VST: VLT Survey Telescope

M. ARNABOLDI[1], M. CAPACCIOLI[1, 2], D. MANCINI[1], P. RAFANELLI[3], R. SCARAMELLA[4], G. SEDMAK[5], G.P. VETTOLANI[6]

[1]Osservatorio Astronomico di Capodimonte, Napoli, Italy
[2]Dipartimento di Scienze Fisiche, Università Federico II, Napoli, Italy
[3]Dipartimento di Astronomia, Università di Padova, Italy
[4]Osservatorio Astronomico di Roma, Monteporzio Catone, Italy
[5]Dipartimento di Astronomia, Università di Trieste, Trieste, Italy
[6]Istituto di Radioastronomia, CNR, Bologna, Italy

1. Introduction: VST Scientific Framework

The VLT era is rapidly approaching: the first instruments, ISAAC and FORS at UT1, will be available by the year 1999. Indeed, the beginning of the new millennium will witness fierce competition among quite a few 8-m telescopes, operated by different groups. As a consequence, there is a strong need to prepare, in a timely manner, suitable target-lists for the VLT, in order for it to play the leading role in ground-based optical and IR astronomy in the next decade. Preparation is one of the keys to success for the VLT observations.

The VLT will work at flux levels for which no whole-sky surveys are available, and most of the currently submitted science cases (SC) will not be feasible without major preparatory work (Renzini & Leibundgut, 1997, *The Messenger* 87, 21; Da Costa et al., 1997, *The Messenger* 91, 49). The SC target selections are based on extensions of current data sets. Only a few spectroscopic or high imaging projects at the VLT will plan to build their own catalogues directly from VLT imaging data. In conclusion, the exploitation of the VLT requires catalogues of objects and supporting observations obtained at other – smaller – telescopes. As an example, multi-object spectroscopy depends on very accurate target positions which must be provided in advance of the actual VLT observations (to set up slitlet arrays for FORS or provide masks for VIMOS and NIRMOS).

The need to find faint or rare but interesting objects to study with the VLT in statistically significant quantities has urged ESO to start the multi-band ESO imaging survey (EIS; Renzini & Da Costa, 1997, *The Messenger* 87, 23), and many other observatories are building up large field-of-view instruments (e.g. the SLOAN project). However, EIS is meant to supply targets only for the near future, but certainly cannot sustain the needs of the ESO community which will be using the VLT for top-level science during the several years to come.

Over the years, broad- and narrow-band wide-field imaging (WFI) has provided the astronomical community with a wealth of data, which has been of great importance in many different fields in astrophysics and cosmology. WFI with 2-metre-class telescopes has been, up to now, the key instrument to produce statistically-controlled target-samples to be studied both photometrically and spectroscopically with 4-m telescopes. The advent of 8-metre-class telescopes requires extensions of WFI down to much fainter magnitudes which are out of reach of photographic material. Planned CCD WFI surveys (such as the SLOAN DSS) will push the magnitude limit down to R_{AB} = 23, but so far they are restricted to the northern sky only.

The above arguments justify the compelling need for a dedicated medium-size telescope with a wide-field imaging capability in the southern hemisphere. This need motivated the proposal to ESO by the Capodimonte Astronomical Observatory (OAC) at Napoli to build the VST (= VLT Survey Telescope) and place it at Paranal.

The VST is meant to be a highly efficient telescope; it will reach a magnitude limit of $R = 25$ AB mag arcsec^{-2} in 3×10 min exposures over a field of 1 deg^2, with an instrumental resolution of 0.21″. The scope of this facility is to supply complete databases for VLT science, and possibly to produce new science from the WFI data alone. Because of its complementary use to the VLT and for an obvious integration in the VLT operating system, it shall run with the same software and be a fully dedicated instrument for multi-band optical imaging.

The VST may be relevant for a number of topics such as those listed hereafter (the list is by no means complete):

(i) Distant objects: quasars, high-z galaxies, clusters of galaxies, supernovae, lensed objects, absorption systems, weak lensing;

(ii) Nearby galaxies: globular clusters, HII regions, planetary nebulae, novae, emission-line stars;

(iii) The Galaxy: the items from (ii) plus subdwarfs, white and brown dwarfs, metal and very rich/poor stars, and microlensing towards the Galactic bulge for statistics on the presence of earth-like planets;

(iv) Optical identifications: the VST will provide optical identifications of objects found at other wavelengths, such as X-rays, IR, microwave and radio continuum sources.

Once the above galactic and extragalactic targets are identified via the VST, they will require further imaging (at different bands and angular resolution) plus low- and high-resolution multi-object spectroscopy (both in the visual and IR) available at FORS1/2, ISAAC, CONICA, VISIR, UVES, VIRMOS. In particular the VST will constitute an essential tool for the construction of surveys.

Therefore, the strong advantages of the VST project in the VLT era are:

1. a wide-field imaging project fully conceived for and devoted to VLT science. Its task will be to provide the preparatory data for the follow-up observations with VLT;
2. a wavelength range from UV to I with high efficiency in the UV;
3. a minimum of additional optics combined with a high DQE detector;
4. the exploitation of the outstanding photometric and seeing characteristics of the Paranal site;
5. the high efficiency in both calibrations and data reduction in view of the complete dedication of the telescope to imaging with a single instrument.

In this paper we describe the history of the project, and the telescope concept. This project is then compared to existing or planned WFI facilities. For a detailed description of the science case with the VST we refer to the “VST proposal”, available upon request at the OAC.

2. History of the Project

Given the scientific framework and the need for such a facility, the OAC Director, M. Capaccioli, planned to engage the Napoli Observatory in the realisation of

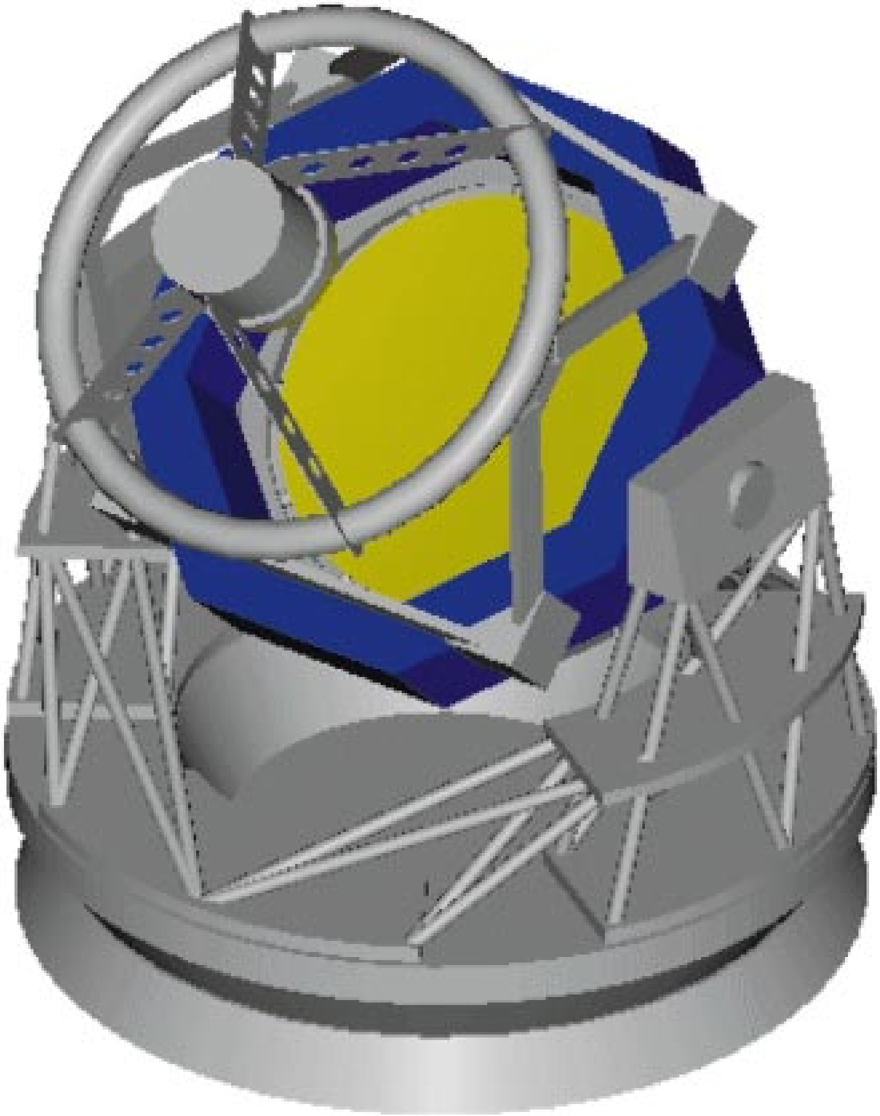

Figure 1: CAD 3-D view of the VLT Survey telescope.

a 2.6-m telescope for wide-field imaging and complementary use to the VLT. For this purpose the Observatory Council decided to allocate 6.5 billion Italian lire of *ad-hoc* funds assigned to OAC by the Ministry of University and Research as part of the programme of developing depressed areas in the south of the country by financing cultural activities and existing centres of excellence in science and technology. This resolution rested also on the consideration that OAC has some background in astronomical instrumentation, given its collaborations with ESO and other European institutions in the VIRMOS project, and its contributions to the TNG, the Italian 3.5-m National telescope, just to name two of its partnerships in international projects. Through its Technology Working Group (TWG) managed by D. Mancini, OAC has also designed and built its first telescope, an alt-azimuthal 1.5-m aperture instrument named TT1 (Toppo Telescope No. 1), which is now waiting for the transportation at Toppo di Castelgrande (Potenza), the former domestic site of the TNG; it should be operational by the end of the current year. Furthermore, science-wise its research staff has a strong interest and a well-established background in surface photometry and wide-field imaging.

In March 1997, the OAC Director appointed a Scientific Steering Committee, chaired by G. Vettolani, to study the case for a 2.6-m WFI telescope, to be proposed to ESO for installation at the Paranal Observatory (Chile). The Committee prepared the proposal with the scientific goals, which were used by D. Mancini and the OAC TWG to develop a preliminary study for the optical, mechanical, and electronic specifications of a 2.6-m telescope with a 1 square degree field-of-view (FOV). The combined scientific and technical proposals were submitted to ESO on June 17, 1997. The project was presented to the Director General of ESO, R. Giacconi, and to the heads of ESO divisions on July 29, 1997. The scientific case and the technical proposal were then revised to incorporate all of the ESO suggestions. It was also agreed to change the project name from the former TT2 (Toppo Telescope No. 2) to VST. During this initial phase of the project, the ESO contact point was S. D'Odorico. The final VST proposal was reviewed by the ESO Scientific and Technical Committee (ESO/STC – 219 document) at the occasion of its 44th Meeting in October 1997. The STC expressed strong support for the project, assigning it a high priority. The VST Memorandum of Understanding between OAC and ESO was submitted to the ESO Council for approval on the 11th–12th of June 1998, and the official kick-off of the project was held during a meeting at ESO on the 24th–25th of June 1998. The OAC will be responsible for the design, construction, and commissioning of the VST, and the OAC will provide up to two astronomers for the support of the VST operation starting in 2000. ESO will be in charge of the design and realisation of the enclosure and its control system plus civil works at the Paranal site and of providing a camera adequate to fulfil the goals of the project.

On March 1998, Zeiss Jena was awarded the realisation of the VST optics; the contract with Zeiss was signed by the end of May and the final optical design agreed by ESO and OAC was forwarded to Zeiss at the end of July. On April the 4th, 1998, ESO issued a call for tender for the realisation of the $16k \times 16k$ CCD camera to be placed at the Cassegrain focus of the VST.

The OAC Council has appointed G. Sedmak, from the University of Trieste, as Project Manager for the realisation phase of the VST and D. Mancini as Deputy Project Manager. The VST Manager on the ESO side will be R.J. Kurz, and the Deputy Manager S. D'Odorico. An Advisory Board will monitor the progress and give inputs to the Project Manager: the Chairman of this Committee is M. Capaccioli, the Co-chairmen are P. Rafanelli and P. Vettolani. The experts are P. Dierickx, K. Freeman, and D. Hamilton. The VST Project Scientist is M. Arnaboldi, and the Chairman for the VST Science Group is R. Scaramella.

3. VST Technical Overview

3.1. The project philosophy

The scientific goals for the VST project can be summarised as follows: a fully dedicated instrument with an excellent image quality on a large FOV, high operational efficiency, high reliability, and compliance with VLT standards. Therefore the project guidelines are:

• Optimisation of the whole system for the global-system cost-optimisation.

• Extended use of finite element analysis, which optimises the structure costs and performances.

• The use of the system just as a survey telescope will make it possible to simplify the overall project during the final design phase.

• The OAC TWG will construct in house part of the telescope subsystems. This will make it possible to achieve a better steady-state mean-time-to-reparation (MTTR), given the knowledge of the system by the TWG team.

3.2. The telescope concept

The VLT Survey Telescope is a 2.6-m telescope, designed for Cassegrain operations, with a corrected FOV diameter of 1.5 degree, to be matched with a 16k × 16k CCD mosaic camera, with a 15 µm pixel. The telescope has an Alt-Az mounting, which allows a high mechanical stiffness and a compact overall structure: a 3-D view is shown in Figure 1. The structure will be an open frame with tubular components in order to increase the stiffness vs. weight ratio and to simplify any installation procedures. The wide-field corrector is designed to cover the whole visual wavelength range, from U to I with an encircled energy of 80% in a 1.7 pixel or better. Following the kick-off meeting at ESO, the corrector design in the VST proposal was revised: the new corrector design foresees the use of two lenses plus a curved dewar window when observing near zenith, and this configuration can be replaced by one lens plus an ADC, when observing in the B to I bands at large zenithal distances. The primary and secondary mirrors will be active and controlled by means of a Shack-Hartman wavefront sensor; the optical scheme of the VST is shown in Figure 2, and Figure 3 shows the encircled energy diagram for the U band in different regions of the focal plane.

The telescope enclosure will be designed in collaboration with ESO. The design takes into account the use of an air-conditioning system to control the temperature of the telescope during the day. The final design of the enclosure will be compliant with a number of nights lost due to wind of about 10% during a year of operation, based on the wind statistics of the Paranal site.

The VST telescope control architecture follows the concepts developed for the VLT by ESO; in doing so, the system coherence is increased, an easier maintenance programme is possible, and the integration into the existing ESO hardware and software environments is ensured. The basic idea is to maximise the use of VLT standards and software, whenever it is possible and convenient.

4. How Does VST Compare with Other WFI Facilities World-wide?

Tables 1–5 provide an exhaustive summary of existing and planned (within a 3-year period) WFI facilities. Table 1 provides a summary of the non-ESO WFI facilities; Table 2 deals with the WFI ESO facilities, and Tables 3 and 4 contain details on planned multi-colour surveys. The last line of Table 3, 4 and 5 reports the values for the VST facility according to the current status of the project.

4.1. Why the Paranal site?

Such a point is crucial in addressing the efficiency of the VST telescope with respect to existing or planned WFI facilities world-wide. The Paranal site has the best uncorrected seeing (0.4″; median seeing 0.65″) in the southern hemisphere and a very high percentage of photometric nights (77%). We can quantify a 35% gain for the percentage of photometric nights, and a 36% gain in the better median seeing (0.65″) of Paranal vs. La Silla (0.87″) which result in an “environmental gain” in efficiency of the Paranal site with respect to La Silla of a factor 2.35. If we consider the “environmental gain” of the Paranal site for the winter season (ideal for the Galactic bulge studies), this becomes a factor 3 from the higher percentage of photometric nights at Paranal during this season. The choice of the Paranal site for the VST will make such a telescope one of the most competitive dedicated WFI facilities in the world, as is clear from the following direct comparison with existing ESO and non-ESO facilities.

4.2 Comparison with non-ESO WFI facilities

From Table 1, in the southern hemisphere, neither existing (UKST, CTIO) nor planned (AAT, GEMINI) WFI facilities can compete with the VST project when we consider scientific programmes aiming at surveying several hundred square de-

TABLE 1. Summary of non-ESO WFI facilities

Name (1)	Aperture (2)	Inst. (3)	Focus (4)	FOV (5)	Mpix (6)	Scale (7)	Year (8)	% (9)	Seeing (10)	Country (11)
NOAO	0.9	16 CCDs	PF	1	67	0.43″	1997	20	1″	USA
ING	2.5	4 CCDs	PF	0.16	16	0.37″	1997	25	0.75″	NL-UK-E
NOAO	4	16 CCDs	PF	0.36	67	0.27″	1997	20	1″	USA
WHT	4	1 CCD	Cass.	0.025	1	0.6″	1997	20	0.75″	NL-UK-E
du Pont	2.5	WFC	Cass.	0.137	4	0.75″	1997	25	0.8″	USA
UH	2.2	8kCCDs	F/10	0.67	67	0.13″	1997	30	0.63	USA
Laval	2.7	CCD	PF	0.5	4	0.6″	1997	100	1″	CAN
Univ.	5.1	CCD	PF				1997	100	1″	CAN
APO	3.5	DSCCD			4	0.141″	1997	20	13	USA
Subaru	8.3	Suprime Cam	PF	0.136	80	0.18″	1999	15	0.6″	Japan
CFHT	3.6	MEGA CAM	Cass.	1	288	0.21″	1999	20	0.6″	France-CAN
Sloan	2.5	30 CCDs	Cass.	9	126	0.4″	2000	100	1″	USA
MMT	6.5	MEGA CAM	Cass.	1	268	0.22″	2000	20	0.8″	USA
Keck II	10	DEIMOS	Nashm.	0.045	134	0.12″		17	0.55″	USA
C.Alto	3.5	WFNIR Omega	PF	0.01	1	0.4″	1997	30	1″	D-E
CTIO	4	4 CCDs	PF	0.25	16	0.4″	1996	15	0.9″	USA-Othr.
UKST	1.2	Plates	Schmidt	43		67″/mm	1997	100	1.6″	UK-AUS
AAT	3.9	CCD	PF	0.02	4	0.367″	1998	30	1.6″	UK-AUS
Gemini	8	CCDs	Cass.	0.56			2000	25	0.25″	UK-USA-CAN-Othr.

Column (1) conventional name of the telescope; Column (2) size of the primary mirror in metre or equivalent diameter in case of multiple telescopes; Column (3) type (CCDs or photographic plates) and name of the instrument for wide-field imaging; Column (4) focus where the instrument is placed; Column (5) FOV in square degree; Column (6) number of pixels in Mpixels; Column (7) scale in arcsec pixel^{-1}; Column (8) expected year of completion; Column (9) fraction of time available for wide-field imaging, based on normal use; Column (10) average seeing at site; with AO, the seeing of Gemini is predicted to be 0.25″ in the wavelength range 0.5–0.9 nm. Column (11) countries.

TABLE 2. Summary of ESO WFI facilities

Name (1)	Aperture (2)	Instr. (3)	Focus (4)	FOV (5)	Mpix (6)	Scale (7)	Year (8)	% (9)	Seeing (10)	η (11)
DENIS I	1	CCD	Cass	0.04	1	1″	1997	50	0.9″	0.015
ESO 2.2 m	2.2	8 CCDs	Cass.	0.3	67	0.24″	1998	75	0.9″	1.125
DENIS J, K	1	CCD	Cass.	0.04	0.06	3″	1998	50	0.9″	0.015
VST	2.6	32 CCDs	Cass.	1	256	0.21″	2001	100	0.7″	13.6

Column (1) conventional name of the telescope; Column (2) size of the primary mirror in metres; Column (3) type (CCDs or photographic plates); Column (4) focus where the instrument is placed; Column (5) FOV in square degrees; Column (6) number of pixels in Megapixels; Column (7) scale in arcsec pixels; Column (8) expected year of completion; Column (9) fraction of time available for WFI, based on normal use; Column (10) average seeing at site; Column (11) survey figure of merit; see eq. 1

grees on the sky. None of these southern facilities is conceived as a fully dedicated telescope for wide-field imaging: all of them suffer either from a small FOV, large pixel-size, poor seeing, or a small fraction of allocated observing time. In comparison with these non-ESO telescopes (see Table 1), one sees that VST has the largest FOV (1 deg^2), with adequate spatial sampling, the best uncorrected seeing (0.4″) in the southern hemisphere, and the largest fraction of time available (100%) for WFI.

Tables 2 and 4 provide, among other parameters, the survey figure of merit η defined as

$$\eta = \Omega \times D^2 \times DQE \times (seeing)^{-2} \times \Delta T \quad (1)$$

where Ω is the area of the detector in deg^2, D is the diameter of the primary mirror, DQE is the quantum efficiency of the detector in the R band for the visible or in K for the NIR, and ΔT is the fraction of the time available for WFI, based on normal use during a year. For the VST, the value of figure of merit, calculated for $\Omega = 1$ deg^2, $D = 2.6$ m, $DQE = 0.85\%$, $\Delta T = 1$ and a mean seeing value $FWHM = 0.65''$, is η (VST) = 13.59. Only two other projects have comparable survey figures of merit: MEGACAM and SLOAN, which are both located in the northern hemisphere. The former project has a η = 5.76 because of a larger mirror diameter (4 m), but only a fraction of the CFHT observing time[1] will be devoted to WFI, while 100% of the time will be available for WFI at the VST. The SLOAN project has a higher η (= 22.5) because of its large FOV (9 deg^2) with respect to the VST. Such a facility will be entirely devoted to a sky survey and its spectroscopic follow up, without the flexibility which is needed for a variety of VLT preparatory works (choice of different areas in the sky, limiting magnitudes and broad bands).

[1]We have assumed here that 20% of the CFHT time will be devoted to WFI.

When considering large sky areas, all other ESO and non-ESO southern telescopes have survey figures of merit which are smaller by at least an order of magnitude than that of the VST.

4.3. Comparison with ESO WFI facilities

Table 5 shows that the only ESO facility competing with the VST is the 2.2-m telescope when it is equipped with a focal reducer and a 8k × 8k CCD mosaic camera. Therefore, the VST telescope is a competitive facility only if it produces a major increase in the telescope efficiency for WFI with respect to the ESO 2.2-m telescope.

We have addressed in detail the “environmental gain” of the Paranal site vs. the

TABLE 3. Summary of Planned Wide-field Imaging Surveys (visible/NIR).

Experiment (1)	WFI (2)	Medium (3)	Bands (4)	Scale (5)	Lim. mag. (6)	Sky cov. (7)	DQE/seeing^2 (8)
Palomar Sch.[1]	43	310^3 plates	J F N	67″/mm	J = 21.5	2.5×10^4	0.04/1″
MEGACAM	1	CCD	B V R I Hα	0.21″	B = 24	10^2	0.80/0.6″
CFHT12K	0.33	CCD	B V R I	0.21″	$I_{AB} = 24$	25	0.80/0.6″
SLOAN	9	CCD	u′ g′ r′ i′ z′	0.4″	$R^2 = 23$	10^4	0.4/1″
DENIS	0.02	CCD	I J Ks	1″, 3″, 3″	Ks = 13.5	2.5×10^4	0.61/0.9″
EIS ESO	0.01	CCD	U B_w V_w I_w	0.17″	I = 23.2	24	0.75/0.9″
EIS ESO	0.01	CCD	U B_w	0.17″	BW = 24.3	1.9	0.85/0.9″
EIS ESO	0.01	CCD	U, Gr, Gg, I, K	0.17″	K = 21.5	0.01	0.85/0.9″
BATC	0.95	CCD	15 I, B[3]	0.85″	V = 21	475	
CADIS	0.01	CCD	K′	0.4″	K′ = 21.2	0.28	0.75/1"
LIMITS	0.1	CCD	40 N.B.[4]	0.6″	R = 23.5	20	0.3/1″
Hα Survey	43	160 plates	Hα	67″/mm		7×10^3	0.04/1.6"
APM	25	210^3 plates	IIIaJ	67″/mm	20.5	2.2×10^4	0.04/1″
2MASS	0.02	CCD	J H Ks	2″	Ks = 13.5	2.5×10^4	0.8/0.9″
NOAO	0.07	CCD	I	0.47″	I = 23.5	16	0.8/1″
NOAO	0.36	CCD	B R I J H K	0.27″	I = 26	18	0.8/1″
VST[5]	1	CCD	U ′ B_W V_W R_W I_W	0.21″	$R_W = 25.5$	300	0.85/0.7″

Column (1) conventional name of the survey; Column (2) detector area in square deg used for the survey; Column (3) plates or digitised images; Column (4) broad or narrow bands covered by the survey; Column (5) scale in arcsec pixel-1; Column (6) limiting surface brightness; Column (7) sky coverage of the survey in square degrees; Column (8) detector quantum efficiency in the R band for optical surveys and K band for NIR surveys, and average seeing;

[1]Data from the CRONA project.
[2]The survey will reach fainter limiting magnitudes in those 5 bands (25 in R) on a strip 2 × 50 square degree, centred on the South Galactic Pole.
[3]15 intermediate-band filters (Δλ = 200, 300 Å) from 330 nm to 1 μm will be used for this survey.
[4]40 narrow-band filters from 400 nm to 1 μm will be used for this survey, plus B, V, R. I.
[5]This is an example of a possible survey with VST.

TABLE 4. Summary of Planned Wide-field Imaging Surveys (visible/NIR) Cont.

Experiment (1)	η (2)	Countr. (3)
Palomar Sch.[1]	1.36	USA-Eur.
MEGACAM	5.76	Fr-CAN
CFHT12K	1.9	France-CAN
SLOAN	22.5	USA
DENIS	0.015	ESO
EIS ESO	0.01	ESO
EIS ESO	0.011	ESO
EIS ESO	0.011	ESO
BATC		USA-China
CADIS	0.03 (3.5 m)	D-E
LIMITS	0.7	CAN
Hα Survey	0.95	UK-AUS
APM	0.81	UK-AUS
2MASS	0.03	USA
NOAO	0.3	USA
NOAO	1.0	USA
VST[2]	13.6	I-ESO

Column (1) conventional name of the survey; Column (2) survey figure of merit as in eq.1; Column (3) countries.

[1]Data from the CRONA project.
[2]This is an example of a possible survey with VST.

TABLE 5. Corrector efficiencies.

Name	1100[nm]	1000[nm]	800[nm]	600[nm]	400[nm]	365[nm]	350[nm]
ESO 2.2-m	0.77	0.78	0.80	0.82	0.81	0.71	0.47
VST 2.6 m	0.87	0.91	0.925	0.90	0.91	0.90	0.86

Efficiency values for the wide-field corrector for the ESO 2.2-m and for the VST 2.6-m telescope according to the VST proposal. The efficiencies for the ESO 2.2-m are extracted from the ESO document INS 97/001.

La Silla site in Section 4.1 to give a factor 2.35 (3 for the winter season). The telescope area (2.6-m vs. 2.2-m) gives another factor 1.4. Furthermore, the VST telescope is designed to give a square FOV of 1 deg^2 for WFI (to be matched by a 16k × 16k CCD mosaic), while the corresponding FOV for the 2.2-m[2] is 0.29 square deg.: the gain in efficiency is then by a factor 3.4 from the larger imaging area. Another point concerns the comparisons of efficiency vs. wavelength of the wide-field corrector for the 2.6 m VST telescope and the ESO 2.2-m, see Table 5.

If we consider the average gain in efficiencies as a function of wavelength, then we obtain for the VST an additional factor 1.16 with respect to the ESO 2.2-m telescope[3]. The overall gain in efficiency of the VST vs. the ESO 2.2-m telescope with the 8k × 8k CCD mosaic camera is a factor 13 (16.5 in the winter season).

Some words are in order for the comparison of the VST with the VLT planned instrumentation. VIMOS will have ~ 0.054 deg^2 FOV, and an estimated ΔT = 0.2: considering the VLT mirror area, VST will be 8.5 times more efficient for WFI than VLT + VIMOS. Although it can reach fainter magnitudes, VIMOS is not a dedicated imaging facility and will have its main use for wide-field spectroscopy, for which it represents a unique facility.

4.4. Telescope performances

We explicitly show efficiency curves, values and assumptions used in the estimates of S/N ratios, by considering a CCD mosaic camera with pixel size of 15 µm, 0.24″ pix^{-1} scale, a CCD quantum efficiency as in Figure 3, based on ESO CCD EEV curves, and the measured efficiency of the UVES multi-coating layers (received from ESO on May 28, 1997).

We have assumed an aluminium coating for the primary and the secondary mirrors, and anti-reflection coated surfaces for the corrector and the dewar window. The total transmission factor of these components is shown in Figure 4 for the wide field corrector according to the optical design in the VST proposal. In the same figure we show the CCD response expected ("goal" or minimum specifications).

The telescope performances expected for the VST are based on the efficiency curve in Figure 3 and a detector area of 1 deg^2. We give here three examples of possible science cases which can fully exploit the VST imaging capability and excellent image quality.

The study of large-scale structures in the universe and galaxy evolution requires galaxy catalogues extended over fairly large areas, which can be obtained through multicolour imaging. A very wide survey (several hundred square degrees) with a limiting magnitude in V of 25.5 AB mag arcsec^{-2}, in at least two bands, can fully exploit the capabilities of the VST. In 30 min-exposures, one reaches Vw_{lim} ~ 25.5 AB mag arcsec^{-2}, which could translate to $Vw_{lim} \approx 24$ for galaxies (one also has Iw_{lim} ~ 24 AB mag arcsec^{-2}, so $Iw_{lim} \approx 22.5$ for galaxies). So, a reasonable estimate can be ≈ 50 hrs of exposures per band per 100 deg^2. If one has about 6 effective hours per night, then we need 17 nights to do accurate photometry in two bands over 100 deg^2. With 17 nights of VST time, we will produce an amount of data which is nearly 4 times that produced by EIS "wide".

Furthermore, for the typical magnitude limit of wide area imaging ($R \simeq 24$), one would measure the photometric parameters and colours for several million galaxies, including a large number of low-surface-brightness galaxies whose properties are still largely unknown. Furthermore, thanks to the very high throughput of VST in the UV, large samples of high-z candidate galaxies can be selected through the Lyman break technique. If 1/3 of a year observing dark time can be devoted to deep multicolour imaging (5 bands, $Iw_{lim} \approx 26$ AB mag arcsec^{-2}), one could cover at least 5 deg^2 and obtain a sample of ~ 8000 candidates with z larger than 3.

High performances are expected also for narrow-band imaging with the VST. As an example, for a 6 × 2000s exposure, the limiting [OIII] 5007 flux at the VST is of 4×10^{-18} erg cm^{-2} s^{-1} (at the 3σ level). In the case of emission line stellar objects like planetary nebulae (PNs), which have a strong emission in the [OIII] λ 5007 line, the limiting [OIII] flux from

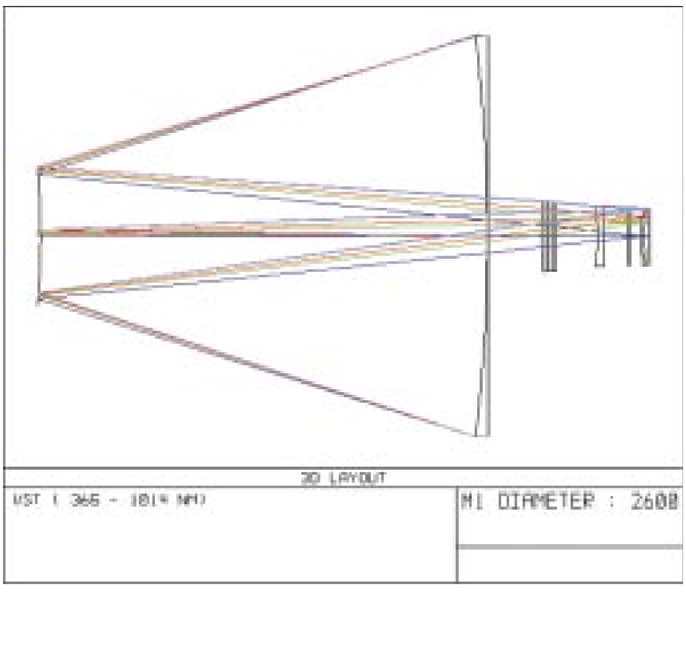

Figure 2: Optical layout in the visual range from 365 to 1014 nm; the wide-field corrector configuration here is with one lens plus the ADC.

[2]The maximum FOV for a square detector at the ESO 2.2-m focal reducer is 0.29 deg^2.
[3]This value is a lower limit: after the ESO kick-off meeting, the optical design for the wide-field corrector has only two lenses (or one lens plus ADC), so the VST corrector efficiency is higher than the estimated one quoted in the VST proposal.

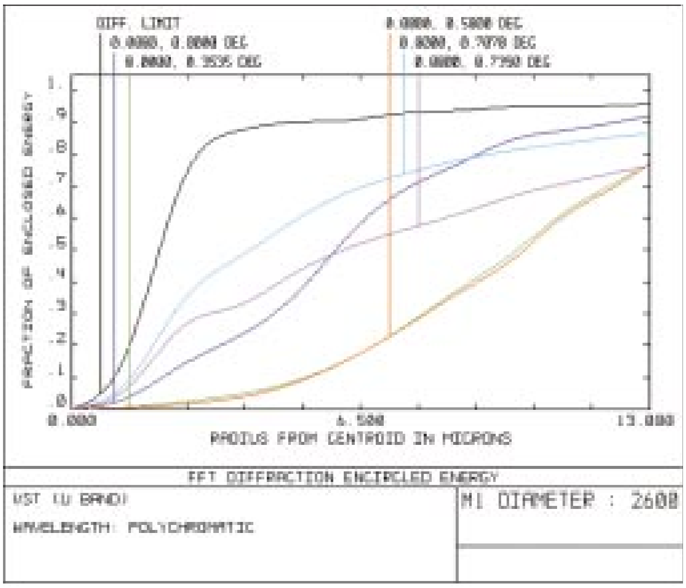

Figure 3. Encircled energy in the U band at different positions in the focal plane.

PNs at the distance of the Fornax/Virgo cluster (17 Mpc) that we can detect at the ESO NTT with EMMI in the multi-object mode is 4×10^{-17} erg cm^{-2} s^{-1}. This limiting flux can be detected today with the 4-m CFHT and the 0.25 deg^2 UH8K camera in about 10 × 2000s exposures with *S/N* = 10.

The limiting [OIII] 5007 flux of 6 × 2000s exposures at the VLT plus the multi-object spectrograph VIMOS (R = 2500) is 5×10^{-18} erg cm^{-2} s^{-1}: by comparison with the limiting flux in this wavelength range at the VST, we can conclude that such a facility is the ideal instrument to produce catalogues for PN candidates for spectroscopic follow-up at the VLT.

4.5. VST data throughput

In order to estimate the VST data flow, we analyse two different possible cases: survey and deep observations mode. In the first case we assume a total exposure time of 30 min to be split in three exposures, while in the second case we consider 2 × 30 min exposures. In both cases we assume an average length of the night at Paranal of 7 hours and two possible options for the CCD:

• Minimal: 8k × 8k with a 16-bit word. Readout is assumed to be fast (10 s) for survey mode, and slow (85 s) for deep observations. Each frame consists of 0.13 Gbyte of data.

• Maximal: 16k × 16k with 18-bit word. Fast readout time is estimated at 1 min and slow readout at 5.5 min. Each frame consists of 0.58 Gbyte of data.

In both cases we take into account a 10% overhead time for each frame. The data flows (in Gb) produced during the average night are listed in Table 6.

5. Summary

From the comparison of the different characteristics and quality parameters displayed in Tables 1, 2, 3, and 4, plus the consideration based on the high throughput at different wavelengths, it appears that the VST is the most competitive project in the Southern hemisphere for WFI. In conclusion, the need for an ESO WFI facility such as the VST is very strong primarily as a complementary tool for the VLT, and also as an independent survey tool. The ESO community needs a survey facility such as the VST in order to produce the databases which are essential to achieve excellence in the science of the VLT era.

TABLE 6. Data flow in Gbytes per night.

Mode	8k × 8k	16k × 16k
Survey	4.9	20.5
Deep	1.7	6.4

6. Acknowledgements

We would like to acknowledge the members of the Scientific Steering Committee – Jacques Boulesteix, Kenneth C. Freeman, Loretta Gregorini, Angela Iovino, Giuseppe Longo, Tommaso Maccacaro, Yannick Mellier, Georges Meylan, Giampaolo Piotto – for their contributions and support to the VST project. The VST proposal would not have appeared in its form without the work and commitment by Enrico Cascone, Debora Ferruzzi, Valentina Fiume, Guido Mancini, Gabriella Marra, Francesco Perrotta, Pietro Schipani, Gianfranco Spirito, members of OAC TWG. We would like to thank Sandro D'Odorico, the ESO contact point during the initial submission of the VST proposal, for his supervision and support to the project, Richard J. Kurz, Philippe Dierickx, Bernard Delabre, Donald Hamilton for their contribution to the VST project, and Alvio Renzini for his enthusiastic encouragement.

M. Arnaboldi
magda@na.astro.it

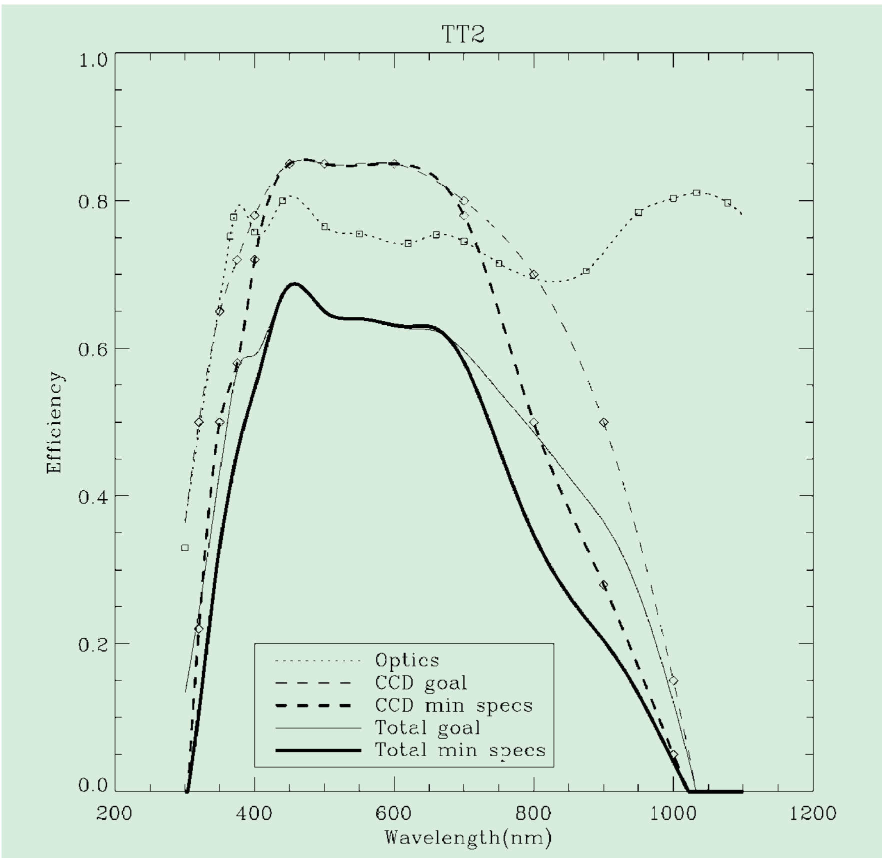

Figure 4. The efficiency curves for the telescope+corrector according to the VST proposal; the CCD response and their product are shown as a function of wavelength.