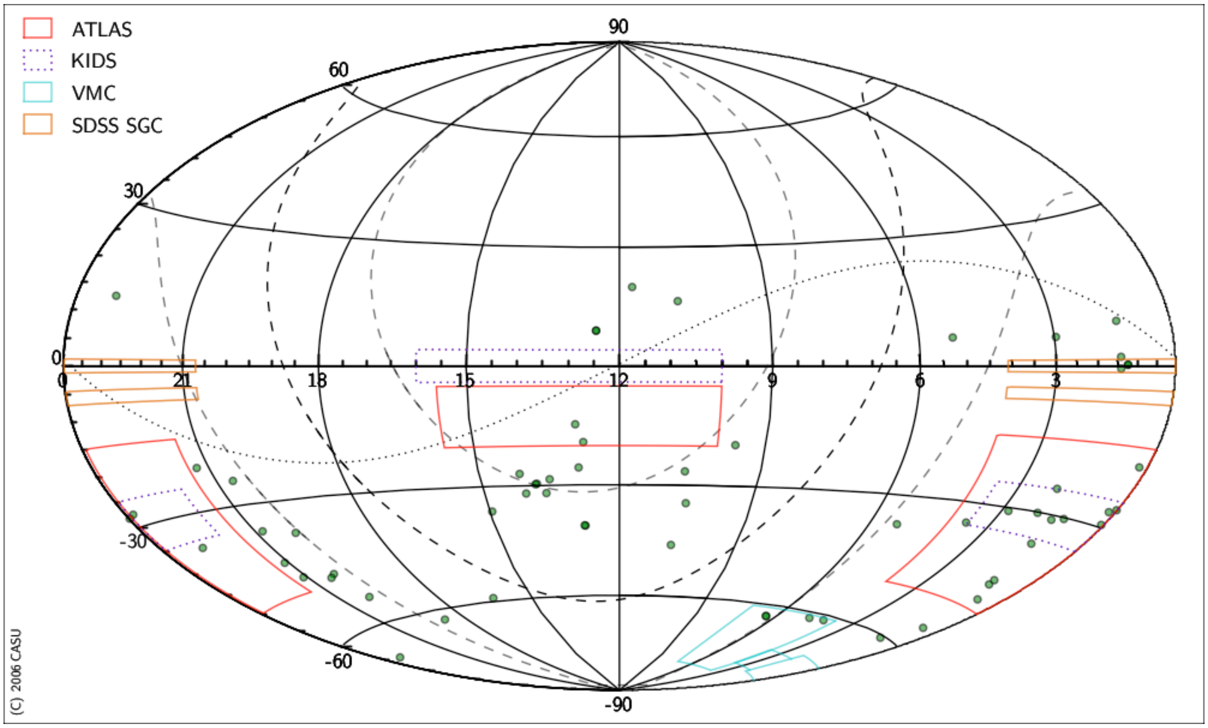

Figure 3: A sample of 64 Abell clusters (solid green dots) with $z \leq 0.03$ and $-90 \leq \delta \leq +20$. The outlined regions show the areas that would be covered by other surveys: VST-ATLAS (*ugriz*), KIDS (optical), Vista Magellanic Cloud (VMC) survey and SDSS South Galactic Cap (SGC).

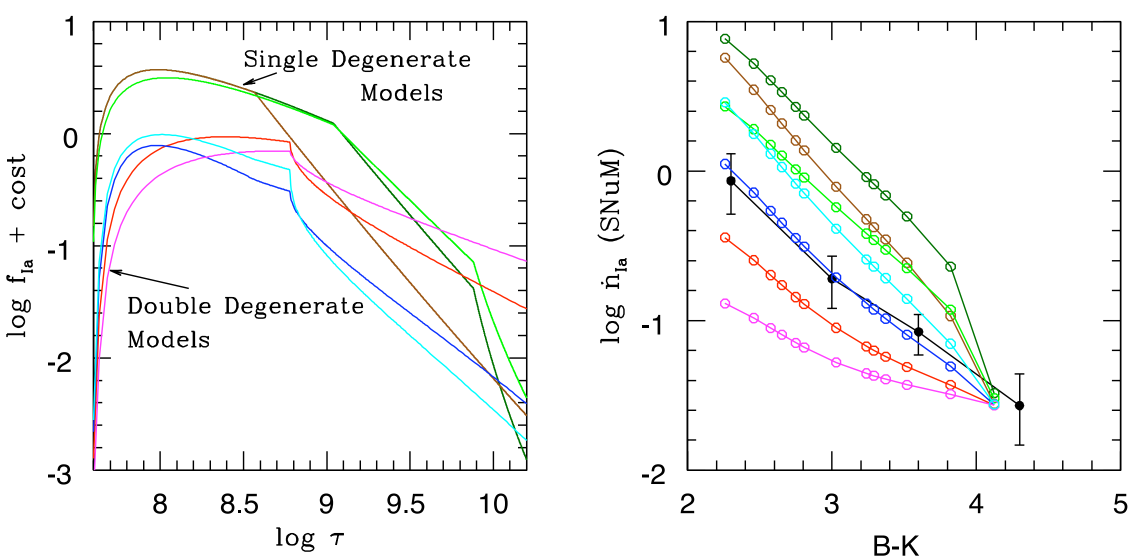

Figure 4: The distribution function of the delay times as predicted for various models of Type Ia SN progenitors (left panel), and the relative predictions for the correlation between the specific Type Ia SN rate and the parent galaxy color (right panel), with the same color encoding. The black dots in the right hand panel show the observed specific Type Ia SN rate (Mannucci *et al.* 2005) in SNUM. The theoretical specific Type Ia SN rate has be normalised to reproduce the observations of the reddest galaxies.

3 Are there ongoing or planned similar surveys? How will the proposed survey differ from those? (1 page max)

There are about a dozen of ongoing surveys, or in act to be operated (see *e.g.* "The Transient Universe Workshop", Kavli Institute for Theoretical Physics, Santa Barbara 13-14 March, 2006, eds. Bildsten, Fryer and Kulkarni), seeking for transients objects (which include SNe). Most of them are in the optical, a few ones in the radio and one in the UV (from satellite). In any case, to our knowledge, there are not ongoing NIR SN searches. This may sound like a lack of interest in carring out a SN search in the NIR, but the main reason for that is purely technological. SNe are rare events: to find them one can either monitor a wide area or go very deep in a small region (to gain in terms of volume sampled). Due to the intrinsic faintness of SNe at NIR wavelengths, going very deep in the NIR is extremely demanding in terms of observing time which, coupled with the requirement of frequent and prolonged monitoring, makes this possibility quite hard to pursue. On the other hand, before WFCAM@UKIRT and now VIRCAM@VISTA, the typical field of view of NIR imagers was limited to a few arcminutes hence ruling out the possibility to monitor large areas effectively.

We are not currently aware of any other survey aimed at providing deep J and K imaging of nearby galaxy clusters in the redshift range covered by our survey ($0.015 \leq z \leq 0.030$). However, a number of other surveys will provide optical and (shallow) NIR coverage of wide areas of the Southern hemisphere (*e.g.* VST ATLAS, SDSS, the proposed VISTA Hemisphere survey etc.) . Optical data is indeed an important complement to the NIR coverage provided by the survey we are proposing, in particular for what concern the study of galaxy clusters (see Sec. 2.1). If necessary, additional optical coverage may be planned with VST. As a reference, we show in Figure 3 the area covered by some of the future surveys and a sample of possible Abell clusters that our survey may observe (see Sec. 4).

4 Observing strategy: (1 page max)

For each period, we plan to monitor 20 nearby Abell clusters ($0.015 \leq z \leq 0.030$) in two bands, J and K, at similar depth, with a frequency of 1 visit/month for three years. We will fill the detector gaps by mean of standard 6-pawprint dithering pattern. This strategy will simplify the comparison with data obtained in different bands and is most convenient for the study of the galaxy in clusters.

The SN search will be carried out in the K band, where the effects caused by extinction are minimised ($A_V = 10$ mag corresponds to $A_K \simeq 1$ mag). However, at each epoch it will be crucial to obtain also a J band exposure because, using the $J - K$ colour, it will be possible to estimate the amount of extinction the putative SN is suffering from and, therefore, trigger the spectroscopic followup accordingly (see Sec. 7). In addition to that, the $J - K$ colour will provide a useful way to probe the galaxy membership to the cluster ($J - K \simeq 0.7 - 0.8$), thus reducing the contamination from background galaxies ($J - K > 1$).

5 Estimated observing time:

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P79	190	18h	any	0.8–1.0	clear
P80	190	6h	any	0.8–1.0	clear
P81	190	18h	any	0.8–1.0	clear
P82	190	6h	any	0.8–1.0	clear
P83	190	18h	any	0.8–1.0	clear
P84	190	6h	any	0.8–1.0	clear

5.1 Time justification: (1 page max)

Total time request: For the SN search part of the survey, we want to be able to detect highly extinguished CC SNe ($A_V \simeq 10$ mag) in the K-band up to $\sim 1 - 1.5$ months after maximum light. To obtain a reasonable sampling of the control time (amount of time during which a SN with these properties will be detectable by the survey) we need one observation (epoch) every month for each cluster. Using the templates from Mattila & Meikle (2001) we derived the following estimates for the magnitude limit required to allow the detection of a typical CC SN with $A_V = 10$ mag of absorption at maximum light, m_K^{max}, and 1.5 months after, $m_K^{1.5}$, in three redshift bins:

- $z = 0.015$ – At this redshift, $m_K^{max} \simeq 16.5$ and $m_K^{1.5} \simeq 17.5$. To reach $m_K = 17.5$ with a S/N$\sim$ 15, it will require a total exposure time per tile of 540 sec (878 sec with the overheads).
- $z = 0.020$ – At this redshift, $m_K^{max} \simeq 17.0$ and $m_K^{1.5} \simeq 18.0$. To reach $m_K = 18.0$ with a S/N$\sim$ 15, it will require a total exposure time per tile of 1080 sec (1418 sec with the overheads).
- $z = 0.030$ – At this redshift, $m_K^{max} \simeq 18.0$ and $m_K^{1.5} \simeq 19.0$. To reach $m_K = 19.0$ with a S/N$\sim$ 13.5, it will require a total exposure time per tile of 5400 sec (6674 sec with the overheads).

Assuming 20 clusters/period evenly distributed in redshift, we will need $\sim$ 190 hours/period (including overheads) to obtain 6 epochs per cluster (1 per month) in both J and K. All the estimates above made use of the ETC v. 1.1. The cluster sample could be selected among rich, nearby Abell galaxy clusters. We stress here that the specific list of clusters that the survey will target can be decided at a later stage and, provided that the total number of cluster/period and redshift range are those given above, we are open to discuss specific requests from other interested groups.

This strategy will give us an expected SN discovery rate of about 10-15 SNe per year. This estimate has been derived from the luminosity and galaxy mixture of the average cluster. An empirical confirmation of these expected numbers comes also from the results of the Australian Abell clusters Supernova survey carried out in the optical (Germany *et al.* 2004). This survey monitored $\sim$ 70 Abell clusters over three years discovering $\sim$ 50 SNe, half of which Type Ia. The expected SN discovery rate we quoted was derived considering that between 1/2 and 2/3 of the SNe were lost because of the extinction and that our cluster sample will be smaller (20 clusters/period instead of $\sim$ 35).

Observing conditions: We require the observations to be taken when the seeing in the K-band is not worse than 1.0 arcsec. This is needed to maximise the reliability of the SN candidate detection procedure, particularly in the innermost regions of the host galaxies. Although photometric conditions are not an issue, we require that, for each cluster, one epoch is taken under photometric conditions (both in J and K) to allow a reliable (relative) photometric calibration of the other epochs. In the NIR the Moon is not a source of concern as much as in the optical, observations can therefore be taken with any Moon phase, provided that, during bright time, the angular separation between the Moon and the observed field is not smaller than $\sim 60°$. Our experience with the UKIDSS survey with WFCAM at the UKIRT telescope is indeed that this approach will minimise problems that might be caused by a) illuminations gradients during the image subtraction of different epochs, b) ghosts caused by internal/dome reflections.

6 Data management plan: (3 pages max)

6.1 Team members:

Name	Function	Affiliation	Country
M. Riello	PI, Survey definition SN detection/rates	University of Cambridge	UK
E. Cappellaro	OB Preparation SN detection/rates	INAF Padova	I
M.T. Botticella	SN detection/rates	INAF Teramo, ESO Garching	I
S. Smartt	Survey definition SN detection/rates	The Queen's University of Belfast	UK
S. Mattila	Survey definition SN detection/rates	The Queen's University of Belfast	UK
F. Mannucci	SN Candidate Photometry	INAF-IRA, sezione di Firenze	I
M. Della Valle	SN Candidate Photometry	INAF Arcetri	I
E. Di Carlo	SN Candidate Photometry	INAF Teramo	I
S. Benetti	Spec. Classification	INAF Padova	I
M. Turatto	Spec. Classification	INAF Padova	I
A. Pastorello	Spec. Classification Manager	Max Planck Institute, Garching	D
S. Valenti	Spec. Classification	ESO Garching	
F. Patat	OB preparation	ESO Garching	
E. Gonzales-Solares	Stacks & catalogues	University of Cambridge	UK
L. Greggio	Modelling	INAF Padova	I
A. Tornambè	Modelling	INAF Teramo	I
L. Zampieri	Modelling	INAF Padova	I
D. Bettoni	Galaxy cluster analysis	INAF Padova	I
G. Fasano	Galaxy cluster analysis	INAF Padova	I
B. Poggianti	Galaxy cluster analysis	INAF Padova	I
		VDFS tasks	
CASU (VDFS) team	Pipeline processing	University of Cambridge	UK
CASU (VDFS) team	Data Quality Control-I	University of Cambridge	UK
J. Emerson	VDFS Coordinator	Queen Mary University of London	UK
WFAU (VDFS) team	Science Archive	University of Edinburgh	UK
WFAU (VDFS) team	Data Quality Control-II	University of Edinburgh	UK
N. Walton	VO Standards	University of Cambridge	UK

6.2 Detailed responsibilities of the team:

We will use the VISTA Data Flow System (VDFS; Emerson *et al.* 2004, Irwin *et al.* 2004, Hambly *et al.* 2004) for all aspects of data management, including: pipeline processing and management; delivery of agreed data products to the ESO Science Archive; production of a purpose-built IVOA compliant science archive with advanced data-mining services; enhanced data products including federation of VISTA survey products with SDSS products. Standardised agreed data products produced by VDFS will be delivered to ESO, with a copy remaining in the Science Archive in Edinburgh and in Cambridge where the Data Quality Control and Candidate Detection database is hosted.
The VDFS is a collaboration between the UK Wide Field Astronomy Units at Edinburgh (WFAU) and Cambridge (CASU) coordinated by the VISTA PI (QMUL) and funded for VISTA by PPARC. The VDFS is a working systems-engineered system that is already being successfully employed for the UKIRT WFCAM sur-

veys as a test bed for the VISTA infrared surveys, and which is sufficiently flexible as to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system.
The survey definition team will be led by the PI (Riello) and include members of the survey team from Belfast (Smartt, Mattila), ESO (Botticella, Patat) and Padova (Cappellaro). They are responsible for generating the OBs using the Survey Area Definition Tool and P2PP and for revising these and monitoring the survey progress using a local (Cambridge) Data Quality Control database as necessary. The Spectroscopic Followup Alert Group will be led by Pastorello and include members from Padova (Benetti, Turatto) and ESO (Valenti). They are responsible for generating the OBs for the followup and for keeping the public SN candidate web pages up to date with the results from the followup runs (classification, spectra, etc.). The SN detection team will be led by the PI (Riello) and include members of the survey team from ESO (Botticella), Belfast (Smartt, Mattila) and Padova (Cappellaro).
Experience shows that the a full scientific validation is only possible when people start trying to do science with the data. Thus we will also have a number of collaborators from Padova, Firenze, Belfast and ESO carrying out the first checks on the pipeline reduced data to assess the overall data quality constraints and that the strategy is actually reaching the desired limits (both as magnitude limit and SN detection limit per tile).

6.3 Data reduction plan:

The data reduction will be using the VDFS, operated by the VDFS team, and augmented by Riello (CASU), Botticella and Mattila, especially for what concern the SN candidate detection. The deep stacked images will be produced by Gonzales-Solares (CASU) and Riello (CASU) as part of their VDFS duties.

6.3.1 Pipeline processing

The Cambridge Astronomy Survey Unit (CASU) are responsible for the VDFS pipeline processing component which has been designed for VISTA and scientifically verified by processing wide field mosaic imaging data from UKIRT's NIR mosaic camera WFCAM and is now routinely being used to process data from the WFCAM at a rate of up to 250GB/night. It has also been used to process ESO ISAAC data *e.g.* the FIRES survey data and a range of CCD mosaic cameras.
The pipeline includes the following processing steps but is a modular design so that extra steps are easily added. All the steps will have been tested on a range of input VISTA datasets. and include: instrumental signature removal – bias, non-linearity, dark, flat, fringe, cross-talk; sky background tracking and removal during image stacking – possible need to also remove other 2D background variations from imperfect multi-sector operation of detectors; define and produce a strategy for dealing with image persistence from preceding exposures; combine frames if part of an observed dither sequence or tile pattern; consistent internal photometric calibration to put observations on an approximately uniform system; basic catalogue generation including astrometric, photometric, shape and Data Quality Control (DQC) information; final astrometric calibration from the catalogue with an appropriate and World Coordinate System (WCS) in all FITS headers; basic photometric calibration from catalogue using suitable pre-selected standard areas covering entire field-of-view to monitor and control systematics; each frame and catalogue supplied with provisional calibration information and overall morphological classification embedded in FITS files; propagation of error arrays and use of confidence maps; realistic errors on selected derived parameters; nightly extinction measurements in relevant passbands; pipeline software version control – version used recorded in FITS header; processing history including calibration files recorded in FITS header.

6.3.2 Supernova candidate detection pipeline

SN candidate detection will be performed by searching the difference of images obtained at different epochs. This technique has indeed proven very successful in a number of SN search programs (see *e.g.* Cappellaro *et al.* 2005). A dedicated candidate detection pipeline is already existing from our previous project with the ESO/MPG WFI at the 2.2m telescope and, given the similar mosaic structure of VIRCAM, it can be easily

adapted to cope with the new detector layout. The most CPU-intensive part of the processing is of course represented by the image subtraction step. We have already used the pipeline to reduce $\sim$ 10 WFI fields (8 2K$\times$4K pixels detectors) in $\sim$ 1 day on a dedicated single processor machine. The number of pixels involved in a subtraction of two Vista images is exactly the same as for WFI, we are therefore pretty confident that the SN candidate detection pipeline will be able to cope with the expected data volume.
After producing the image differences, we will use the VDFS software to produce the catalogues which will then be fed into our SN candidate detection engine. This will use a number of measured parameters in the two epochs and the difference image to produce a list of SN candidates in decreasing order of likelihood. The candidate list will then be ingested into the candidate database both to make them public and to allow all the team members to contribute to the followup candidate selection process remotely. A simplified version of this tool has already been used during our previous SN search campaign (see Cappellaro *et al.* 2005). We stress that there is no need here for dedicated manpower to produce a completely working version because the effort required is quite modest given that the PI, as member of CASU, will have to develop it anyway as part of his personal VDFS tasks.
Our experience is that the search will be sensitive not only to SN events but also to other variable sources like, *e.g.* Active Galactic Nuclei (AGN), Quasars, variable stars and asteroids. To reduce the "noise" due to these spurious sources, we can exploit the variability history (*i.e.* light curves) of the each field, as recorded in our database, to aid the candidate selection process.

6.3.3 Science archiving and survey information publishing

The concept of the science archive (SA, Hambly *et al.* 2004 and references therein) is key to successful exploitation of wide field imaging survey datasets. The SA ingests the products of pipeline processing (instrumentally corrected images, derived source catalogues, and all associated metadata) into a database and then goes on to curate them to produce enhanced database-driven product. For more information about the SA please refer to Hambly *et al.* (2004).
Although pipeline processed data will be transferred and ingested into the SA, we will set up our own SN candidate database to feed the public web site where the newly detected SN candidates will be published. The database will also provide the back-end of the candidate detection pipeline, which is not part of the VDFS (see section 6.3.2). Our group has already both the knowledge and the expertise to follow this approach (see *e.g.* Cappellaro *et al.* 2005 and Riello 2003). We indeed feel it would be easier, quicker and more reliable to have the SN candidate detection and management part administered internally by the survey team instead of demanding its implementation and operation to a third party. Moreover the overhead required by data transferring to Edinburgh, database ingestion and final release of the data products by the SA is absolutely unacceptable because of the need for a prompt response to trigger the spectroscopic followup. This notwithstanding, the standard VDFS products will be eventually available from the SA anyway, therefore there will not be any problem for the community to benefit from the features offered by the SA.

The SN candidate lists will be published and updated on a dedicated survey web site complemented by: candidate coordinates, finding charts, preliminary photometric measurements, classification and spectrum (right after the spectroscopic followup). Confirmed SNe will be published by mean of IAU Circulars immediately after the spectroscopic followup and the spectra will be made available on the survey web site. This will ensures that the whole SN community will be able to select the most interesting objects and plan the subsequent spectroscopic and photometric followup. Before the beginning of each observing period, detailed information about the target list will be made available on the survey website. The flexibility of the SN search component of the proposed survey will indeed make it possible for interested parts to contact the survey team to discuss possible changes to the survey target list for the following semester (*e.g.* different target priorities).

6.4 Expected data products:

There will be two main types of data products: those produce by the standard VDFS processing, and those produced by the SN candidate detection pipeline. In particular:

- Instrumentally corrected frames (pawprints, tiles etc) along with header descriptors propagated from the instrument and processing steps (science frames and calibration frames). Statistical confidence maps for each frame [VDFS]
- Stacked data for dithered observations [VDFS]
- Derived catalogues (source detections from science frames with standard isophotal parameters, model profile fitted parameters, image classification, etc.) [VDFS]
- Data Quality Control database [VDFS]
- Database-driven image products (stacks, mosaics, etc.) [VDFS]
- Realtime SN candidates and variable sources list (coordinates, finding charts, photometry)
- Confirmed SN candidates (classification, spectra, IAU reference)
- Deep J,K stacks and catalogues.

6.5 General schedule of the project:

Detection of candidates will be an continuous process during the entire lifetime of the survey. When completed, the survey will produce deep (up to $\sim$ 18 hrs) stacked images, confidence maps and object catalogues for each monitored galaxy cluster. However, we believe that useful science may be carried out also using intermediate depth data, we therefore plan to schedule incremental releases of stacked tiles (plus catalogues) within three months after the end of each period. The incremental release approach will make it possible to assess the scientific quality of the galaxy cluster data allowing the interested parts to plan independent followup programs, *e.g.* to cover other passbands or to obtain spectroscopic information, and to tune the observing strategy for the remaining periods.

7 Envisaged follow-up: (1 page max)

Spectroscopic classification for all SN candidates is required, both to confirm their nature and to allow the rate estimate within the two distinct classes of thermonuclear and core-collapse events. On the other hand, J and K photometry will provide useful information about the extinction suffered by the targets. Therefore, depending on the amount of reddening and the apparent magnitude of the candidates (which varies according to the SN class) different instrumental configurations are required for the follow-up of newly discovered objects.
In order to estimate the required telescope time, we have taken the most extreme case of a normal Type II at $z = 0.03$, heavily extinguished ($A_V = 10$, *i.e.* $A_K \simeq 1$). Under these circumstances, the SN will reach a typical K band magnitude $\sim$ 18.5 during the plateau phase. Therefore, such an object can be spectroscopically classified only with a 8m-class telescope, making VLT+ISAAC the ideal facility for this purpose. In order to obtain a S/N $\sim$ 5 at the continuum level, which our experience shows is sufficient to clasify the candidates on the basis of the broad emission features often accompanied by P-Cyg profiles, we need a total exposure time of 2 hours with a low resolution configuration. Target of Opportunity (ToO) observations are required to carry out in an effective way the candidates classification. Given the number of targets expected, a total exposure time of 10 hours/period with ISAAC is needed. This will allow the classification of about 5 highly reddened candidates per period.
For brighter (SNe Ia, Hypernovae, SNe IIn...) or less-reddened events a 4m-class telescope is perfectly suitable. NTT+SOFI is the ideal facility for the classification of moderately extinguished objects, while NTT+EMMI or E3.6+EFOSC2 will be used for low-extinction candidates. A moderately reddened ($A_V \simeq 4$) object at $z \sim 0.02$ requires an exposure time of $\sim$ 40 min with SOFI in order to have a $S/N \sim 50$, while an unreddened SN at the same distance needs the same exposure time to get comparable S/N with EMMI (or EFOSC2). In order to obtain good S/N spectra of 4-5 candidates in the range 900-2500nm, we require 5 hours per period with SOFI, and 5 hours with EMMI (or EFOSC2).

Therefore, a total of 20 hours of ToO time will be needed to classify spectroscopically all detected candidates. It is worth noting that besides providing the SN type, a fundamental piece of information in the framework of rate estimates, the availability of near-IR spectra and light curves are indeed valuable, since in this spectral range SNe are nowadays still poorly sampled. Therefore our survey will lead to a significant improvement in understanding the still unclear behavior of these objects in the NIR domain and the physical properties of SNe exploding in dusty environments.

8 Other remarks, if any: (1 page max)

To permit spectroscopic follow-up, it is crucial that the survey images are made available to the proponents as early as possible for immediate processing ($< 1-2$ weeks). A possible alternative is a detection pipeline running on a dedicated computer at Paranal.

References

Abell G. O., Corwin H. G. & Olowin R. P., 1989, ApJS 70, 1
Balogh M. L. *et al.* 2001, ApJ 557, 117
Barris B. J & Tonry J. L., 2006, ApJ 637, 427
Cappellaro E. *et al.* , 1999, A&A 351, 459
Cappellaro E. *et al.* , 2005, A&A, 430, 83
Daddi E. *et al.* 2004, ApJ 600, 127
Daddi E. *et al.* 2005, ApJ 626, 680
Giavalisco *et al.* 2004 ApJ 600, L93
Dahlen T. *et al.* , 2004, ApJ 613, 189
de la Rosa E. *et al.* , 2006, MNRAS in press
Emerson J.P. *et al.* , 2004 "VISTA data flow system: overview", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 401.
Fasano G. *et al.* , 2006, A&A 445, 805
Germany L. *et al.* , 2004, A&A 415, 863
Greggio L., 2005, A&A 441, 1055
Hambly N.C. *et al.* , 2004 "VISTA data flow system: survey access and curation; the WFCAM science archive", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 423.
Irwin M.J. *et al.* , 2004 "VISTA data flow system: pipeline processing from WFCAM and VISTA", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, voll. 5493, 411.
Kodama T. & Bower R., 2003, MNRAS 346, 1
La Barbera F. *et al.* , 2003, A&A 409, 21
Lin Y., Mohr J. J. & Stanford S. A., 2003, ApJ 591, 749
Madau P., Della Valle M. & Panagia, N., 1998, MNRAS 297, L17
Mannucci F. *et al.* 2003, A&A 401, 519
Mannucci F. *et al.* 2005a, A&A 433, 807
Mannucci F., Della Valle M. & Panagia N., 2005b, MNRAS (in press) astro-ph/0510315
Mattila S. & Meikle P., 2001, MNRAS 324, 325
Mattila S., Meikle P. & Greimel R., 2004, NewAR 48, 595
Mobasher B. & Trentham N. 1998, MNRAS 293, 315
Riello M. 2003, MmSAI, 74, 984
Strolger L. *et al.* , 2004, ApJ 613, 200