will be able to discover 40 supernovae up to a redshift of 0.5 each week. The advantage of LITE for this search is of course its very good image quality and photometric performances which will help to detect supernovae as faint as $m_V = 23$ embedded in distant galaxies. The redshift determination will be done with the VLT.

Another domain will be the continuation of the brown dwarf research by microlensing effects on stars in the Magellanic Clouds. The two existing experiments are based on a 40-cm telescope and a 4-million-pixel CCD camera for the French MACHO instrument at ESO, and a 1.20-m telescope and a double 4-million-pixel CCD camera for the Australian-American instrument at Mont Stromlo. LITE will provide a gain by a factor 10 compared to these instruments.

Three types of observational programmes are considered: (1) a multicolour astrometric and photometric survey in individual fields selected according to Galactic structure and stellar programme, (2) a multicolour and slitless, low-resolution spectroscopic survey of typically 100 square degrees for cosmological observations and supernova research, and (3) observations in front of the Magellanic Clouds for detection of brown dwarfs. All of these programmes require very good image quality.

The scientific requirements call for LITE being a telescope of 2.5 m diameter with a mean image quality, including seeing, of 0.8 arcsec (or better) over a field of 1.5 degree (or more). This can only be achieved with good sampling of the image PSF by the CCDs. For a typical pixel pitch of 15 microns, 0.3 arcsec pixels are achieved with 10 m focal length; this corresponds to an f/4 aperture ratio. We first designed a quasi-Ritchey Chretien system with a Gascoigne corrector, but we finally adopted a new optical concept worked out at the Tautenburg Observatory, with the assistance of Ray Wilson from ESO. It is a modified version of the 3-mirror Paul-Baker telescope which provides a plane focal surface at the "prime focus" location, behind the secondary mirror. A preliminary design study has shown that for a telescope with 2.5 m diameter and focal ratio f/4, an image quality of 0.4 arcsec can be obtained at the edge of a 2.5-degree field, and significantly better towards the centre. Compared to the initial Cassegrain solution, this design has two important advantages, the absence of chromatic aberrations, because there are only reflecting mirrors, and a very easy baffling system to suppress straylight.

As a baseline, the CCD camera will be organized around thin, backside illuminated Thomson CCDs, each with 2048 x 2048 pixels and 15 micron length. These CCDs are being developed for the VLT, and the thick version should become available in 1993 and the thin one in 1994. The three-side buttability allows to make strips of 2 CCD widths. A 1-square degree surface can be covered with 36 CCDs. Readout time of the whole array will be as low as 30 seconds, thanks to a parallel acquisition system. Cryogenic temperatures will be provided by a closed cycle cooler in order to simplify the operations.

The natural site for this telescope is near the VLT, in the Paranal area, where it may take advantage of the excellent seeing and the large number of photometric nights as compared to the other Chilean sites. Discussions will take place with ESO to study this possibility.

The definition phase of the project will be undertaken in 1993. We must still settle the details of the German-French collaboration, work out the relationships between the consortium and ESO, and obtain funding. The actual start of the project is expected in 1994 and the beginning of the observations in 1999. In the present status of the project, nothing has been absolutely fixed and new groups are welcome to join. If you are interested, please do not hesitate to contact us. We expect to make a first presentation of the project at the IAU Symposium on Wide Field Imaging in Potsdam next August.

Projects similar to ours are under development, in particular the Sloan Digital Sky Survey (SDSS) in the USA. We wish to emphasize the differences between our project and the SDSS. The main goal of the SDSS is to make a survey over a large fraction of the entire sky (~ π steradians), both in photometry and in spectroscopy, and with the same telescope. However, the use of the SDSS 2.5-m telescope for spectroscopic measurements will naturally limit the observations to moderately faint galaxies only. The necessity of the all sky survey pushes towards the largest possible field, but at the detriment of image quality, and to a transit instrument which simplifies the operations.

In our case, the spectroscopic observations are planned with the much larger VLT, which, of course, can reach much deeper. Due to the increasing number of objects at fainter magnitudes, we cannot expect to cover a large fraction of the sky. On the contrary, we shall only be able to obtain images significantly deeper than the SDSS by limiting the sky coverage. For LITE, the priority of optimization is then image quality first, and field of view second. In addition, the pointing mode of operation is more suitable for very deep imaging than a transit mode. While many scientific areas are common to both instruments, the trade-offs are different, and the scientific programmes will be different too.

We believe that the combination of the VLT and LITE will offer a unique capability of probing the deep sky and will become a prominent instrument for future cosmological studies.

# The ESO Red Sky Survey – a Tool for Galactic and Cosmological Studies

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## Motivation

The ESO/SERC R-Survey of the southern sky is the observational contribution of ESO to the first complete sky survey south of −17.°5 declination. The other part, the ESO/SERC J-Survey, was observed in Australia. The ESO-Schmidt telescope at La Silla produced 606 photographic red plates covering some 15,000 square degrees of the sky, the UK Schmidt Telescope in Coonabarabran, Australia, took the corresponding blue/green J-plates. Sky coverage of the same order of magnitude is still far beyond the range of

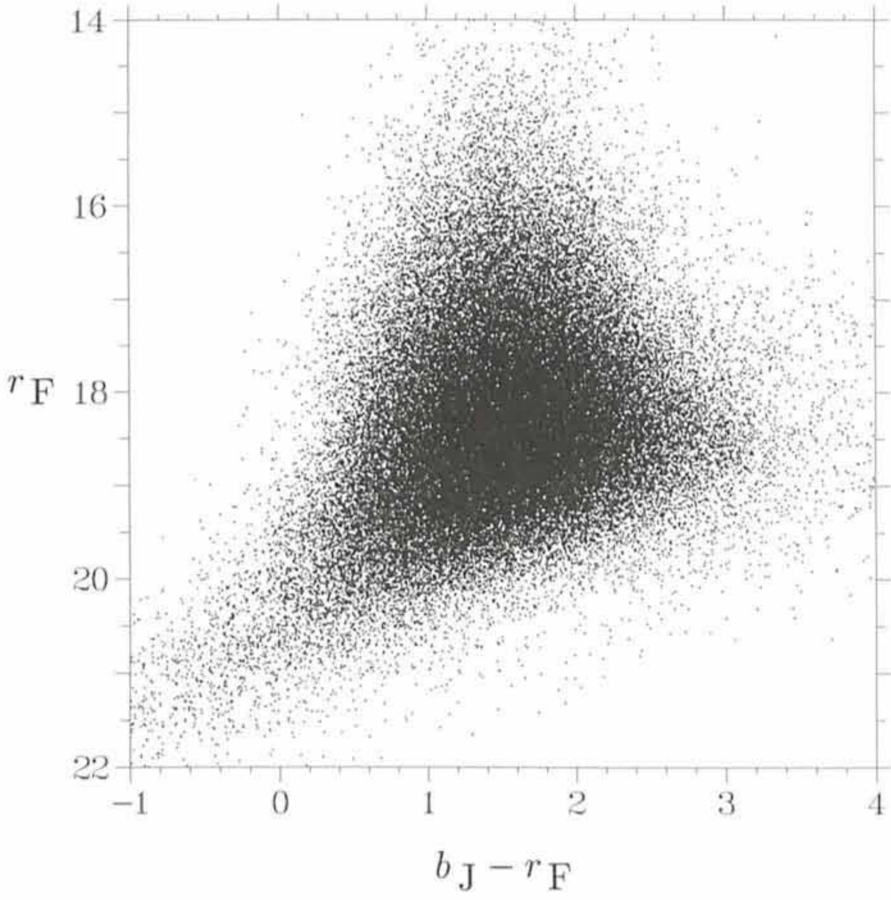

Figure 1: *The colour-magnitude diagram of 84,000 galaxies from 6 ESO/SERC R-plates.*

CCDs, which were not even introduced into astronomy when the atlas project started in the early 1970s, and wide-field telescopes specially designed for CCD imaging are only in the planning stage. Nobody knows the time scales on which an equivalent or deeper CCD survey can be realized, and a photographic atlas is still a singular tool for large-scale studies.

The Sky Atlas Laboratory at ESO-Garching, as before in Geneva, took the responsibility of producing and editing both parts of the ESO/SERC Atlas, including the laborious tasks of quality controls, partially re-evaluating the original photographs as well as checking every single one of almost 200,000 glass or film copies of the atlas fields, to ensure highest quality before they were distributed to hundreds of institutions around the world.

The J-atlas, the observational contribution of the UK, was digitized at two UK institutions: at the Institute of Astronomy in Cambridge with the APM machine and at the Royal Observatory Edinburgh with the COSMOS machine. Thus, it seemed appropriate to have the R-atlas digitized in an ESO member country.

The Astronomical Institue of Münster University (AIM) took up the challenge. We needed the atlas for our work, and there were some ulterior motives. One was getting an additional PDS 2020GMplus microdensitometer (thanks to the Federal Ministry of Science and Technology of Germany) for the time-consuming task of scanning. Both PDS machines were equipped with powerful new amplifiers, developed and constructed at AIM (the "plus" to the original name indicates this addition), which permit us to use the double-slit machines to the mechanical limit of their scanning speed of 200 mm $s^{-1}$. Another one is our contribution to ROSAT source identification. While Edinburgh has provided ROSAT headquarters at the Max-Planck-Institut für Extraterrestrische Physik in Garching with catalogues from the J-plates, AIM provides R-catalogues. Last not least, the data base resulting from the R-atlas is a tribute to the two people who created the red atlas: to Hans-Emil Schuster, who dedicated many years on La Silla to the tedious and responsible task of taking the plates – as earlier for the ESO Quick Blue Survey (QBS) – while training his assistants to perfection, and to Richard West who, together with his able helpers, produced the complete atlases at ESO headquarters – as he now edits the new three-colour POSS II/ESO Survey.

## Digitization, Data Reduction and Catalogues

The area chosen by us for digitization, data reduction and interpretation covers 216 plates. It encompasses almost 5000 square degrees of the sky between declinations $-17\overset{\circ}{.}5$ and $-82\overset{\circ}{.}5$ and right ascensions $20^h30^m$ to $5^h30^m$. Outside this area, star densities become too high for proper automatic detection and evaluation of single objects. 1.5 years were invested for scanning and basic reductions. The step size of 15 μm and the aperture of 20 μm × 20 μm yield a positional accuracy of $0\overset{''}{.}3$. Due to the double slit and the high density range of our amplifier (its effective limit is determined by photon statistics rather than by sensitivity) we are able to measure system magnitudes $14 \leq m \leq 21$ with an accuracy of about $0\overset{m}{.}1$ in the middle range, and $0\overset{m}{.}2$ in the very bright and very faint ranges. For magnitude corrections on individual plates (center-edge sensitivity variations) internal methods are used; for the determination of catalogue zero points, standard sequences are measured with the Dutch 0.90-m telescope at La Silla and, in collaboration with the University of South Africa, Pretoria, with the 1.0-m telescope of the South African Astronomical Observatory (SAAO).

The galaxy catalogue lists 7.1 million galaxies down to magnitude $m = 21$, the star catalogue almost 20 million stars to the same limit. The catalogues will literally broaden – and hopefully deepen – our views in observational cosmology as well as in stellar statistics.

## Project History

In 1986, we started the Münster Redshift Project (MRSP) by measuring direct atlas plates as the indispensible counterparts of objective prism plates, used for the determination of redshifts. At this time the red survey was not yet complete and we chose J-plates for the start. The first 400 square degrees were used to develop scanning techniques and reduction algorithms and to introduce and implement methods in stellar statistics and observational cosmology. The low dispersion objective prism plates (reciprocal linear dispersion of 246 nm/mm at Hγ) were taken with the UK Schmidt telescope.

Redshift measurements from objective prism plates need reliable zero points. This induced us to add astrometry to our programme and to use plate transformations from direct to objective prism plates to define reference positions. To date more than 120,000 galaxy redshifts have been measured in 12 fields and are presently used for cos-

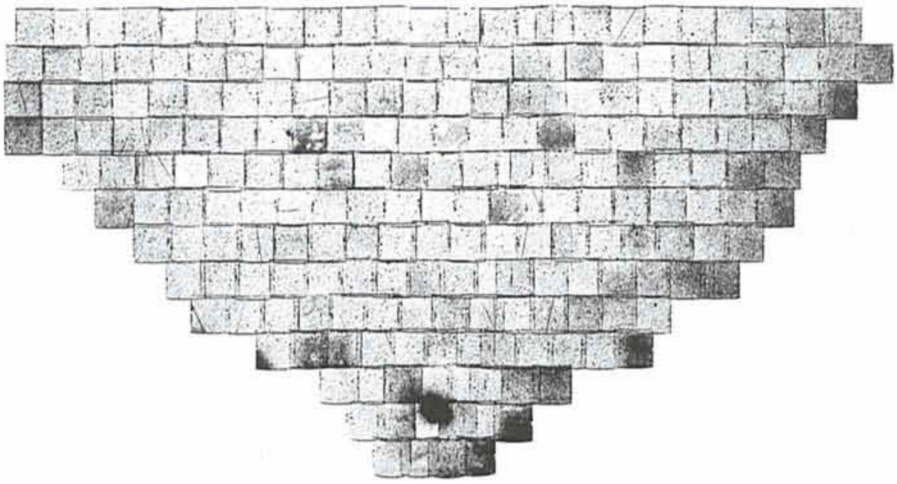

Figure 2: *The distribution of artifacts found on 216 plates of the ESO/SERC-R-Atlas. The individual plates are clearly outlined by the plate frames, which are scanned but rejected as artifacts by the software. The increase of artifacts towards the Milky Way region is due to the increasing numbers of rejected overlaps.*

mological investigations. Colour information is an important additional tool.

Astrometry from Schmidt plates also provides us with statistical proper motions in the Milky Way and in neighbouring galaxies. Using for the first epoch ESO QBS plates and for the second epoch ESO Schmidt plates, taken 15 years later specifically for the project, the absolute proper motion of the LMC was determined and other Local Group galaxies are now investigated. Astrometry is a useful tool for the interpretation of stellar colour-magnitude diagrams.

## Magnitude Calibrations

Magnitudes are obtained in a lengthy process: each measured isophotal and aperture magnitude is subjected to transformations, corrections and calibrations, amounting to 8 steps for galaxies and 6 steps for stars. The overlap regions of the 216 fields are used to adjust all plates to a common zero point. CCD sequences, distributed over the whole area, are needed to transform the plate magnitudes into an international system.

All hypersensitized Schmidt plates have a tendency to loose sensitivity towards the plate edges. This effect, together with that of vignetting, must be corrected. Desensitization is severe for J-plates, especially the older ones, taken before UK astronomers became aware of the effect and found partial remedies. Although the effect is smaller on R-plates, it cannot be neglected. The best way, short of having tens of calibration sequences over each plate (which would require a dedicated 1-m telescope on La Silla for several years) are magnitude corrections based on the comparison of galaxy numbers per unit area in the central part of the plate and at the edges. Galaxy counts on several plates near the SGP as a function of local photographic background densities yield a good average correction curve for the magnitudes. The quality of this curve is tested by comparing the results in the regions of large plate overlaps.

Magnitudes from the J- and R-plates are labelled $b_J$ and $r_F$, the symbols indicating the blue and red passbands and the photographic emulsions Kodak IIIa-J and Kodak IIIa-F (for the atlas used in combination with filters). About 70% of all objects brighter then $r_F = 20$, i.e. 35,000 stars on the average R-plate, and more than 11,000 galaxies are sufficiently well matched with their J-counterparts to yield the colour index $b_J - r_F$.

## Colours and Magnitudes

Colours of stars and galaxies hold information on intrinsic and extrinsic parameters, such as stellar temperatures and dust absorption, galaxy populations and cosmological effects. Colour-magnitude diagrams of field stars comprise objects at largely different distances, representing two or three different stellar populations – halo, thin disk and possibly thick disk. With the aid of astrometry, we can interpret colour-magnitude diagrams of stars with measured proper motions $\mu > 0''.1\ \mathrm{yr}^{-1}$. This helps us to find good starting parameters for simulations, used to explain the colour-magnitude diagrams of all stars. Preliminary results support the presence of a thick disk.

Colour-magnitude diagrams of galaxies include mixtures of morphological types with different dust content, at all inclination angles, in a range of redshifts and affected by evolution. The colour-magnitude diagram in Figure 1 shows 84,000 galaxies with all these characteristics and can only be explained by comparison with simulations.

Tracing the effects of galaxy evolution for magnitudes $r_F \approx 20$ with large statistical samples may lend credulity to the conclusions drawn from the much smaller samples available so far. The comparison of colour distributions of intrinsically faint and bright galaxies may yield constraints for the timescales of formation and evolution of massive and of low-mass galaxies.

For fluctuation analysis in cosmology, using galaxy counts-in-cells in three dimensions, magnitude measurements of the same objects in different spectral ranges may help to smooth the effects of magnitude errors. These must be small when larger scales are to be reached. Large-scale fluctuation analysis needs large survey volumes of equal extent in all spatial dimensions and is thus a task which can well be achieved by photographic surveys with their large sky coverage, and with z-values from objective prism plates – provided the magnitudes can be improved.

Colours are of interest for objects which we identify as quasar candidates on the basis of their objective prism spectra. Almost 12,000 candidates have been found so far. On the basis of earlier measurements, we expect to find usable redshifts for about 75% of the candidates. In spite of our bias towards Lyman α quasars, the colour distribution of this sample will be of interest for comparison with quasar surveys where the objects are selected by colour.

Colours are also of technical help. Together with the morphological types of galaxies, determined automatically within the MRSP down to $b_J = 19.5$, colour information can aid in determining the mixture of galaxy types in various samples and thus the K-corrections to be applied. This avoids systematic errors due to global K-corrections and yields more reliable luminosities and distances.

Finally, one might mention the possibilities of having an independent check on results from cosmological investigations using $b_J$ magnitudes. Controversial conclusions, such as the ones drawn from galaxy counts $N(_J)$ within the APM Project may be independently supported or rejected with $N(r_F)$ counts. For large samples of galaxies, angular correlation functions $w(\theta)$ will be determined on the basis of $r_F$ magnitudes and comparisons will be possible of results from essentially the same volume of space and from data which were ob-

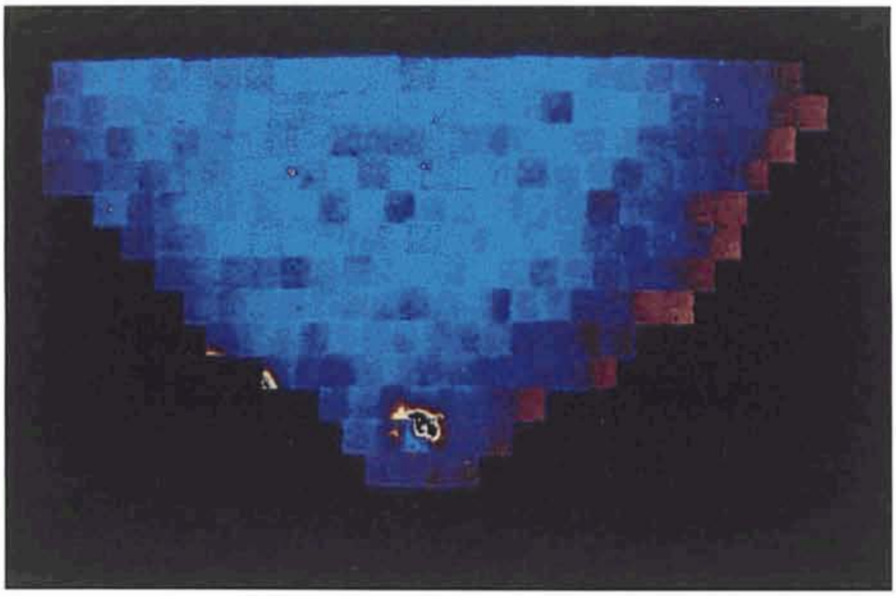

Figure 3: *The distribution of stars on 216 plates of the ESO/SERC-R-Atlas. It shows strong density gradients towards the Milky Way, which are indicated by increasingly redder colours. Aside from this gradient and some plate-to-plate variations, which are due to the fact that zero points and limiting magnitudes have not yet been adjusted, the distribution is quite smooth. The extremely crowded regions of the SMC and LMC are seen in the lower centre and to the lower east. The brightest white spot is the Sculptor dwarf galaxy, its nearest neighbour the Fornax dwarf galaxy.*

tained with very similar techniques – except that the different passbands may introduce different selection criteria and measuring errors.

## Artifacts

Leaving the realm of cosmology and coming literally down to earth, we may look at the artifacts found on the survey plates, as displayed in Figure 2. There is no doubt that most artifacts are man-made. Aside from dust, which is unavoidable even in a relatively clean measuring environment, and satellite trails, found abundantly, a large source for artifacts are blended stellar images which no doubt owe their existence to the imperfection of imaging and image analysis techniques – aside from the earth's atmosphere. The number of artifacts increases towards the Milky Way fields, in the vicinity of the SMC, seen in the lower middle of the total field, as well as in the LMC which just touches some fields on the eastern side. Other dense regions, such as star clusters and clusters of galaxies, are not so obvious. Surprisingly, the plate edges are well delineated by artifacts. Because of the generally small overlap regions of the plates, all scans have been made over somewhat larger regions than covered by useful data, just to be sure not to loose information. Cutting the edges properly is then a software process which lists the plate frames as artifacts.

## Stars

Figure 3 shows the distribution of stars. The most striking feature is the rapid steepening of the density gradient towards the Milky Way region at the eastern and western edges of the total field, apparent fromt the dramatic change in colour in this false colour presentation. Noticeable changes in star density across even short distances are indicated by colour changes within individual plates. In addition, each as yet uncalibrated plate has its own zero point and magnitude limit, leading to systematically enhanced or reduced numbers of objects, as is indicated by different hues in the central part of the field. They will disappear after proper plate calibration, which is possible as soon as all CCD standards are obtained. Nevertheless, the overall impression even of the uncalibrated plates is one of a smooth stellar background with no trace of large-scale structures.

## Galaxies

The galaxies whose distribution provides an observational stepping stone for cosmology, are shown in Figure 4. Again, the magnitudes are uncalibrated and the plates have different magnitude limits. Because the galaxy number densities show no systematic gradients over large areas, the patchiness can be removed – just for viewing purposes – by presenting each one of $10^4$ bins per plate normalized to the mean number density over a given plate. At the low resolution of the image shown here, the general pattern is not affected by this procedure. Quantitative analysis, of course, has to wait for proper plate calibration.

It is rewarding to see that the distributions of stars and galaxies are quite different – as is expected. It gives us

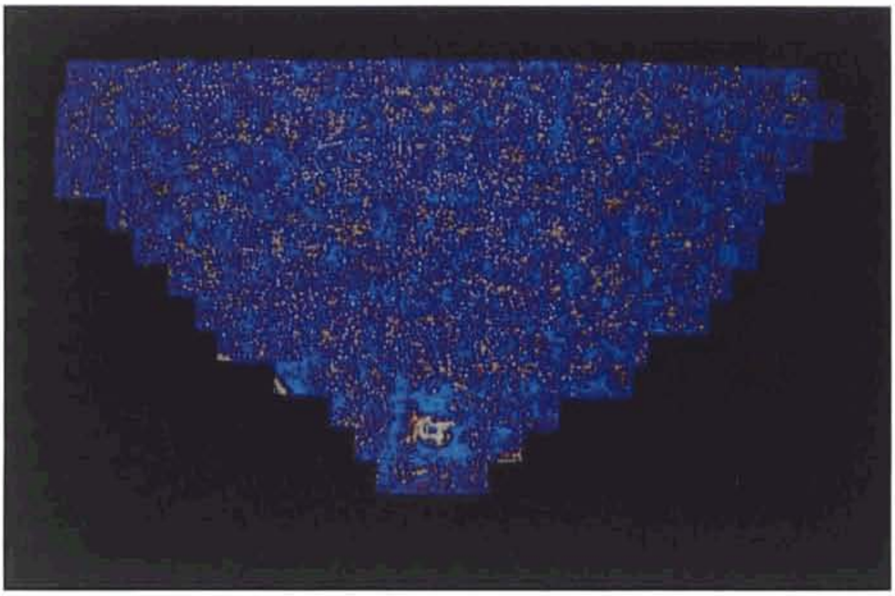

Figure 4: *The distribution of galaxies on 216 plates of the ESO/SERC-R-Atlas. The intricate pattern known from other galaxy surveys is clearly seen. A small percentage of blended stellar images in the rich regions of the SMC and LMC shows up as misidentified galaxies. The apparent decline of contrast towards the Milky Way region is an artifact due to increasing numbers of misclassified overlapping stars and the normalization procedure described in the text.*

some confidence that the tricky process of star/galaxy separation works well. Visual checks of our method suggest that the automatic star/galaxy separation yields errors smaller than 10% at reasonably high galactic latitudes.

An automized comparison of the data from the R-plates with those from the J-plates has the advantage that the classification of all objects can be checked. Although the quality of the procedures is not tested by the comparison, the reliability with which the procedures work on the same object at different brightness levels and on plates taken under different observing conditions will become apparent. Another test is the comparison between automatically determined morphological types of galaxies on R- and J-plates. Its outcome will be more difficult to interpret because of additional physical effects. It will be interesting to see whether a colour dependence of morphological classification can be quantified.

## The Stage and the Plot

Dwelling on basic details, such as removing artifacts and struggling with photographic magnitudes, while results from the red survey are still in the making, reminds us of showing a stage in daytime.

Nothing looks glamorous and the actors are still rehearsing. We hope, however, that the scenery promises to become a worthy background for a great production. The plot will be presented in the version offered by the ESO/SERC Atlas which, together with powerful measuring machines and computers, has opened new possibilities for staging the drama of the universe.

The topics and papers given below are acknowledgements to our coworkers who are not mentioned as coauthors.

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# First Technical Run of the COME-ON-PLUS at the ESO 3.6-m Telescope

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From December 6 to 15, 1992, the new VLT adaptive optics prototype system, the so-called Come-On-Plus system, was tested at the 3.6-metre telescope (Fig. 1). This system [1, 2, 3] is an upgraded version of the previous prototype, Come-On [4].

The main characteristics are its 52-actuator deformable mirror, the photon counting wavefront sensor using an Electron Bombarded CCD and the modal control [1, 2, 3]. During this run two visible wavefront sensors were used, one for visible magnitudes up to 9.5 and one for visible magnitudes up to 16. The imaging channel was equipped for this run with a 32×32 InSb infrared camera from the DESPA/Observatoire de Paris working in J, H, K, L, M bands. The scale was 50 milliarcsec/pixel which provides a field of view of 1.6 arcsec.

Long and short exposure images in the J, H and K bands were obtained with

Figure 1.