3500 times during the month of January 1998 and averaging 4000 hits per month in 1997.

## 8. Conclusions

Even though the weather was not very co-operative at the beginning of the survey, it is fair to say that EIS is achieving most of its originally planned goals. A detailed account of the ongoing work has been presented to the EIS WG and to the OPC. As a result, the OPC has given the go ahead for the continuation of EIS-WIDE and has allocated time for EIS-DEEP. It should be mentioned that since SOFI will only be available in June, the EIS WG has recommended that the goals of the original DEEP-I and II[7] be combined to cover the HDFS region and its flanking fields, with the observations scheduled to start in July 1998.

Observations for EIS-WIDE with EMMI will be completed in March 1998, to be followed by U-band observations with SUSI-2 in the fall of 1998 over about 1.5 square degrees of patch B. already covered in B, V and I. At the same time the preparations have started for the EIS-DEEP observations. Trial reductions with single frames, taken with EMMI and SUSI, have shown that the EIS pipeline can adequately handle dithered optical images. Attention will now turn to interfacing EIS with the SOFI data reduction pipeline.

The EIS pipeline is already a reality, taking raw data and producing co-added images, object catalogues and derived catalogues, largely unsupervised. Most of the remaining work is to implement and verify the production of final object catalogues with the required “context” information for data-quality control, essential in the preparation of complete samples for statistical studies. The pipeline has been developed with one eye on short-term needs and the other on the long-term, which should facilitate its upgrade to handle the data from the wide-field camera at the ESO/MPIA 2.2-m telescope.

Preliminary results clearly indicate that the EIS data meet the requirements for the primary science goals of the project which, in conjunction with the various by-products outlined above, make this pilot programme a success. One of the important remaining challenges is to make the data reach the community in a timely and easy-to-use manner. Hopefully, by doing so, EIS will pave the way for gradually more ambitious public surveys.


## Acknowledgements

We would like to thank the members of the EIS Working Group, for their scientific input in the definition of the survey, and the OPC for their support of this pilot programme. We would also like to acknowledge the support of DMD, in particular M. Albrecht, the NTT team, the ECF, in particular R. Albrecht, and Jim Beletic for innumerable discussions. We would like to express our thanks to A. Baker, D. Clements, S. Coté, E. Huizinga and J. Rönnback for their contribution in the early phases of the EIS project and C. Lidman for providing data from his survey. We are also grateful to Yannick Mellier, Marc Postman and Steve Kent for their help on several fronts and for providing some test data, and D. Koo for valuable comments during his visit to ESO.


### *References*


1. Bertin, E. & Arnouts, S., 1996, *A&A Supplement*, **117**, 393.
2. da Costa, L., 1997, *The Messenger*, **88**, 34.
3. Epchtein, N. et al., 1997, *The Messenger*, **87**, 27.
4. Fruchter, A.S. & Hook, R.N., 1997, to appear in *Applications of Digital Image Processing XX*, ed. A. Tescher, Proc. S.P.I.E. vol. **3164**, in press.
5. Hook, R.N. & Fruchter, A.S., in ASP Conference Series, Vol. **125**, *Astronomical Data Analysis Software and Systems VI*, ed. G. Hunt and H.E. Payne (San Francisco: *ASP*), 147.
6. Postman, M., Lubin, L.M., Gunn. J.E., Oke, J.B., Hoessel, J.G., Schneider, D.P. & Christensen, J.A., 1996, *AJ*, **111**, 615.
7. Renzini, A. & da Costa, L., 1997, *The Messenger*, **87**, 23.


# Après EIS


*A. RENZINI, VLT Programme Scientist*



*1999 will be the first year of the VLT scientific operations, yet this will not be the only novelty brought by the new year. In 1999 the flow of scientific data from the old La Silla Observatory will be several times higher than in 1998. Indeed, with the full dedication of the ESO/MPIA 2.2-m telescope to wide-field imaging, the ESO community will have for the first time an efficient survey instrument: the 8k $\times$ 8k camera covering a 0.54° $\times$ 0.54° field of view. In the meantime, the construction is about to start of a new 2.5-m telescope to be placed on Paranal by 2001, which will have a four times bigger field of view (and data flow rate). This sudden expansion of ESO wide-field imaging and survey capabilities requires a major effort by both ESO and its community, in order to take full advantage of these new facilities that are primarily designed to support and foster the science to be done with the VLT.*


## 1. Providing Targets for the VLT

With the advent of the VLT, European astronomy has – perhaps for the first time in this century – a real chance to successfully compete in ground-based, optical-IR astronomy. In the early years of next century there will be twelve 8-m-class telescopes in operation. Competition will be fierce, and leading or lagging behind others in critical areas of astronomical research will not just depend on the performance of the big telescopes and their instrumentation, but also on the ability to *timely* feed them with the appropriate targets. For this very reason, imaging surveys as a continuous, long-term need for the full scientific exploitation of the VLT are now widely endorsed within the ESO community.

For such surveys, 2–4-m-class telescopes are much more cost-effective than the VLT in finding objects of special interest for the deep imaging and spectroscopic study at the VLT itself. For this to be true, such targets have to be relatively rare, and the imager must have a substantially larger field of view compared to VLT imagers. Instead, if the potential targets are very numerous per field of view of the VLT imagers (e.g. FORS, VIMOS, NIRMOS), then the VLT itself may offer a competitive, or even more appropriate alternative. Classes of such “rare” objects that are scientifically attractive targets for the VLT are listed in Table 1.

While these potential targets will certainly not exhaust the capabilities of the VLT, it seems fair to say that all together they are likely to take a major share of the VLT observing time. This is exemplified in Table 2, instrument by instrument, following the order of instrument implementation at the VLT. The list is probably largely incomplete, yet it should give an idea of the variety of VLT programmes that will depend on independent wide-field imaging. No attempt is made here to describe the scientific goals of the specific possible programmes, but to a large extent they are self-evident. Yet, a couple of examples may help illustrate the case.

(1) Clusters of galaxies are very interesting objects *per se,* and allow a number of astrophysical investigations such as the study of the member galaxies, of their mass distribution by mapping the gravitational shear and magnification, etc. However, as recently illustrated in a spectacular way, clusters can be used as *gravitational telescopes* to magnify background galaxies at extremely high redshifts ($z \gtrsim 5$) that otherwise would be beyond reach even to an 8-m-class telescope. However, with the scanty statistics presently available one may expect that only a tiny fraction of all clusters will contain a bright red arc produced by a magnified $z \gtrsim 5$ galaxy. Quite probably, thousands of clusters will have to be inspected before collecting a statistically significant sample of extremely high redshift galaxies for the VLT spectroscopic study. Redundant samples of moderate redshift clusters are essential even for the detailed study of their member galaxies, because especially interesting spectral features (e.g. the Mg/MgH blend near 5000 Å used to derive the $Mg_2$ index and the central velocity dispersion in ellipticals) will not be contaminated by atmospheric lines only for clusters within relatively narrow redshift intervals.

(2) High redshift galaxies ($z \gtrsim 3$) are now easy to find via photometric redshifts. Measuring the mass of such galaxies is of paramount importance for a proper comparison with current theories of structure and galaxy formation. However, most galaxies so far discovered are too faint for the internal kinematics to be properly understood, hence for their mass to be determined. This should be possible only for galaxies at the top end of the luminosity function at higher and higher redshift, when such objects become rarer and rarer, hence larger and larger areas need to be surveyed.

Similar arguments hold for most of the targets listed in Table 1, as interested readers can easily convince themselves. Hence, the VLT need for targets yet more difficult to find is only bound to increase, as it will progressively complete the observation of the more obvious, or more common, or easier-to-find targets. This is especially true as the various VLT UTs will progressively come to completion along with their instrumentation. Moreover, and this is the really critical point, the VLT Observatory will not work in a vacuum, but will have to compete with many other observatories of its class. To ensure the VLT will maintain a leading role, ESO wide field capabilities should be first class, fully competitive with those at other observatories.

*TABLE 1: EXAMPLES OF VLT TARGETS FROM SURVEYS.*

**• High-redshift objects**

- High-redshift clusters of Galaxies (HRC)
- High-redshift clusters with bright foreground star (HRCS)
- High-redshift quasars (HRQ)
- Close pairs of high-redshift quasars (HRQP)
- Multiply lensed quasars (MLQ)
- Most luminous high-redshift galaxies, i.e. the top end of the luminosity function at each high redshift (MLG)
- High-redshift galaxies with strong emission lines (ELG)
- High-redshift supernovae (HRSN)
- Extremely red galaxies (ERG)

**• Objects in relatively nearby galaxies (ONG)**

- Globular clusters
- H II regions
- Planetary Nebulae/ Intergalactic PN
- Emission-line stars
- Novae
- Top end of the IMF

**• Galactic stars (STARS)**

- Subdwarfs
- White Dwarfs
- Very metal poor stars
- Very metal rich stars
- Other special stars
- Brown dwarf candidates (BDC)
- Highly magnified lensed stars

**• Solar-system objects (SSO)**

- Remote comets
- Unknown asteroids
- Transneptunian objects

## 2. ESO Wide Field Imaging Capabilities

### *2.1 The Wide Field Imager at the 2.2-m Telescope (WFI@2.2)*

After starving for so many years for wide-field imaging, the ESO community will soon face the opposite problem, i.e. a limited capability to *digest* the enormous flow of data in the form of wide-field images that is about to start. The new 8k × 8k camera (WFI@2.2) to be placed next October at the 2.2-m telescope will provide a field of view of 0.54° × 0.54° (for more information see http://www.ls.eso.org/lasilla/Telescopes/2p2T/E2p2M/ELVIS/news/ELVISP62.html) When factoring in telescope aperture, field of view, troughput of the optics and QE of the CCDs, the WFI@2.2 will be ~ 6 times more efficient than EMMI for wide angle (survey) work. The WFI@2.2 will have 12 times the field of view of EMMI (that was used for EIS), will deliver images with 16 times larger digital format than EMMI/red, and – perhaps most importantly – the 2.2-m telescope will be the first of its class wordwide to be fully dedicated to wide-field imaging with a large-format camera. For comparison, EIS-WIDE consists of just about 30 nights with EMMI@NTT. All in all, with the advent of the WFI@2.2 the survey potential capability of ESO over the three year period 1999–2001 is equivalent to ~ 200 EIS(!).

To continue this comparison a little further, it is easy to realise that the number of pixels of the WFI@2.2 CCDs is about twice that of all other ESO instruments on La Silla, namely 67 Mpx vs. ~ 35 Mpx. When considering that the WFI@2.2 will be permanently mounted at the 2.2-m, while the other telescopes will on average use either a 1k × 1k or a 2k × 2k device, it follows that the WFI@2.2 data flow alone will be several times larger than the combined flow from all other ESO telescopes on La Silla. During 1999, the WFI@2.2 data flow is estimated at a rate of ~ 8 Gby/night, which compares to ~ 4 Gby/night from the VLT UT1. The global ESO data-flow rate will then increase by a factor larger than five in 1999 compared to 1998.

This surge in data flow clearly requires adequate preparation and investments not only at ESO premises, but especially at concerned institutes in the ESO member states where this flow will eventually

*TABLE 2: TARGET NEEDS OF VLT INSTRUMENTS.*

**UT1**

**FORS1**

| | |
|---|---|
| HRC: | multicolour photometry of cluster galaxies<br>spectroscopy of cluster galaxies (redshifts, scaling relations)<br>deep high-res. imaging (gravitational shear maps)<br>giant-arc spectroscopy (redshift, star-formation rate) |
| MLG: | spectroscopy (redshift, internal kinematics, abundances, star-formation rate) |
| MLQ: | imaging; spectroscopy (variability, absorption systems) |
| ELG: | spectroscopy (redshift, abundances, kinematics) |
| ERG: | Spectroscopy (redshift, abundances, kinematics) |
| HRSN: | spectroscopy (redshift and classification) |
| ONG: | spectroscopy (kinematics, abundances) |
| SSO: | spectroscopy |

**ISAAC**

| | |
|---|---|
| HRC: | multicolor photometry of cluster galaxies<br>spectroscopy of cluster galaxies (redshifts, scaling relations)<br>giant-arc spectroscopy |
| MLG: | spectroscopy (redshift, internal kinematics, abundances) |
| ERG: | imaging, spectroscopy (redshift, star formation rate) |
| HRQ/HRQP: | spectroscopy (absorption systems) |
| STARS: | spectroscopy (radial velocity, abundances) |
| BDC: | spectroscopy |
| SSO: | imaging; spectroscopy |

**CONICA**

| | |
|---|---|
| HRCS: | High-resolution imaging; spectroscopy (morphology, scaling relations) |
| MLG: | High-resolution imaging; spectroscopy (morphology, scaling relations) |
| MLQ: | imaging, spectroscopy (variability, absorption systems) |

**UT2**

**UVES**

| | |
|---|---|
| HRQ/HRQP: | high-resolution spectroscopy (intergalactic medium at high z) |
| STARS: | high-resolution spectroscopy (radial velocity, abundances) |

**FORS2**

Same as FORS1

**GIRAFFE (formerly called FUEGOS)**

All programmes will need target lists from a wide-field imager

**UT3**

**VIMOS**

| | |
|---|---|
| HRC: | Integral Field spectroscopy |
| MLQ: | Integral Field spectroscopy |

**VISIR**

| | |
|---|---|
| MLG: | imaging; spectroscopy (abundances, star-formation rate) |
| ERG: | imaging; spectroscopy (abundances, star-formation rate) |
| BDC: | imaging; spectroscopy |

**UT4**

**NIRMOS**

| | |
|---|---|
| HRC: | Integral Field spectroscopy |
| MLQ: | Integral Field spectroscopy |

**CRIRES** (probably none)

**UT1**

**SINFONI**

| | |
|---|---|
| MLG: | 3D spectroscopy (internal kinematics) |
| MLQ: | 3D spectroscopy (absorption systems) |
| ERG: | imaging; spectroscopy (abundances, star-formation rate) |

meet its final destination. It is also important to realise that the data flow will keep increasing in the following years, exacerbating the situation if proper measures are not immediately taken. In fact, two more UTs will enter operation in 2000, and the last UT in 2001, along with an even more demanding survey telescope.

### *2.2. The VLT Survey Telescope (VST) on Paranal*

Though already a respectable facility for survey work, the 2.2-m telescope is now just a temporary solution for the ESO needs of wide-field imaging. The offer of a new 2.5-m telescope on Paranal made by the Capodimonte Astronomical Observatory was enthusiastically endorsed by the STC at its meeting of October 28–29, 1997. According to current planning, the telescope will be delivered for operation during 2001.

It is estimated that the 2.5-m telescope on Paranal will have an overall efficiency $\sim$ 12 times higher than that of the WFI@2.2. This figure comes from the combination of better site, higher throughput, and larger field of view and format of the camera (one square degree covered by at least a 16k $\times$ 16k array of CCDs). Therefore, the availability of the new telescope will mark another quantum jump in the ESO capability of conducting imaging survey work, primarily – though not necessarily exclusively – in support of VLT Science. With its very large detector, the data flow from the VST will rival the data flow of the whole VLT/VLTI. Although the VST with its one square degree camera will not be the largest telescope with a very wide-angle imager, it will likely be the first such facility to be fully dedicated to wide field imaging. ESO is now issuing an Announcement of Opportunities for the procurement of this camera.

The sharing of the observing time at the new telescope will naturally follow the same scheme of the 2.2-m: there will be guaranteed time for the MPIA in compensation for an anticipated eventual decomissioning of the 2.2-m telescope, for the CAO for having provided the telescope, and to the institutes that will have provided the instrumentation. Nevertheless, probably substantially more than 50% of the time will still remain available to the rest of the community.

The advantages offered by the VST over the 2.2-m telescope can be appreciated when considering that a factor $\sim$ 10 gain in efficiency means that either a given survey can be completed ten times faster, or that for a given telescope time a ten times larger area can be explored (hence ten times rarer objects can be found), or that a survey can be pushed more than one magnitude deeper, or that more numerous pass-bands or narrower ones can be used. Clearly, such a jump opens a whole unexplored parameter space, offering to the community a variety of opportunities and alternatives all very attractive for the VLT science, though not only for it. For example, the large proportion (~ 77%) and even distribution of photometric nights on Paranal makes the VST uniquely suited for the extensive observation of microlensing events in the Galactic bulge, and the search of extrasolar planets using this technique (cf. *The Messenger*, 90, 15). In essence, a long-sighted scientific planning for the use of the VST should be of great benefit for the ESO community, and the experience gained with the 2.2-m telescope will be critical in this respect.

## 3. Surveys from Present to Future

### *3.1. Building a Strategy*

From these crude numbers it emerges that – as far as wide-field imaging is concerned – from now on the real bottleneck is not in getting observing nights and images, but in the ability to process them properly, and especially to do so in a timely fashion. The sooner suitable targets are found for the VLT, the sooner ESO astronomers will have an opportunity to anticipate other observatories in fundamental discoveries. It would instead be both a missed opportunity and a waste of resources if images from the WFI@2.2 were to remain unused waiting for the necessary HW/SW tools and human resources to be secured. A demonstrated capacity to deal with a large volume of data should be considered as a double plus by OPC when allocating time at the 2.2-m telescope.

ESO is now setting out a plan to help the community to cope with such an enormous increase in data flow. Of course, ESO cannot provide hardware or manpower to institutes in the member states, but can help in various other ways. To some extent EIS was designed to address these problems, starting just before the beginning of VLT operations a survey that no other institute in the member states was prepared to undertake on such a short notice and tight schedule. The primary aim was to simplify for ESO users the selection of VLT targets, thus allowing them to concentrate on the preparation of an aggressive use of the VLT. But in doing the survey, additional advantages are coming for the community. Indeed, EIS will soon provide the ESO community with:

• Survey data (images and catalogues)

• Survey software tools

• Astronomers trained in survey work.

In fact, besides survey data, all software that has been developed, adapted, and implemented for EIS is publicly available to the ESO community. With the advent of the WFI@2.2 this survey software needs to be significantly expanded and upgraded, with the aim to (1) allow a prompt use of the 2.2-m for survey work, and (2) make the survey software and tools really "portable", i.e. distributing them to the community. These tools will allow a series of image processing to be performed in an automatic fashion, including image coaddition, dithering, mosaicing, astrometric and photometric calibrations, etc. The aim is to allow interested institutes in the member states to undertake major survey work (either public or private), but of course some of these tools will also be useful to process images for more modest projects dealing with a limited number of frames.

It is unlikely that ESO will have the necessary resources for making the survey pipeline fully portable (e.g. fully documented, independent, etc.). Essential to make it portable are the astronomers having been trained themselves in survey work at ESO, first with EIS, then with the WFI@2.2. Much of the EIS Team is indeed composed of astronomers from the community, having spent several months working in Garching, then returning to their home institutes bringing back their experience with survey work and its tools. Institutes interested in developing their own independent capacity in wide-format image processing may consider the opportunity to send people at ESO to work in the EIS Team, then getting them back with accrued experience and bringing along well understood tools with which they have gotten fully acquainted. With this process one builds on the EIS experience, and with relatively modest incremental efforts one aims at enabling the community to take full advantage first of the WFI@2.2, and later of the further expanded capabilities of the VST.

### *3.2. The 1999 Pilot Survey at the 2.2-m Telescope*

The EIS Working Group has recommended to start in Period 62 a Pilot Survey at the 2.2-m telescope, taking of order of one third of the available time. The Pilot Survey is now being designed under the supervision of the Working Group, and will be submitted to the OPC by April 15. If approved, ESO will make an effort to implement the following schedule:

• October-December, 1998: implementation, commissioning, and science verification of the WFI@2.2.

• April-December, 1998: EIS pipeline upgrade to WFI-survey pipeline and its commissioning.

• January 1 – March 31, 1999: WFI@2.2 offered to the community in Period 62.

• January 1 – March 31, 1999: Observations for the Pilot Survey.

• February 1 – July 31, 1999: Processing of the Pilot Survey data.

• July 31, 1999: Release of the survey products.

Thus, 1/3 of the dark time in the second half of Period 62 will correspond to about 15 nights. Given the factor of ~ 6 advantage of the 2.2-m telescope for survey efficiency over the NTT, this is equivalent to ~ 90 NTT nights, or roughly three times EIS-WIDE. The Pilot Survey will then represent a major step forward with respect to EIS, even if using a modest number of nights.

Observations and data processing for the Pilot Survey will be conducted by a dedicated Team which, similar to the EIS Team, will be composed by astronomers from the community and will be supported by ESO and ECF staff and fellows.

EIS and Pilot Survey data will immediately enter the VLT Archive, and will in fact provide an opportunity to scientifically verify the Archive itself. Proprietory VLT data will not be accessible for one year after release to the PIs, hence little users access to the archived VLT data is expected during 1999. Instead, public survey data will immediately be accessible through the Archive, and a major use of them is expected in the preparation of the VLT programmes and proposals. This will offer the opportunity for an early test and optimisation of Archive procedures and data distribution.

### *3.3. Beyond 1999*

What is going to happen after the 1999 Pilot Survey is difficult to predict at this time. Public and private major surveys, first with the WFI@2.2 and then at the VST, will probably coexist with a series of less demanding imaging programmes. The share of telescope time among these various uses of the facilities will be recommended by the OPC on the basis of the scientific merit and the requests from the community.

The Working Group for public surveys (possibly reconstituted through an Announcement of Opportunities process) will continue on its tasks to collect input from the community, scientifically optimise public surveys before their submission to the OPC, and monitor the execution of the surveys and the release of their products.

With the survey pipeline being installed at other institutes in the community, the capability to process large amounts of survey data will disseminate, and the necessity to maintain a survey Team at ESO will progressively diminish. This will be especially true after the VST starts operating, and the survey pipeline will have been upgraded to cope with images from its camera, each likely to be composed by 32 subimages each of 2k × 4k format. All in all, with this long-term programme in imaging surveys new ways of cooperation and interaction between ESO and its community will be explored, with the prime aim of getting the ESO community more and more competitive in the VLT era.

---

arenzini@eso.org