PROFILE OF A KEY PROGRAMME:

A Survey of Nearby Clusters of Galaxies

A. MAZURE[1], E. ESCALERA[1], P. KATGERT[2], G. RHEE[2], R. DAN HARTOG[2], P. DUBATH[3], P. FOCARDI[4], D. GERBAL[5], G. GIURICIN[6], A. BIVIANO[6], B. JONES[7], O. LEFEVRE[8], M. MOLES[9], J. PEREA[9]

[1]Université de Montpellier – CNRS, France; [2]Sterrewacht, Leiden, Netherlands; [3]Observatoire de Genève, Switzerland; [4]Dipartimento di Astronomia, Bologna, Italy; [5]Observatoire de Meudon, France; [6]Osservatorio di Trieste, Italy; [7]Nordita, Copenhagen, Denmark; [8]CFHT, USA; [9]Instituto de Astrofísica, Granada, Spain

1. Introduction

Detailed analysis of the structure of a large sample (well representative of all richness and morphological classes) of rich clusters of galaxies may provide several constraints for theories of the formation of large-scale structure on scales of the order of a few Mpc.

Since the overall relaxation time of a cluster is larger than the Hubble time, it could be expected that present-day clusters are at best partially relaxed – a situation which could be revealed by the presence of subclustering.

The convincing detection of dynamically significant substructure in clusters may put severe constraints on the scenarios of formation and on the shape of the initial fluctuation spectrum. However, this detection, as well as dynamical analysis, requires a large number (at least 100) redshifts per cluster.

Peculiar velocities of clusters with respect to the Hubble flow could in principle reveal the characteristics of the mass distribution on larger scales (such as the inter-cluster distance). The Cold Dark Matter Scenario, however, does not predict large-scale peculiar velocities with respect to the Hubble flow for rich clusters. It therefore appears desirable to confirm e.g. in the Southern galactic hemisphere the large-scale peculiar motions which have been claimed to exist (Bahcall et al., 1986) but questioned by other authors. Again, this requires a suitable sample and several redshifts per cluster.

2. Definition of an Observational Programme

The preceding motivations have led us to design an observational programme which has been accepted by ESO as a Key Programme. We have thus selected a sample of clusters of galaxies from the revised and South extended Abell catalogue (Abell, Corwin and Olowin, 1989); the sample can actually be divided into two subsamples since the selection has been performed following two different criteria. On the one side we needed a set of clusters sufficiently rich to allow a meaningful structural and dynamical analysis, possibly covering almost equally all Bautz-Morgan morphological types and having a redshift of $\cong 0.05$. This last requirement ensures that we explore several core radii and cover a sufficiently large range of magnitudes on a field of 30 arcmin (Optopus field). We found 30 clusters (the so-called "structure" clusters) satisfying all these requirements. On the other side, we selected 100 clusters (the "peculiar" clusters) which are expected to form a complete sample up to z=0.1 in the Southern galactic hemisphere. This large subsample will be used to map and analyse the large-scale peculiar motion field. There is a partial overlap (12 objects) among the two subsamples, giving a total of 118 clusters for the whole sample. We plan to obtain spectroscopy and photometry for about 150 members of the "structure" clusters and 30 to 50 members of the "peculiar" ones. Spectroscopy is being obtained by using the OPTOPUS instrument at the ESO 3.60-m, whilst CCD photometry (Danish 1.54-m) is required in order to calibrate our photographic one.

For each selected cluster, catalogues of galaxies have been obtained by scanning photographic plates (glass copies of the red PSS for the northern clusters and film copies of the SRC survey for the southern ones) using the Leiden ASTROSCAN plate-measuring machine. Objects are selected around the cluster centre within several Abell radii. The typical size of a scanning region is about one square degree for "peculiar-motion cluster" and 4 square degrees for "structure" ones. By setting a threshold value (typically at 5 times the sky noise above the background) a list of objects is then produced. For each object the following final parameters are kept: (i) the centre of gravity position, (ii) a photometric parameter, the logarithm of which is in good approximation a linear function of magnitude, (iii) the second moment of the density distribution, which is a measure of the size of the image, and (iv) the number of image pixels which have a photographic density above the detection threshold. Star-galaxy separation is performed by plotting: second moment of the density ver-

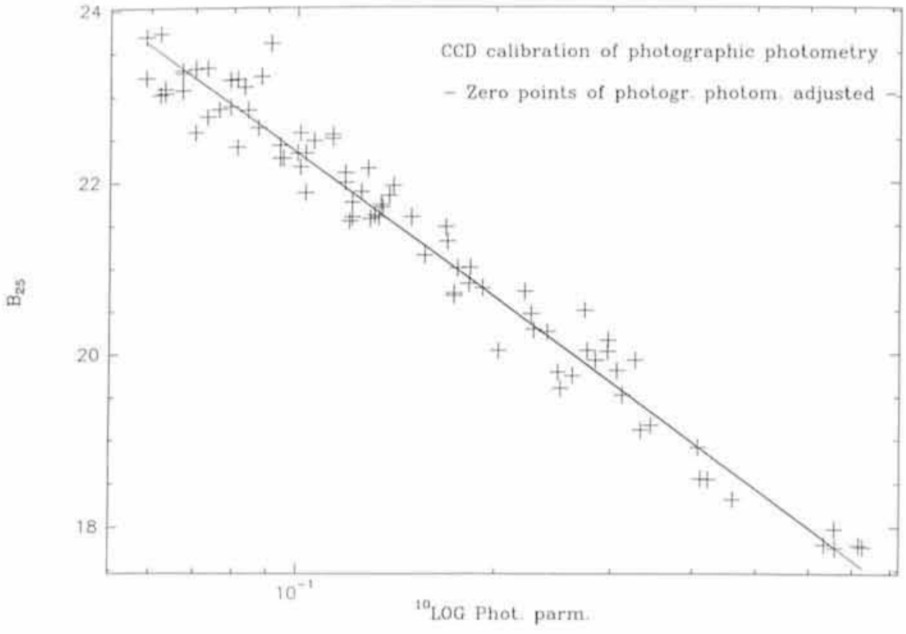

Figure 1: *Photometric parameter versus B magnitudes for the combined data. Straight line corresponds to the best fit.*

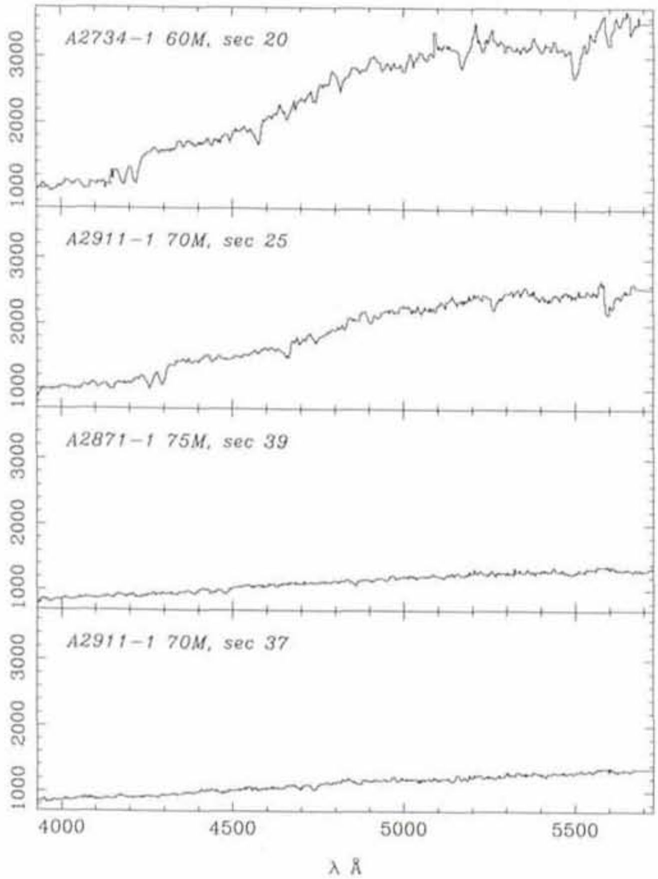

Figure 2: *Four calibrated spectra of decreasing quality.*

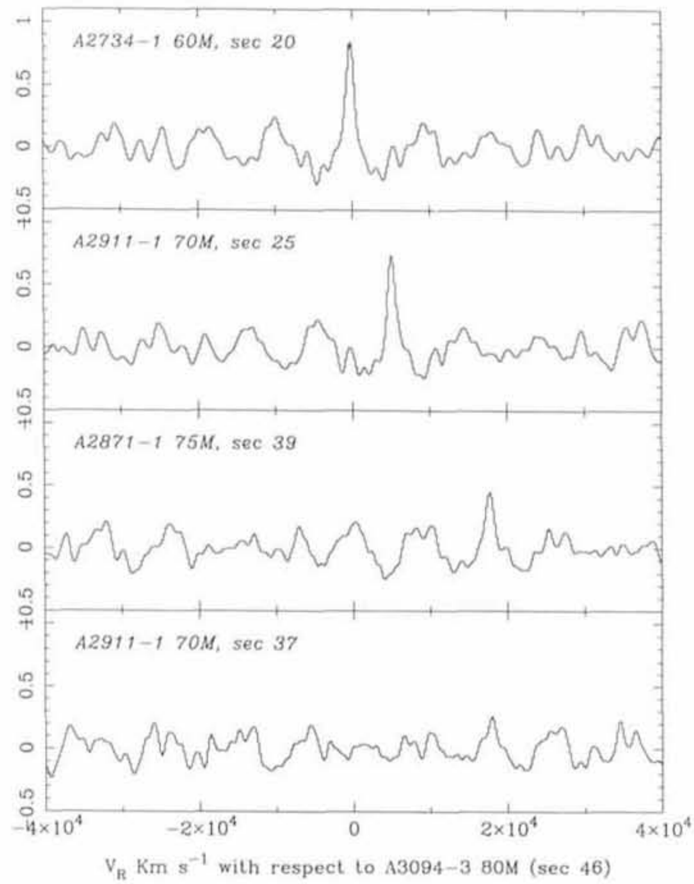

Figure 3: *Correlation function peaks for the spectra of Figure 2 using a bright galaxy of our sample as template.*

sus photometric parameter. The stars' locus is well defined and separated from the galaxy one. Anyway, unresolved double stars and bright saturated galaxies can fall in unproper positions. Visual inspection of the candidate galaxies and of the bright stars is performed in order to avoid misclassification.

The final catalogues are then used to produce OPTOPUS files in order to punch the plates (30 and then 50 fibers/plate) for each OPTOPUS run.

3. Observations and Reduction

So far, observations were made in September and October 1989, March and April 1990 and September and October 1990 both for spectroscopy (3.6-m + OPTOPUS) and CCD photometry (1.54-m Danish).

CCD photometry is being performed in order to calibrate our photographic photometry.

For this purpose, CCD frames have been taken for each OPTOPUS field, covering the largest possible range in magnitudes so as to minimize errors in the calibration. CCD frames are taken in both B and R colours, exposure times being typically of 15 min in B and 5 min in R. Several standard stars and secondary fields were also observed during the night. Photometric observing runs suffered partial bad weather or bad conditions (seeing of about 4 arcsec in October 1989) and technical problems (pointing was lost several times due to computer crash) leading however to a reliable bulk of data, but on a smaller than expected number of objects. These CCD data have been processed using the IRAF package and a faint galaxy photometry package (Lefevre et al., 1986) installed on SUN workstations at CFHT. The reduction yields photometric parameters (positions, ellipticities, R_{25}, B_{25}...) for several hundred of galaxies. These B and R magnitudes were then used in order to calibrate the photometric parameter P produced by ASTROSCAN. Taking into account the relative magnitude offset from plate to plate, a linear relation between B_{25} and log P was fitted to the combined data (goodness of fit 0.98) and shown in Figure 1. From this picture, it turns out that the dispersion in the correlation between photographic and CCD magnitudes is of about 0.25 magnitudes and that the limiting magnitude of our spectroscopic survey is about $B_{25} = 21$.

The OPTOPUS multifiber instrument coupled with Boller and Chivens spectrograph has been used at typical resolutions of about 10 Å and spectral range between 3900 and 5900 Å. Since March 1990 the spectroscopic efficiency has been greatly increased thanks to a new optical configuration, an increased number of fibers (50 instead of 30) and the possibility of plugging the fibers in the plate at the desk of the observing room during the previous exposure acquisition. More recently (October 1990) the availability of the new Tektronik CCD detector, having a much lower read-out noise, gave another significant improvement at the system overall efficiency making OPTOPUS a real "industrial-era" z-machine.

Spectroscopic data reduction, which includes fibers extraction, wavelength calibration, continuum removal and cross correlation, has been performed by means of FIGARO routines, well suited for our aim, installed in Granada and Montpellier on Vax stations. Wavelength to pixel solution is obtained on a long arc (20 mn), exposure of an He-Ne lamp taken at the beginning of each night so as to ensure a high S/N even of faint features. Relative shift is computed and applied on each subsequent arc frame. Arc frames were taken both before and after the cluster exposure to minimize errors induced by mechanical flexures of the instrument which turn out anyway to be negligible.

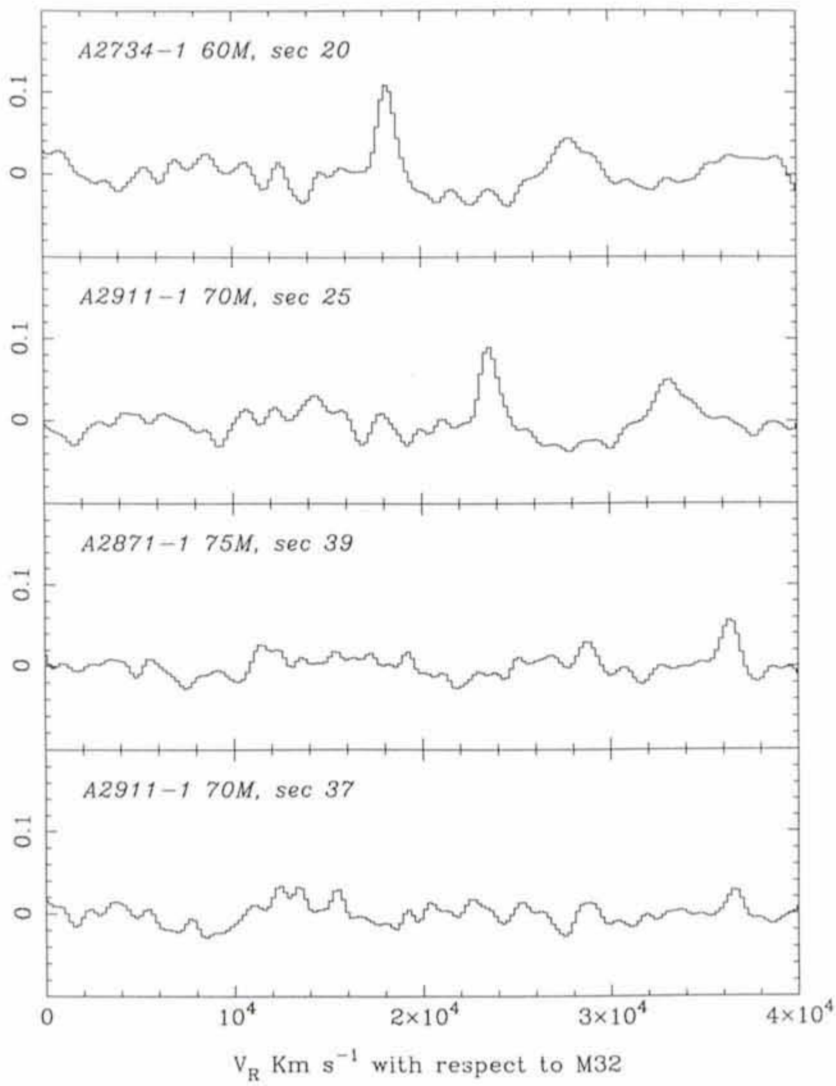

Figure 4: *Correlation function peaks for the spectra of Figure 2 using M32 as template.*

The wavelength solution obtained by a 3rd order polynomial fit to our data leads to a typical rms per frame of 0.08 to 0.1 Å (maximum value being about 0.3, 0.4 Å). To illustrate the quality of our data, a set of wavelength calibrated spectra of decreasing quality is shown in Figure 2. The redshifts were then determined by cross-correlation technique. We found that best results are obtained using as template a galaxy spectrum belonging to our sample and having a high S/N, as can be seen by comparing Figures 3 and 4, which show the correlation peaks obtained correlating the spectra of Figure 2 with a bright galaxy belonging to our sample and with a standard velocity template (M32). The zero point can be subsequently determined by cross-correlating the galaxy template with a few well-known velocity objects (like e.g. M32, NGC 4111) of which we got spectra with different instruments. So far, about 3,000 spectra have been collected. The efficiency (number of actually determined velocities/number of spectra) has increased from about 60% (the first runs) to about 85% (the last ones) due to better set-up and a more efficient acquisition device leading presently to about 2,000 measured velocities. All these data have been reduced and a histogram of radial velocity for the whole sample is shown in Figure 5. It can be seen that the data are peaked at $z = 0.05$ as we may expect due to our selection criteria. The errors on the velocities are obtained following Tonry and Davis pre-

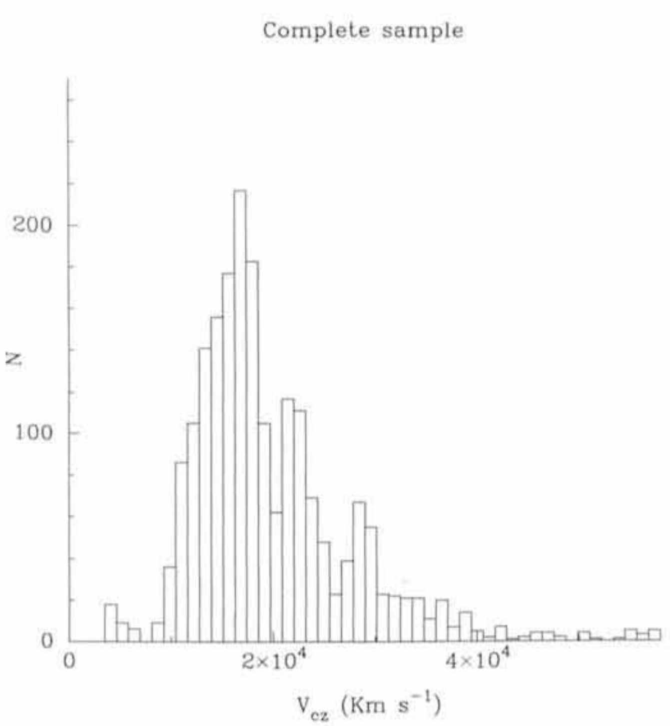

Figure 5: *Histogram of the velocities for the presently available data.*

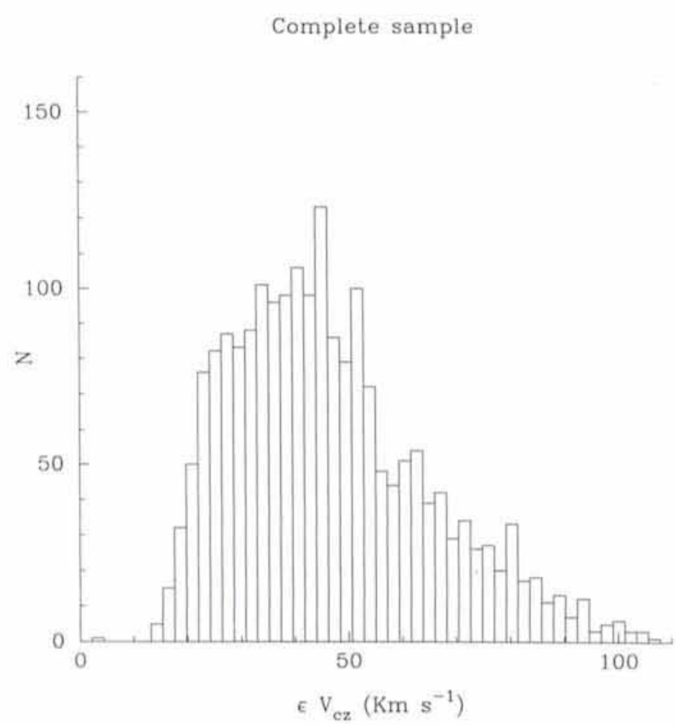

Figure 6: *Distribution of the errors in the velocities for the presently available data.*

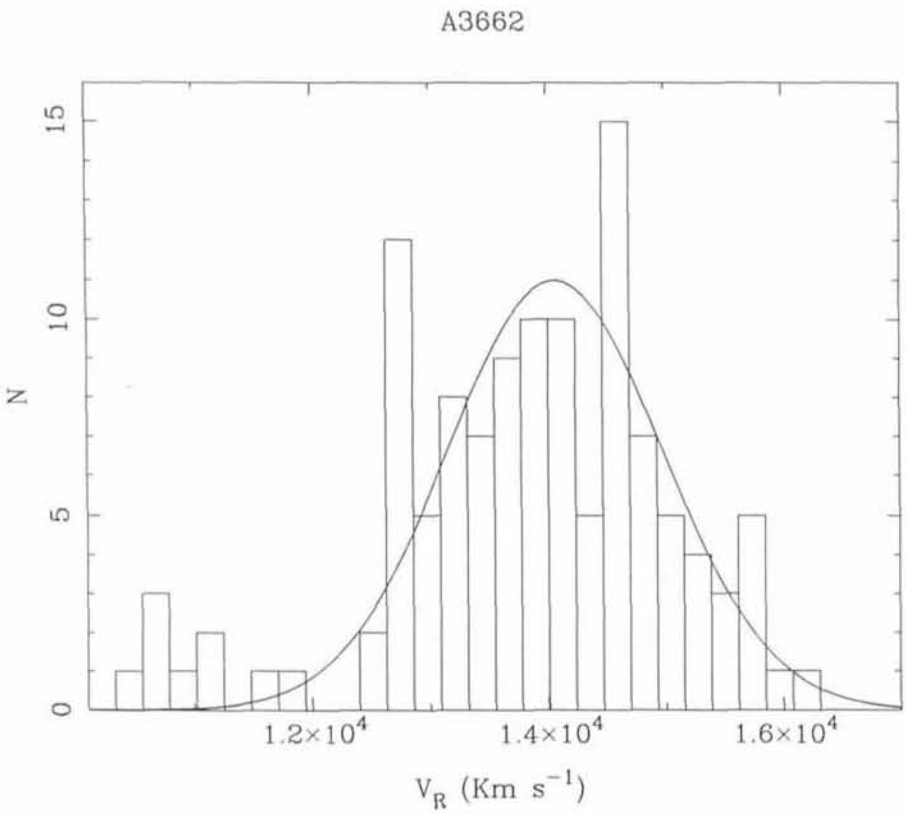

Figure 7: *Distribution of the velocities obtained in one field of the cluster A3662; a gaussian fit is superimposed.*

scriptions (1979); we get a typical value of 40 km/sec as can be seen in Figure 6 in which the histogram of the errors for all the available data is shown. It should be noted that the large scatter is due to a substantial improvement of the error value which decreased from about 60 km/sec for the first runs to about 30 km/sec due to the increased S/N of the last-run spectra. Comparison to external data is under progress. Finally, in Figure 7 we show the distribution of velocities obtained in one field of the cluster A 3662; this is a "structure" cluster, that is a cluster on which we plan to perform detailed dynamical analysis. More data are thus going to be acquired, nevertheless, even from this single field we can suspect the presence of a complex structure (two peaks?). Further data will allow a check on the reality of this feature.

In conclusion, the aim of our project is to give new results both on the structure and dynamics of clusters of galaxies and on their peculiar motions with respect to the Hubble flow. For these reasons we have drawn a composite sample of more than 100 clusters, for which we plan to collect a large bulk of spectroscopic and photometric data. The Optopus multi-fiber instrument is particularly well suited to our aim. It would not have been possible to design such a large project without a large amount of granted telescope time as it is in the philosophy of the ESO Key Programmes.

References

Abell, Corwin, Olowin, *Ap. J. Suppl.*, **70**, 1, 1989.

Bahcall, Soneira, *Ap. J.*, **311**, 15, 1986.

Lefevre, Bijaoui, Mathez, Picat, Lelievre, *Astron. Astroph.*, **154**, 92, 1986.

Tonry, Davis, *Astron. J.*, **84**, 1511, 1979.

A Progress Report on the VLT Instrumentation Plan

S. D'ODORICO, J. BECKERS and A. MOORWOOD, ESO

1. The VLT Instrumentation Plan

The Very Large Telescope of the European Southern Observatory is the most ambitious project in the history of ground-based optical-infrared astronomy. With its four 8-m telescopes to be operated as separate units and in a combined mode and the associated array of smaller telescopes for interferometry it represents a unique technical and managerial challenge. Within the overall project, the procurement, installation and operation of a set of instruments at the different foci of the array are in itself an effort much larger than anything done in the past at ESO or at any other observatory. At the same time it is crucial to achieve the scientific goals of the project. For this reason the definition and procurement of the first-generation instruments was tackled very early in the project schedule. In June 1989, ESO elaborated and distributed widely in the community a Preliminary Instrumentation Plan which was based on recommendations by the VLT Working Groups, set up to give advice on the scientific use of the VLT, and technical work carried out at ESO. Based on the responses and comments to this Plan, ESO prepared a revised version which was adopted by the Scientific and Technical Committee in March 1990. This Instrumentation Plan now includes ten instruments and two replicas and a tentative schedule for their implementation at the VLT. Some of the instruments are relatively well defined, for others preparatory work is under way to arrive at a complete set of specifications. A review article on the VLT instruments has been published in the *Journal of Optics* (1991) Vol. **22**, p. 85. Excluded from this plan is the instrumentation to be designed for the VLT Interferometer. Figure 1 shows the mechanical structure of the unit telescope and the foci positions and Table 1 lists the various instruments with their assigned location. The complement of instruments at the first two telescopes can be considered as relatively frozen but the information on the last two telescopes is indicative and might be updated as the project evolves.

A cornerstone of the VLT Instrumentation Plan is the participation of institutes in the ESO member countries in the construction of most of the instruments. This is a major departure from the current situation which sees the quasi-totality of the installed ESO instruments to be the result of internal development. The new approach is dic-