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The VLT Goes to Paranal!

The Council of the European Southern Observatory, in session on December 4, unanimously decided that the world's largest optical telescope, the 16-metre equivalent Very Large Telescope, shall be placed on Cerro Paranal, an isolated mountain top at 2664 m altitude in the central part of Chile's Atacama desert, some 130 kilometres south of the town of Antofagasta and 12 kilometres from the Pacific coast.

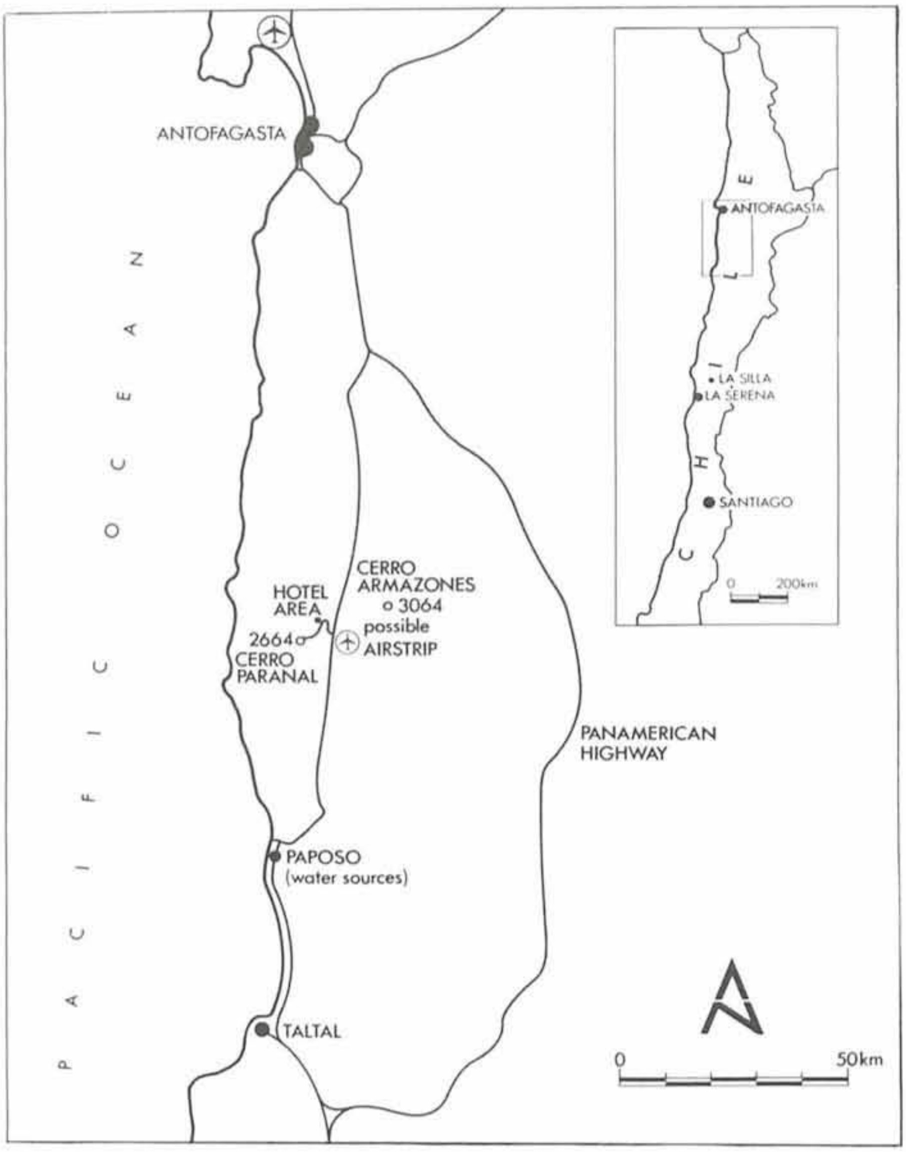
In anticipation of the choice of Cerro Paranal as the future site of the VLT Observatory, the Chilean Government has donated a 725 km^2 area around Paranal to ESO in order to ensure the continued protection of the site against all adverse influences, in particular light pollution and mining activities.

For more than six years, continuous, accurate measurements have shown that Paranal is the best continental site known in the world for optical astronomical observations, both in terms of

This aerial picture of Cerro Paranal was taken in late 1990 from the south. The Pacific coast is to the left, at a distance of 12 km. The constructions at the left are the living quarters for the site survey team, in place since 1983. On the top of the mountain various instruments are installed which permanently monitor the atmospheric quality and perform meteorological measurements.

number of clear nights and stability of the atmosphere above.

The meteorological and climatological investigation incorporated a detailed comparison between Paranal and the present site of ESO's telescopes, La Silla, by means of identical measuring equipment. Despite La Silla's worldwide reputation for excellent observing conditions, Paranal was found to be even better, mainly because of its location in a more stable and drier climate in the most arid part of the Atacama desert. *(continued on page 67)*



Superseeing at Paranal

The engineers who build the ESO 16-m equivalent Very Large Telescope and its associated instrumentation are facing great challenges ahead because the sites in the Chilean Atacama desert may be even better than originally thought.

As the ESO seeing monitors (DIMM) have now reached their nominal accuracy, the sites under study have begun to reveal their very best observing qualities. It is imperative that the VLT must be able to take full advantage of nights of superb seeing and transparency which will be used as performance criteria for the total error budget of the telescope after completion.

Though hourly seeing averages better than 0.5 arcsec are not uncommon at Cerro Paranal – this happens during approximately 16% of the total observed time, with a median seeing of 0.66 arcsec over the year – the longest periods of excellent seeing are the easiest to use in a semi-flexible scheduling mode of operation. In that respect, a record of excellence was hit this September when the seeing was better than 0.5 arcsec during a full night, including three consecutive hours better than 0.3 arcsec.

The site monitoring will continue after the decision on the location of the VLT now taken. It will focus on three major tasks:

- construction of a data base for the site parameters which will be used for the development of a prediction model for flexible scheduling.
- analysing the effect of local sources of thermal pollution like the wake of buildings, of metallic structures, and of electronic units, and
- pursuing research and development work on the monitoring of parameters related to interferometry, such as speckle lifetime and outer scale of turbulence.

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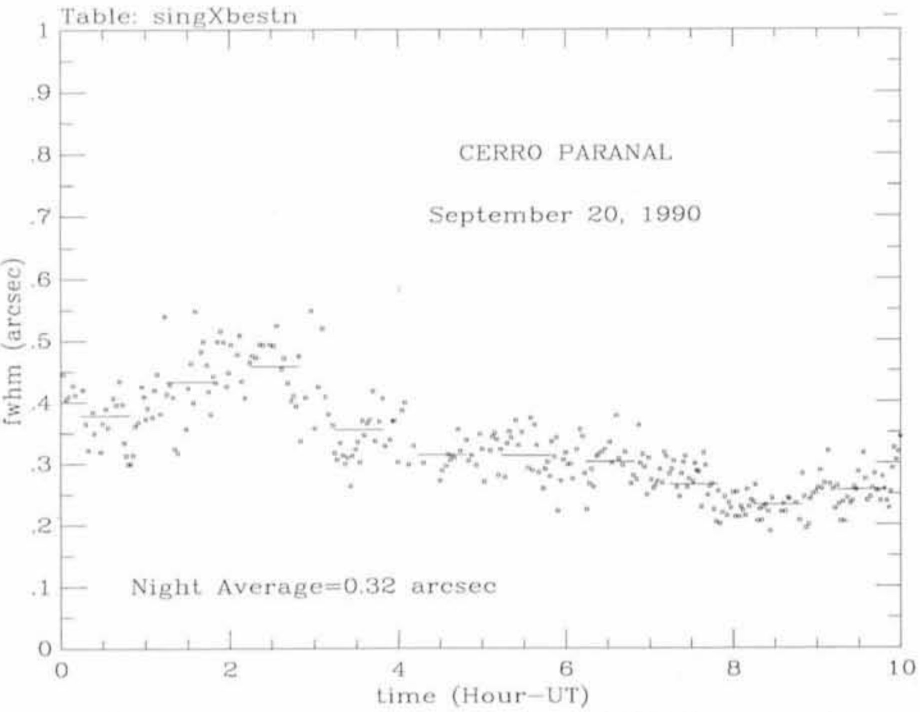

Figure 2: *New seeing record at Cerro Paranal: the dots are individual measurements by the DIMM; horizontal bars correspond to one hour linear binning. The seeing is defined as the FWHM at zenith, at wavelength 0.5 μm, and is measured 5 metres above ground on the summit.*

An Optical Counterpart of SgrA* at the Galactic Centre?

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The nature of the very Galactic Centre is still mysterious: It could be a cluster of seemingly normal young luminous stars, or a somewhat massive black hole surrounded by an accretion disk (see Genzel and Townes, 1987, *Ann. Rev. Astron. Astrophys.* **25,** 377) – or even something more exotic. The characteristic feature of the innermost region is the coincidence within 2″ (i.e. 0.1 pc) of the unresolved nonthermal radio source Sgr A* with the peak of the diffuse infrared stellar light distribution. The fact that there is no discrete infrared counterpart to Sgr A* adds to the curiosity as to the relation of Sgr A* with the Galactic Nucleus. A detailed optical study of the region and the candidate sources is hindered by the enormous foreground extinction reaching 30 mag in the visual. However, by pushing as red as CCD's practically allow (i.e. near 1 μm), one can reduce the extinction to about 14 mag and at the same time increase the detectability for intrinsically blue sources – ultimately with the hope of detecting a "hot" counterpart for Sgr A*.

On July 24, 1990 we used the 3.5-m NTT telescope on La Silla to image the Galactic Centre region through a Gunn z filter (ESO # 417, cut on 920 nm, long pass) using EFOSC 2 with a Thomson chip, 1024 by 1024 pixels, image scale 0.3 arcsec/pixel, and a sensitivity of 6% at 950 nm. The total response produces a bandpass of 100 nm centred at 950 nm with a peak throughput of 3.3%. However, since the bandpass is nominally open in the red, albeit with very low throughput, the effective wavelength may be shifted towards or even beyond 1 μm. This is because the high absolute values of the extinction encountered towards the Galactic Centre (A_V up to 30 mag) imply very high differential reddening effects, which may easily overwhelm the decrease in the CCD response.

The seeing was mediocre but, more importantly, very stable (1.″05 FWHM). With this seeing we oversampled the PSF by a factor of 3. We obtained five frames with an exposure time of 40 min each and random 10–20% field centre offsets, plus dome and sky flat fields. Careful alignment including a resampling by another factor 4, and rejection of detector defects and cosmics, gave us a coadded 200 min effective exposure. A 10″ by 12″ window from the summed frame is shown in Figure 1. The two brightest sources are IRR1 and IRR2 of 17.6 mag at 980 nm (Henry et al., 1984, *Ap. J.* **285,** L27). The limiting magnitude of the image is 24 mag at 950 nm (sky level 25000 e^- per original pixel; 125000 e^- for IRR1 and IRR2). This is the deepest sub-1 μm) CCD image ever obtained of the Galactic Centre region.

Given the high signal-to-noise ratio, we were able to apply image deconvolution techniques on far-red images of the Galactic Centre region for the first time. We used the Lucy algorithm of iterative deconvolution (Lucy, 1974, *A.J.* **79,** 745), implemented into the IDL environment by H.-M. Adorf (ST-ECF). The largest field size treated was 512 by 512 image elements, corresponding to 36″ by 36″. The gain in resolution obtained after 50 iterations was a factor 2.5 (i.e. 0.″4 FWHM for point sources). During deconvolution, the image of the star IRR2 (the upper left one of the two bright objects in Fig. 1) remained very circular and unresolved, while IRR1 (the bright star in the centre) became elongated from SE to NW. A slight indication of this can also be seen in the original. Figure 2 shows the sharpened frame, modified by subtraction of a scaled unresolved stellar image from the centre of gravity position of IRR1.

To our surprise, two faint sources (20-21 mag) were hidden behind the seeing disk of IRR1. We designated the slightly fainter SE object GZ-A and the brighter NW component GZ-B. It is remarkable that GZ-A and GZ-B coincide with the position of Sgr A* (indicated by the white cross in Fig. 2) to within 0.″3 and 0.″5, respectively. Transformation of the absolute radio position of Sgr A* onto our frame (with an r.m.s. error of 0.″5) was achieved through the 950 nm counterparts of a dozen previously known 2-μm sources, most of which have been detected here for the first time. Among these are IRS7 (the object due north of Sgr A* near the upper boundary of Fig. 2) with a total of 2000 e^- recorded,

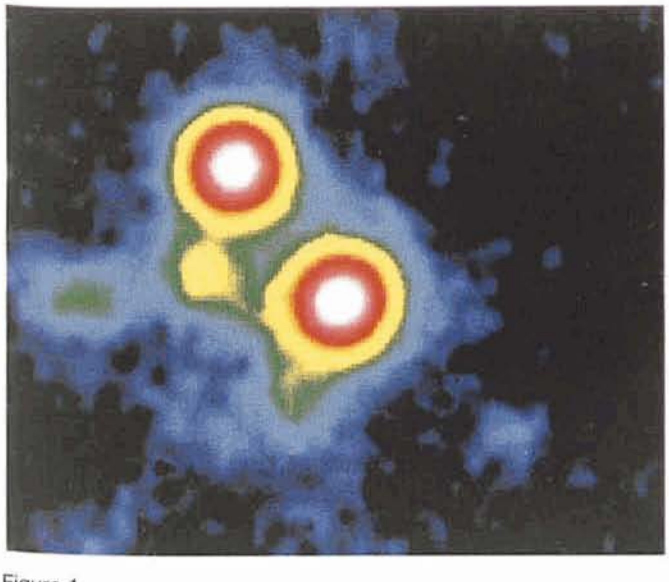

Figure 1.

Figure 2.

as well as IRS9, IRS13, IRS21, IRS29, IRS35 (cf. Tollestrup et al., 1989, *A.J.* **98,** 204). GZ-B may be identical with IRS16NW, while GZ-A seems to have no prominent 2-μm counterpart.

Because of the near coincidence of GZ-A and GZ-B with Sgr A*, it may well be that the two sources are indeed in the Galactic Centre. If this is the case, the observed magnitudes could be consistent with either a group of young stars or the optical radiation from an accretion disk around a black hole. The estimated luminosity in both cases would be of order $5 \cdot 10^6 L_\odot$. A nonthermal origin of the radiation, in particular for GZ-A, cannot be excluded either. Also the possibility of chance alignment with faint foreground objects or a physical companion of IRR1 cannot be rejected at present. Clearly, these new objects are interesting enough to deserve further detailed observations: high angular resolution imaging at different wavelengths, spectroscopy and perhaps even polarimetry.

PROFILE OF A KEY PROGRAMME

Optical Identification Content of the ROSAT All Sky Survey

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On June 1, 1990 the X-ray satellite ROSAT was launched from Cape Canaveral on a Delta II rocket (Fig. 1). The project is a collaboration between Germany, the United States and the United Kingdom with the Max Planck Institute for Extraterrestrial Physics (MPE) as the leading scientific institution. During the first 6 months of the mission, ROSAT is performing the *first all-sky survey* made with an imaging X-ray telescope. The data rights for this survey lie with MPE.

Among the instruments on board ROSAT (Fig. 2) is the Positional Sensitive Proportional Counter (PSPC) which will be used for the all-sky survey. This imaging detector has a low resolution ($\Delta E/E = 0.4$) spectral capability over the soft X-ray energy range from 01.–2 keV. This energy range is considerably softer than that of the Einstein Observatory, so that one might confidently expect different proportions of different known classes of X-ray sources to be detected and, of course, even new classes of objects.

On the basis of the Einstein Observatory Extended Medium Sensitivity Survey (EMSS) one would expect to detect ≈ 100,000 X-ray sources over the whole sky. This will enable the acquisition of X-ray data for large samples of various classes of astronomical objects, in particular stars, AGN and clusters of galaxies. Obviously, one cannot hope in the foreseeable future to optically identify 100,000 sources. Our proposal aims at defining and observing a viable subsample of the ROSAT survey in order to completely identify the X-ray sources in that sample.

During the all-sky survey, ROSAT will scan along great circles of constant ecliptic longitude roughly perpendicular to the position of the sun. As the sun moves along the ecliptic, the scan path of the satellite follows and after a period of 6 months the whole sky will be covered. The exposure time varies from ≈ 600 seconds near the ecliptic to 30,000 seconds near the ecliptic poles. Other effects mainly involving background radiation and hydrogen column density will modify this sensitivity for detecting sources in a predictable manner. Figure 3 shows a small part of the survey, a strip of $\approx 6^\circ \times 13^\circ$ centred at $\alpha = 5^h30^m$, $\delta = -57^\circ$, accumulated from five days of data from August 9 to August 14. The area shown consists of 26 square degrees on the sky and therefore represents ¼ of the ESO Key Project Field II. The bright source in the lower right hand corner is LMC X-3. So far 34 sources have been detected in this section of the all-sky survey. For weak sources (< 20 counts) a 90% confidence error radius < 1 arcmin is expected, while for strong sources this radius would be 30–40 arcsec.

The average X-ray flux limit of the ROSAT survey will be roughly 3×10^{-13} erg/cm^{2}s. The results of the identification process will provide the basis for statistical studies of the X-ray properties of stars, quasars, AGN, BL Lac objects and clusters of galaxies. In particular, log N-logS and X-ray luminosity functions will be determined. This unbiased sample will also serve to calibrate all other samples selected from the all-sky survey. The existence of the Parkes and Australia Telescope radio surveys will permit correlations with radio properties.

Our sub-sample covers an area of 575 square degrees divided into 4 regions from which, on the basis of the EMSS at high galactic latitudes, we would expect to detect ≈ 380 extragalactic objects and ≈ 610 stellar objects in our Galaxy. With 380 objects, we will have the basis for statistical studies of the proportions of quasars, AGN, BL Lac objects and clusters of galaxies. Since the areas have been defined partly because of optical work planned or in progress by others (e.g. objective prism surveys, multi-colour surveys at low N_H column density, and other multi-colour surveys) there is also the possibility of comparing samples made using completely different criteria. For example, the proportion of X-ray quiet to X-ray loud AGN is of some interest both from the point of view of physical properties of AGN themselves and from the point of view of cosmology. Another important and topical question is that of the large scale structure and distribution of extragalactic sources. Equally important will be the follow-up programme of individual objects that emerge as a result of the particular energy range of this survey.

Among the stars, again using the EMSS as a guide, we might expect the following proportions of objects: dMe, dKe – 20%, non-accreting, active binaries – 15%, cataclysmic variables – 2%, pre-main-sequence stars – 4%, B stars – 4%. This leaves >50% in a loose category of normal, solar-type stars. What proportion of these may be white dwarfs is not easy to predict, but it could be quite high as a result of the soft energy range of the PSPC detector. This may prove to be a highly efficient means of detecting white dwarfs.

Our approach to efficient optical identification will be as follows. In conjunction with the detected X-ray sources and their positional error boxes, we propose to use the following type of data, most of which are already in hand and require no further telescope time.

Candidate identification for the all-sky survey will be made by cross-correlating with the Royal Observatory Edinburgh's (ROE) already digitized catalogue of the SERC Southern Sky J Survey. However, since there is expected to be on average more than one confusing star as well as the correct identification per X-ray error box, we propose to use colour information obtained from Schmidt UR and existing J plates to isolate the most likely candidate. Since the Einstein and EXOSAT deep surveys indicate that 80% of all identifications are likely to be quasars, AGN or M dwarfs, we can separate M dwarfs by their very red colours, and redshift $z < 2.2$ quasars (which will comprise the vast majority of the quasars) by their UV excess. Prior identification of brighter M stars would prevent longer integrations on fainter confusing stars. An increase in efficiency of a factor 2 is expected by using colour information.

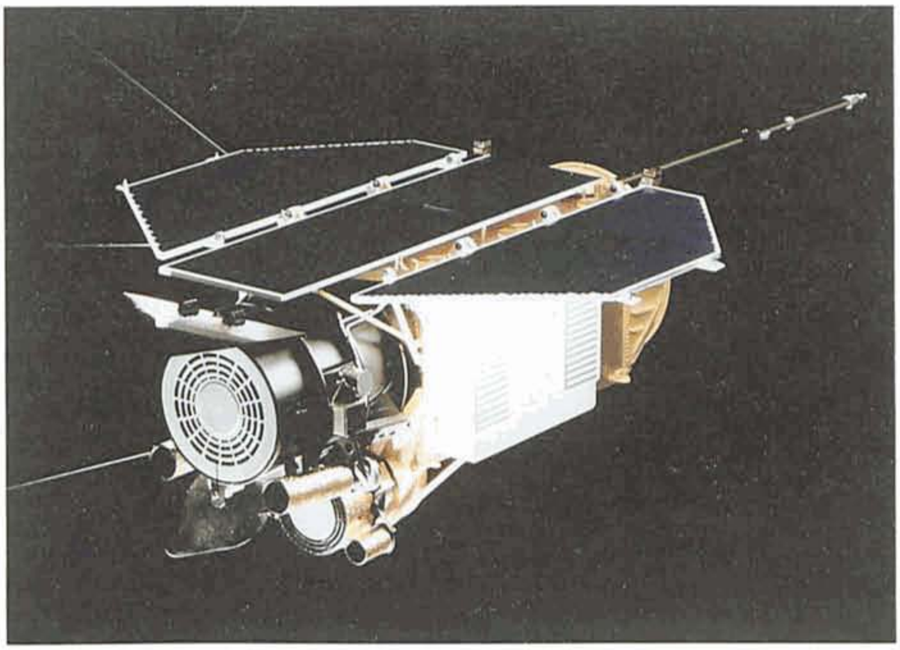

Figure 2.

Figure 1.

Digitized measurements from U and R plates covering the selected areas are virtually complete, while the J band data already exist in catalogue form.

Spectroscopy will be carried out on a variety of telescopes according to the brightness of the candidates. Using the EMSS as a reference, we estimate that of the expected 990 X-ray sources in our sample, 790 will be brighter than B = 18.5 and 200 will be fainter than 18.5 (this may be an underestimate of the proportion of fainter sources in the ROSAT survey which is expected to go deeper and to detect fainter extragalactic sources).

The 200 or more sources fainter than 18.5 must be observed with the ESO 3.6-metre and NTT. Of the 790 objects brighter than 18.5, about 325 will be stellar objects brighter than B = 15 and will be observed at low resolution with the ESO 1.52-m telescope. 230 candidates can be observed with FLAIR-2 on the UK Schmidt telescope. FLAIR-2 is a fibre-fed spectrograph which will be able to obtain spectra of up to 100 objects per exposure down to B ≈ 18.5 and agreement has been reached to ride piggy-back on another programme working at the SGP. The remaining 235 candidates in this magnitude range in the other selected fields would need to be observed with the 2.2-m, 3.6-m or NTT.

In addition, experience from the EMSS follow-up has shown that often more than one stellar object with a reasonable f_x/f_v ratio is associated with one X-ray source. The secondary criterion for stellar X-ray identification is the presence of chromospheric emission lines or rotationally broadened absorption lines in the spectrum of the star. This will require higher-resolution spectroscopy particularly for RS CVn and W UMa binaries and solar-type stars with moderate levels of chromospheric activity. Therefore, towards the end of the survey this type of spectroscopic work will be necessary for an estimated 250 stars.

All members of our team feel that it is important to allow time for follow-up observations of important, exciting, interesting or new objects as soon as possible. We have therefore requested that, contiguous with the time allotted specifically to meet the requirements of identification, an extra allocation be made to allow for follow-up. This will allow team members to profit better from the somewhat arduous tasks of survey identification.

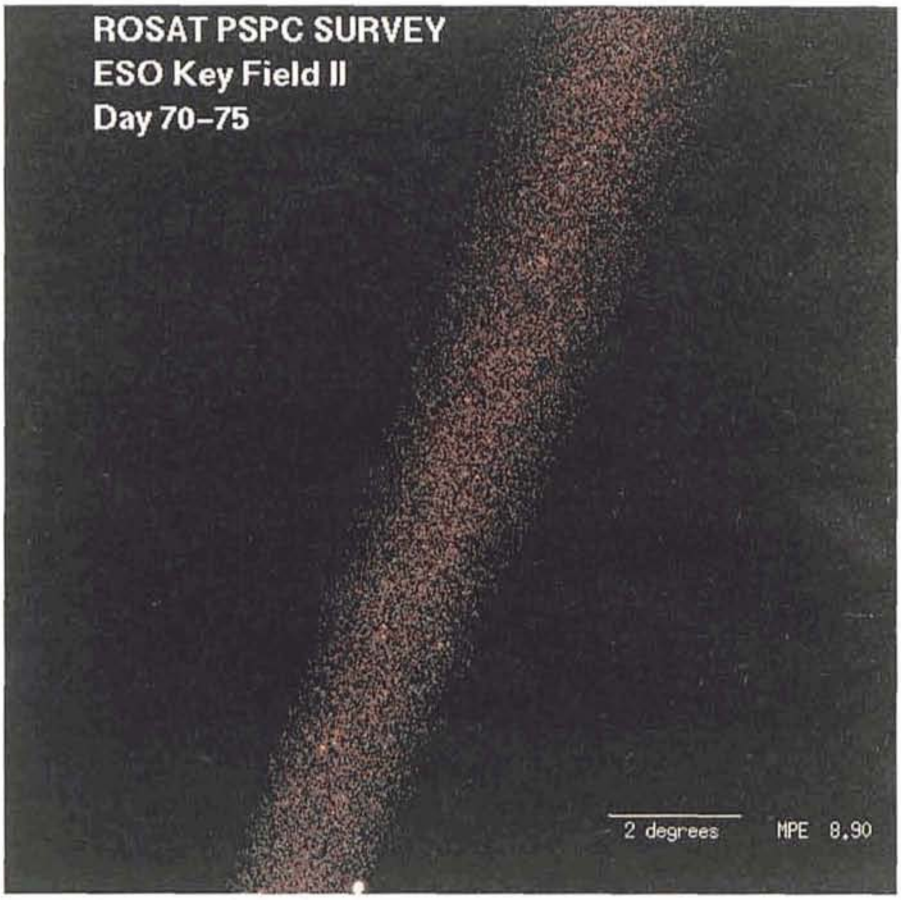

Figure 3.

PROFILE OF A KEY PROGRAMME

Stellar Evolution in the Galactic Bulge

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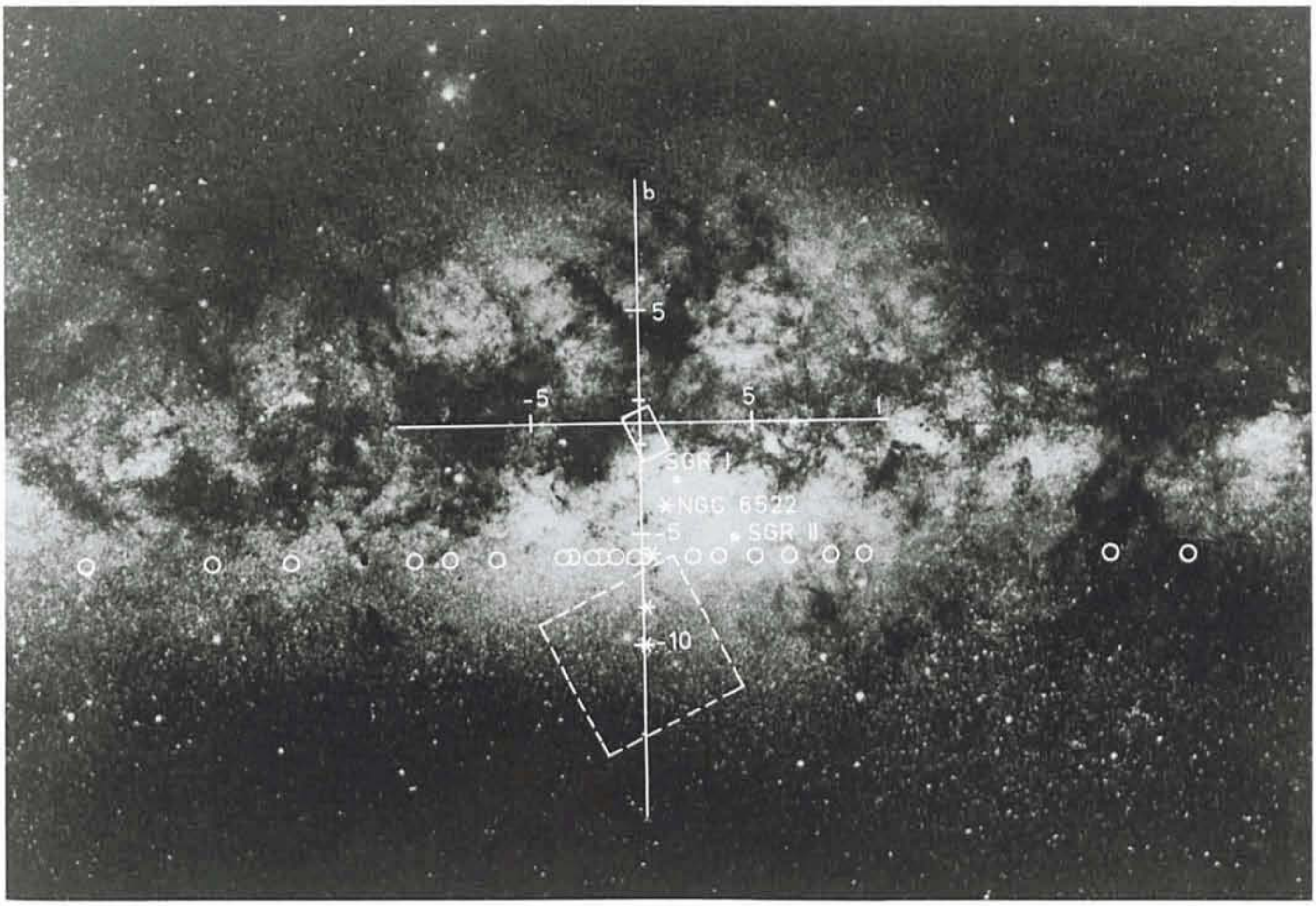
Large-scale maps at infrared wavelengths obtained with IRAS and COBE show our Milky Way as an edge-on spiral galaxy, and clearly reveal the Galactic Bulge. This separate component of our Galaxy can be considered as the nearest ellipsoidal stellar system. Studies of its stellar content are crucial not only for our understanding of stellar evolution and stellar populations in general, but also for calibrating the measurements of the colours and line strengths of the integrated light of elliptical galaxies (Whitford, 1986).

Some parts of the Galactic Bulge outside the galactic plane can be studied optically. In particular, there is a 6°.5 by 6°.5 field (900 pc by 900 pc) of low and homogeneous extinction, centred at $l = 0°$, $b = -10°$, which in the mid-fifties was chosen by Baade and Plaut as a good field to search for variable stars by photographic techniques (cf. Blaauw, 1955). It is often referred to as the Palomar-Groningen Field Nr. 3, or simply as the Baade-Plaut field. Its location is illustrated in Figure 1. Recently, Wesselink (1987) has repeated part of Plaut's painstaking work by measuring B and R Schmidt plates with an automatic measuring machine, and using a photo-electric calibration sequence. He obtained more accurate magnitudes, and confirmed Plaut's list of variable stars. As a result, nearly all Miras, Long-Period Variables, Semi-Regular Variables, and also the RR Lyrae stars have now been identified. Accurate periods and light curves have been determined for all stars with periods less than 300 days. We are extending Wesselink's work, with the aim of constructing a



The Bulge of our Galaxy (ESO photograph, 1986, The Messenger, ***46,*** *14–15). The photograph covers approximately 60 by 45 degrees. The Baade-Plaut field is indicated by the dashed square. Terndrup's (1988) deep CCD photometry fields are denoted by asterisks. The open circles are Blanco and Terndrup's (1989) survey fields for late-type giants. The solid rectangle indicates the central field studied in the IR by Catchpole et al. (1990). Baade's Windows: NGC 6522, Sgr I and Sgr II.*

Hertzsprung-Russell diagram for a sample of more than one million stars in the Baade-Plaut field. This is done by means of automated photographic photometry (in U, B, R, I) which yields magnitudes and colours to an accuracy of 0.03 mag. Because the number of stars is so large, we expect that even "fast" evolutionary phases will be well represented.

The evolution of low and intermediate mass stars (1–8 $M_\odot$) ultimately leads to the Asymptotic Giant Branch phase (AGB), which is followed by the formation of a planetary nebula. Miras and OH/IR stars are situated at the top of the AGB. They are very luminous, long periodic, mass-losing variables: Miras have periods up to 500 days, while IR stars have even larger periods. During this phase the stars enshroud themselves in a circumstellar gas/dust shell. General scenarios for AGB evolution are available (e.g., van der Veen 1989), but much more quantitative work has to be done and several details have to be cleared up. In particular, at present it is unclear whether or not there is increasing mass loss on the upper AGB, and if there is, what consequences this has for the evolution of these late-type stars. Do Miras evolve into IR stars by an increasing mass loss or do these two groups represent late-type stars with different masses and therefore different luminosities? It has always been difficult to distinguish between these two scenarios as distances and therefore luminosities generally are uncertain.

The Baade-Plaut field is ideal for a study of the late and luminous stages of stellar evolution in the Galactic Bulge. All the objects are at about the same distance, and many of the AGB stars have been found already through Wesselink's work. In addition, we have a sample of candidate IR stars selected from the IRAS Point Source Catalogue by means of the F25/F12 flux ratio criterion (cf. Whitelock et al., 1986). We are carrying out near-infrared photometry on these objects to investigate the nature of the IRAS sources, and to determine the bolometric luminosities of the AGB stars (cf. Whitelock et al., 1990). When repeated sufficiently often, such measurements will also give the pulsational period of the star. Finally, we will also search for planetary nebulae by comparing narrow band exposures with the ESO Schmidt telescope – centred around the prominent Hα or [OIII] emission lines – with available continuum UK Schmidt R plates.

We expect to obtain many objects in all phases of the AGB evolution, so that a comparison of the relative numbers will yield the duration of each phase, including the fast ones. The results will be analysed using state-of-the-art stellar evolutionary tracks. This should allow a precise delineation of the link between Miras, Long-Period Variables, Semi-Regular Variables and OH/IR stars, and a derivation of an accurate period-luminosity relation. The direct relation between mass-losing giant stars and planetary nebulae can be established independent of distance-scale related problems.

We are taking optical spectra of many of the Mira's, from which we hope to derive their metallicities, so that we can address the luminosity/metal abundance differentiation. The spectra will also provide radial velocities, thus shedding light on the dynamics of the Bulge. The mix of stellar objects as a function of galactic latitude (or metallicity) can be determined, in particular when our study of the Baade-Plaut field is combined with similar studies of other Bulge fields, such as Baade's window (Terndrup, 1988; Rich, 1989), and the central region (Catchpole et al., 1990). This is important also for the understanding of the stellar composition of the bulges of other galaxies.

In summary, this Key Project aims at improving our understanding of stellar evolution on the AGB by a comprehensive study of the Baade-Plaut field in the Galactic Bulge. Thise will provide information on the history of the Bulge.

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PROFILE OF A KEY PROGRAMME

Kinematics of the Local Universe

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Introduction

How matter is organized in the Universe is a fascinating problem to solve because it imposes severe constraints on the scenarios describing how matter was created and how it has evolved. Unfortunately, the way is hard because of our necessarily subjective point of view and the subtle biases which affect this description. Historical evidence shows that understanding the determination of the velocity field is of fundamental significance. For instance, the discovery of the location of the centre of our Galaxy is one of the most typical examples: the location, first discovered by H. Shapley (1) from the asymmetry of the distribution of globular clusters, was accepted only when dynamical arguments were given by J.H. Oort (2).

Later some astronomers (3, 4) pointed out that the galaxies are arranged in a kind of belt almost perpendicular to

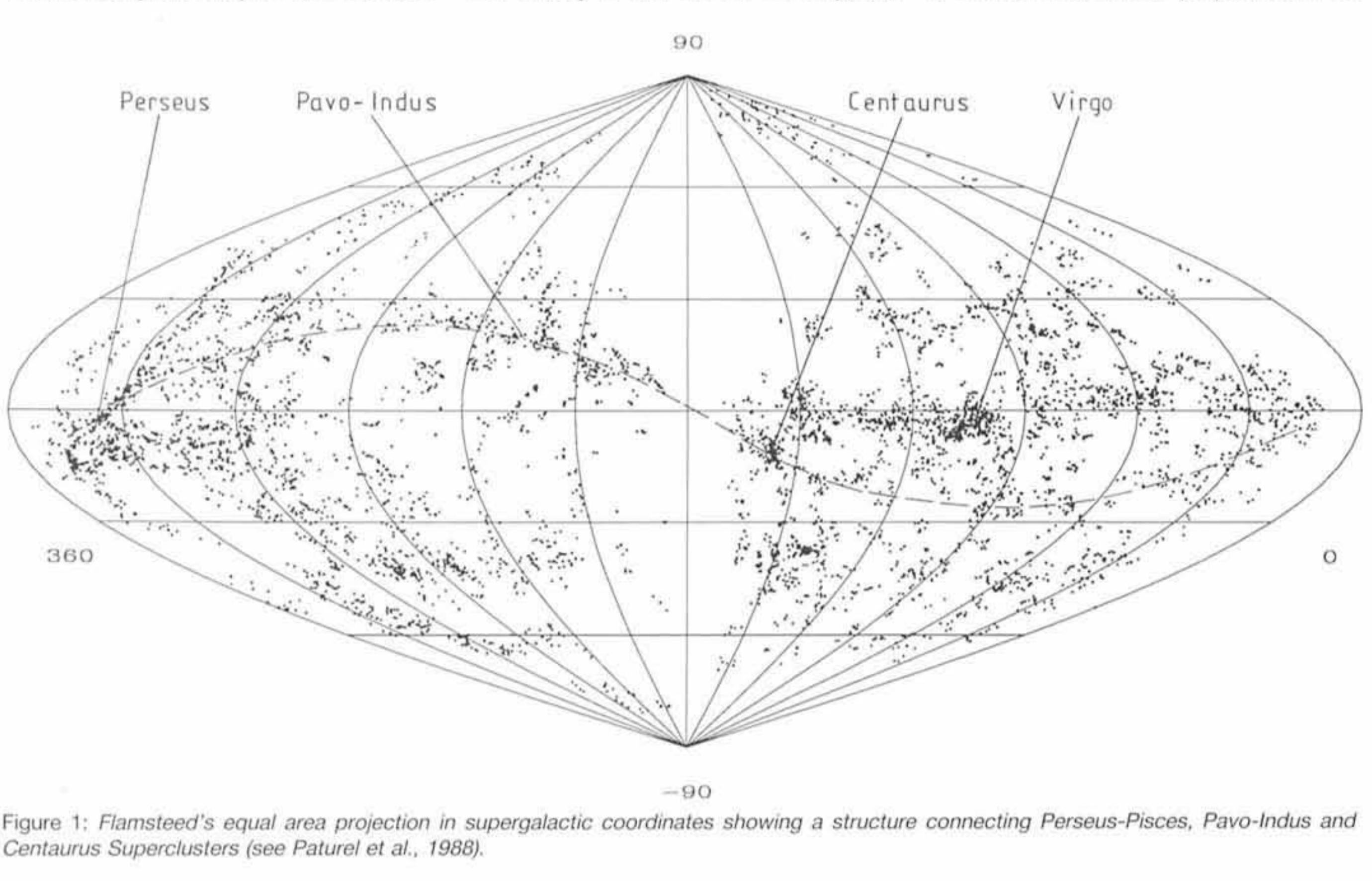

Figure 1: *Flamsteed's equal area projection in supergalactic coordinates showing a structure connecting Perseus-Pisces, Pavo-Indus and Centaurus Superclusters (see Paturel et al., 1988).*

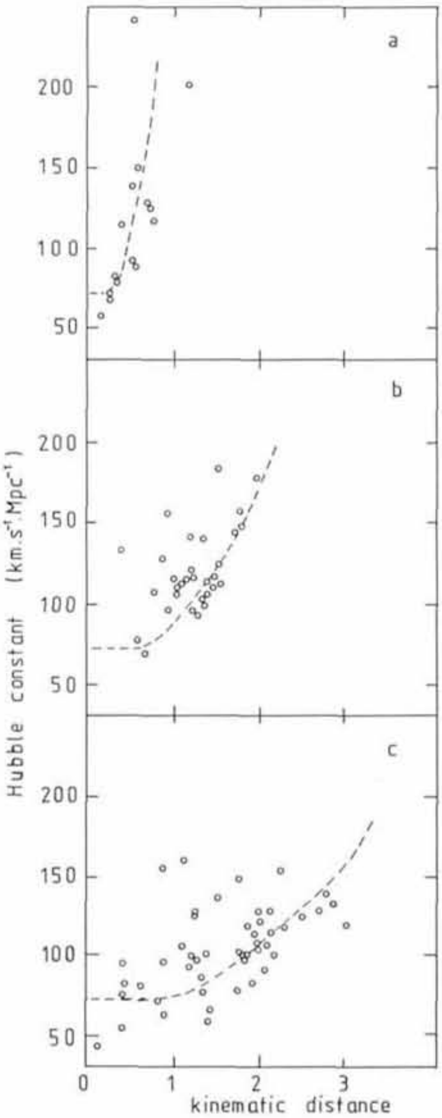

Figure 2: *A given sample affected by the Malmquist bias: Theory and observation. The Hubble constant H_o is plotted versus the kinematic distance (expressed in units of the Virgo cluster distance) for three luminosity classes: Figure 2a Low luminosity galaxies; Figure 2b Medium luminosity galaxies: Figure 2c High luminosity galaxies. At a given distance, the higher the luminosity, the lower the bias (see Bottinelli et al., 1988).*

the plane of our Galaxy. In 1953 de Vaucouleurs (5) described this kind of Milky Way of galaxies as the Local Super Galaxy (now called the Local Super Cluster). Again the existence of such a large system was accepted only when dynamical evidence appeared (6, 7).

Today, astronomers are in an almost similar situation. The existence of a very large structure has been suspected (8, 9, 10, 11). Figure 1 shows Flamsteed's equal area projection in supergalactic coordinates. An S-shape connecting Perseus-Pisces, Pavo-Indus and Centaurus Superclusters is visible. The search for dynamical arguments is thus highly suitable to test the reality of such a large system.

For this purpose, essentially two different approaches operate:

– The first one consists in measuring the distance d and the radial velocity V_r of a sample of galaxies and deriving the peculiar velocity $V_p = V_r - H_o d$, where H_o is the Hubble constant. It has been used by Lynden-Bell et al. (12) to infer a rather complex peculiar velocity field implying the existence of an important mass concentration (5.4×10^{16} $M_\odot$) – the so-called "Great Attractor" (hereafter GA) – located in the direction of the Hydra-Centaurus supercluster but lying beyond it (at 4350 $km{\cdot}s^{-1}$ instead of 3000 $km{\cdot}s^{-1}$)

– The second one relies on the observation of the distribution of galaxies and provides the peculiar velocity field from the gravitational acceleration through the linear perturbation theory (13). The use of an IRAS galaxies sample (14, 15, 16, 17) and of an optical sample (18) confirm the anisotropy of the velocity field but do not support the idea of a GA lying beyond the Hydra-Centaurus supercluster.

Why do both ways not lead to the same conclusion? We may suspect that the disagreement arises from distortions induced by erroneous determinations of distance.

Distance Determination and Malmquist Bias

Both methods need accurate relative distances. A zero-point error may affect the determination of the Hubble constant H_o but not the study of the velocity field, which requires only a good linearity of the distance scale. Unfortunately, it is not easy to be sure of the linearity because of biases.

In a series of papers started in 1975, Sandage and Tammann claimed that distance determinations are biased; many astronomers were reluctant to accept this idea with its implications probably because of the lack of clear proof. In 1975 and 1984, Teerikorpi (19, 20) studied from a theoretical point of view the bias arising when determining distances from a magnitude limited sample (the so-called Malmquist bias). This analysis has been confirmed with actual data (21, 22, 23). Let us explain how it works:

If a class of galaxies is characterized by a symmetrical luminosity function (for example a Gaussian function of mean absolute magnitude M_o and dispersion σ), any sample of these galaxies, limited to an apparent magnitude m_{lim}, will not contain the less luminous galaxies, due to this cut-off. The limiting absolute magnitude M_{lim} at distance r is simply given by $m_{lim} - M_{lim} = 5 \log r + 25$, if r is in Mpc. Therefore, at any distance r, the mean absolute magnitude of the galaxies belonging to this sample is brighter than M_o. Then, if one measures the apparent magnitude of a galaxy in this sample and assumes that its absolute magnitude is M_o, the derived distance will be, on the mean, underestimated and this underestimation increases with increasing distances. However, if the sample is deep enough (faint m_{lim}), at small distances the underestimation becomes negligible. Figure 2 shows how a given sample is affected by the bias according to the theory (assuming a gaussian luminosity function) and to observations. The agreement between theoretical prediction and observation is satisfactory.

To overcome these pernicious effects, it is essential to work with complete samples limited by an apparent magnitude (or an angular diameter) as faint as possible. The problem is thus to build an adequate sample.

The Sample

Since 1983 we have been building an extragalactic database (24) in which the most important, available measurements are collected for 73,000 galaxies. The Catalogue of Principal Galaxies (25, 26) constitutes the frame of this work. This database has been used to homogenize the relevant data; special care was paid to HI data (27, 28) and to apparent diameters (29). Besides, our participation in the Third Reference Catalogue of Bright Galaxies (30) provided us with accurate apparent magnitudes and morphological types.

The apparent diameters are available for 72 per cent of the galaxies. When they are reduced to the standard system D_{25} (diameter defined up to the limiting surface brightness of 25 $mag.arcsec^{-2}$) they constitute a good substitute to magnitudes. The conclusion is that it is feasible to derive the distance from the Tully-Fisher relation (hereafter TF, 31) expressed in diameter:

$$\mu = -5 \log D_{25} + a \log V_m + b.$$

In this relation V_m is the maximum velocity rotation deduced from the 21-cm line width corrected for inclination and dispersion effects (32, 33).

Thus, a study of the peculiar velocity field has been undertaken from a complete sample of 3856 spiral galaxies having photometric diametres larger than 1.6 arcmin. For each galaxy it is necessary to know both the radial velocity and the distance estimated from the diameter-TF relation.

When the radial velocity is known, it is easy to derive the distance modulus from 21-cm line observations with the meridian radio telescope in Nançay

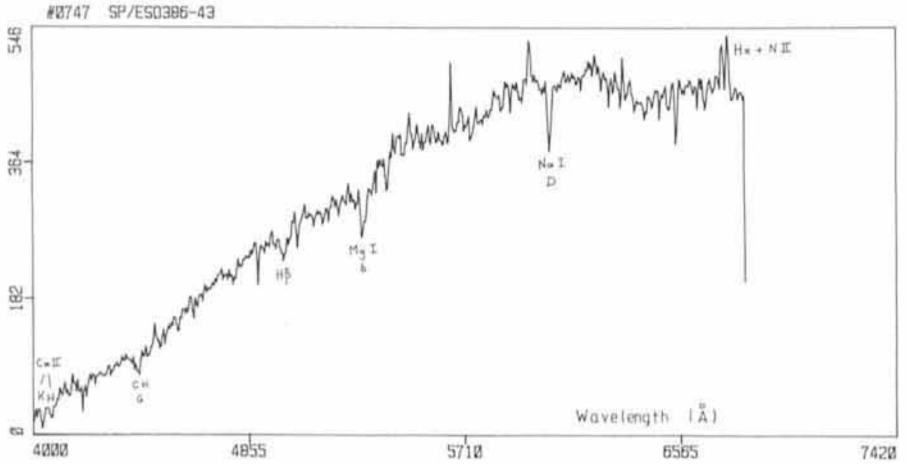

Figure 3: *An example of a calibrated spectrum obtained a few seconds after the end of the exposure.*

(France) which can observe declinations above −38 degrees and where guaranteed observing time has been granted.

Thus, the most important target is to quickly obtain optical radial velocities. Among our sample, more than 600 galaxies still lack this fundamental information. Fortunately, the very efficient modern spectrographs allow us to carry out such a large programme. The main part of these galaxies lies in the southern hemisphere and constitutes the subject of the present ESO Key Programme at La Silla. A joint programme has been undertaken at Observatoire de Haute-Provence (OHP) for the Northern Hemisphere.

Radial Velocity Measurement

The ESO 1.52-m telescope and OHP 1.93-m one are both equipped with very similar spectrographic acquisition systems.

ESO observations are performed with the B&C spectrograph (grating No. 16 with dispersion 187 $Å.mm^{-1}$) at the 1.52-m ESO telescope. The coverage in wavelength is 3956-6820 Å. At OHP, the CARELEC spectrograph attached to the 1.93-m telescope has more or less comparable characteristics. The dispersion is 260 $Å.mm^{-1}$ and the coverage is 3733–7633 Å.

The same procedures, based on IHAP software, were developed at both observatories. Let us give more details about this efficient method to derive radial velocities.

Four IHAP-BATCH programmes have been written; they work at ESO as well as at OHP.

The first batch (called CALIGULA) is used for the calibration at the beginning of each night: i.e. measurement of the OFFSET, determination of the FLAT-FIELD, and test of the He-Ar calibration lamp (He lamp in OHP).

The second batch (called SPARTACUS) produces a calibrated astronomical spectrum. The automated calibration is made using a spectrum of the calibration lamp measured just before the astronomical spectrum. Such a calibrated spectrum is shown in Figure 3.

Generally, the first spectrum of the night is a spectrum of a standard star. Thus, it is possible to reduce each galaxy spectrum using the cross-correlation batch programme (called CROCO). The operator must first select the spectral region which will be used (in order to avoid some poorly detected regions or some strong emission lines). The programme automatically performs the transformation into a log scale for the wavelength axis and then displays the cross-correlation function (cross-correlation between the galaxy spectrum and the standard star spectrum; see Fig. 4). The radial velocity of the galaxy (more exactly: the difference between the radial velocity of the galaxy and the radial velocity of the reference star) is automatically deduced from the maximum of the correlation function.

The last batch programme (called MELINOS) allows us to determine the radial velocity just by picking out the line on the calibrated spectrum. Giving the rest wavelength of the line to the batch programme will result in printing the corresponding radial velocity. This programme is well adapted to deal with emission lines or spectra with poor S/N ratio (typically when the maximum of the cross-correlation function does not exceed 0.4).

It is highly recommended to derive the velocity from both CROCO and MELINOS in order to take into account all information contained in the spectrum.

Last Step: HI Measurements

When the radial velocity is known and properly corrected to the heliocentric reference system, it is quickly communicated to the Nançay radio telescope for measurement of the HI line width. It has happened that some HI measurements were finished just a few days after the measurement of the radial velocity. Figure 5 shows the HI line profile for an ESO galaxy detected in Nançay.

Obviously, not only the width is derived from the HI line profile: the HI velocity and the HI flux are also valuable by-products.

At the present time, one observing run has been performed at each Observatory (ESO and OHP). Thus, it is too early to draw scientific conclusions; nevertheless, after only 7 nights of effective work, 77 new radial velocities have been obtained. The target of this key programme therefore seems to be quite attainable. Whatever the result may be,

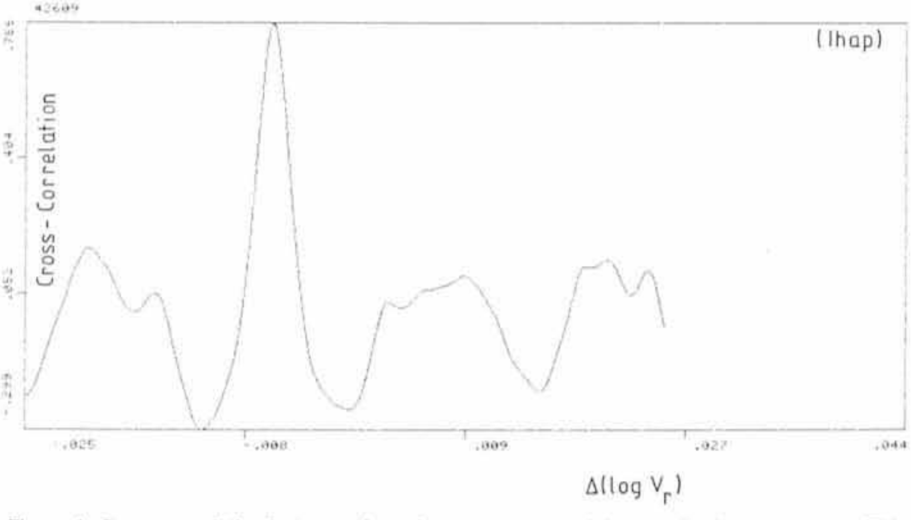

Figure 4: *Cross-correlation between the galaxy spectrum and the standard star spectrum. This method is very fast; the radial velocity can often be obtained before the start of the next exposure.*

our understanding of the kinematics of the local Universe will be improved.

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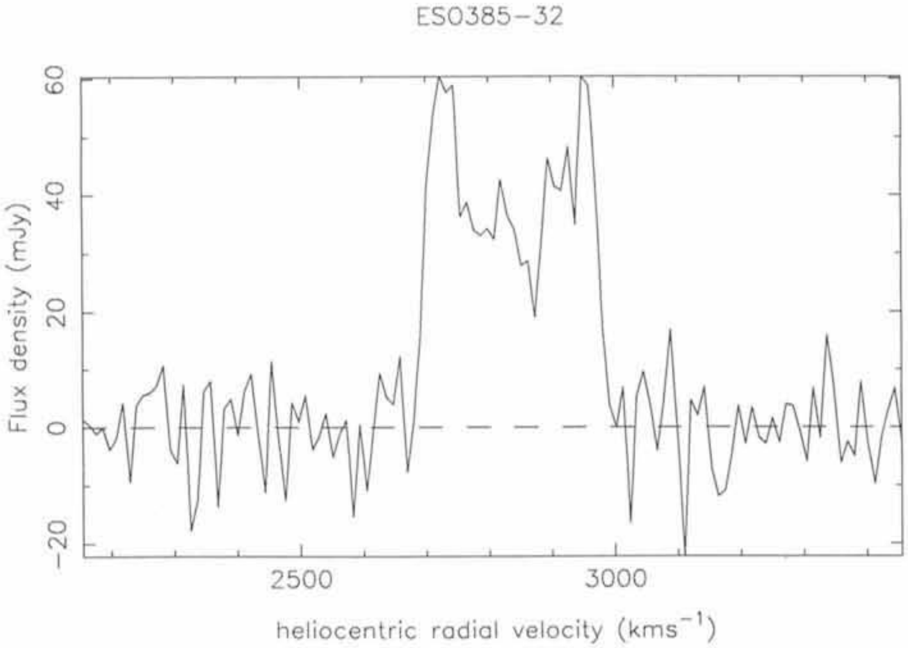

Figure 5: *HI line profile of ESO galaxy ESO 385-G32 detected with the Nançay radio telescope.*

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PROFILE OF A KEY PROGRAMME

Arc Survey in Distant Clusters of Galaxies

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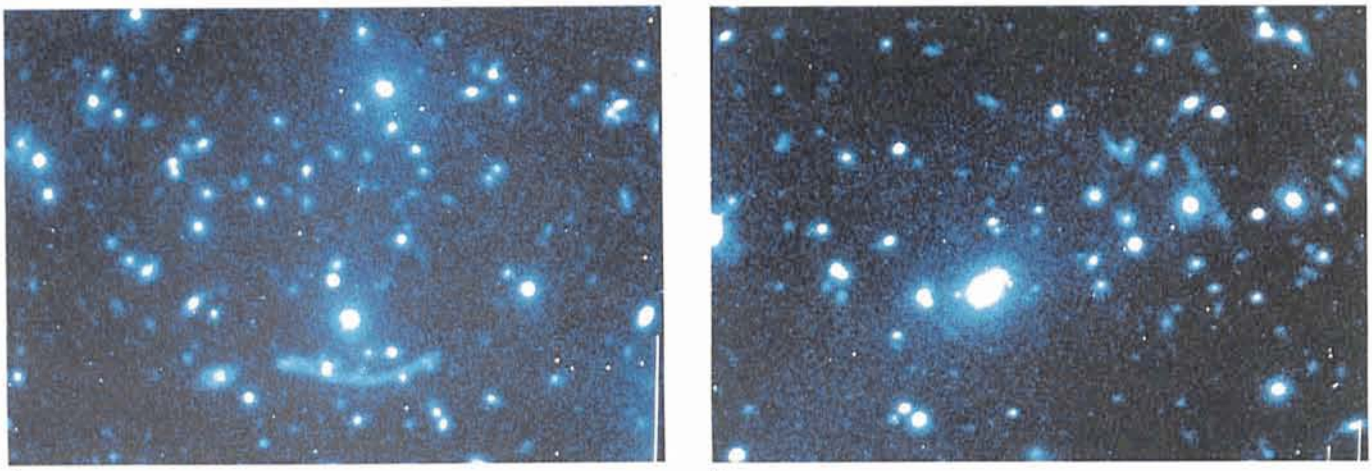
First Steps in the Study of Luminous Arcs

The first luminous arcs were discovered in the centres of rich clusters of galaxies by Soucail et al. (1987) and Lynds and Petrosian (1986). The redshift of the giant arc in Abell 370 ($z = 0.725$) was finally measured with EFOSC/PUMA at the ESO 3.6-m telescope in October 1987 (Soucail et al., 1988). It definitively confirmed that they were gravitationally distorted images of background galaxies by clusters of galaxies (Fig. 1).

During the same period, Tyson (1988) obtained ultra-deep CCD photometry in a sample of empty fields and detected a numerous population of very faint galax-



A

B

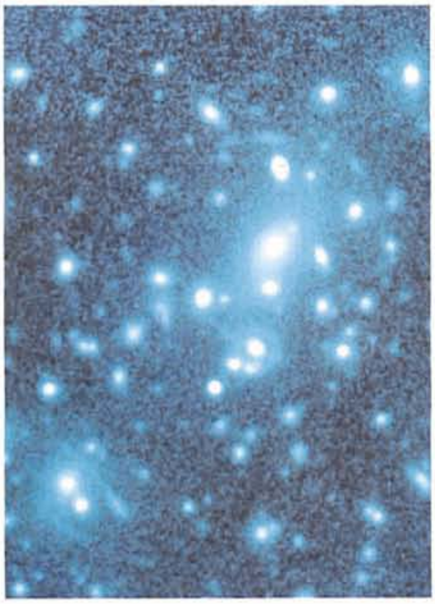


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Figure 1: *Images of the most spectacular cases of arcs and arclets already observed: A. The giant arc in A370: $z_{cluster} = 0.374$, $z_{arc} = 0.725$ (CCD image from the Canada-France-Hawaii Telescope).*
B. The "straight arc" in A2390: $z_{cluster} = 0.232$, $z_{arc} = 0.913$ (CFHT image).
C. The complex system of arcs and arclets in the centre of the cluster A2218: $z_{cluster} = 0.171$ (CCD image from Calar Alto, Spain).

ies. From their blue colour, the low surface brightness and the number counts, he concluded that these objects are most probably distant galaxies with a mean redshift between 1 and 3.

Fort et al. (1988) finally noticed several small tangentially elongated structures in the cluster-lens A370 which were named "arclets" with reference to the giant arcs. These arclets were immediately interpreted as gravitational images of other distant sources, the cluster acting as a lens for all the background objects. The comparison of their blue colour index ($B-R \simeq 1$) with evolutionary models of galaxies supported the hypothesis of galaxies at redshift about 1, also consistent with the formation of distorted arclets in a cluster at $z = 0.374$.

Although the arcs and Tyson's blue population were independent discoveries, it appeared that they could together open a new and fruitful field of investigation in observational cosmology. No more than 3 years after the first discovery of giant arcs, we are ready to start an extended survey of clusters of galaxies and to take advantage of the new opportunities offered to us by the use of these giant "natural telescopes".

The "Arc Survey": Observational Strategy

Up to now, about 10 large arcs, whose brightness is about one tenth of the sky brightness, have been identified in rich clusters and more than 50% of them have a measured redshift. For example the redshift of the giant arc in C12244-02, obtained after about 15 hours of integration time, is $z = 2.238$ and corresponds probably to the most distant field galaxy observed up to now (Mellier et al., 1991, see Fig. 2). The frequency of discovery of luminous extended arcs is now smaller and probably many of the brightest ones have already been observed. On the other hand, the faint arclets are much more regularly found in rich clusters. However, the price to detect them is to do photometry at a surface brightness level of $\mu_B > 28$ to 28.5, corresponding to the brightness of most of the galaxies of Tyson's population. Under this condition, and if the background sources are indeed at large redshift (an assumption that we should further be able to check properly) we should find up to 50 arclets per cluster in the most favourable cases (Tyson et al., 1990): rich clusters at intermediate redshift (0.2–0.4) with intense X-ray emission.

In practice, with the 20 nights allocated on the NTT for this ESO Key Programme, and considering the long exposure times necessary to reach the faint levels required to detect the arclets (3 to 4 hours per filter per field, segmented in about 50 randomly shifted exposures of 300 sec. each), we expect to survey 15 clusters with redshift between $z = 0.15$ and 0.8 in 3 photometric bands (B, R and I). We refer to the report of a preliminary run we had on the NTT in January 1990 with the TH 1024×1024 CCD to demonstrate the feasibility of such a programme. The survey is strongly supported at CFHT and benefits from a collaboration with T. Tyson and his collaborators on American telescopes (CTIO, KPNO) in order to build up, through a joint international effort, a comprehensive and homogeneous data base of "cluster-lenses" for statistical analysis of the arclets' distribution.

Moreover, a side-observing programme was initiated in collaboration with the University of Barcelona, with access to the William Herschel Telescope in the Canarian Islands (R. Pello, B. Sanahuja) and the University of Durham, with access to UKIRT in Hawaii (R. Ellis and collaborators) to study an unbiased sample of distant magnified galaxies ($z = 0.8$ to 2.5) which are intrinsically fainter by one or two magnitudes compared to the present-day deepest spectroscopic surveys (Cowie et al., 1990, Mellier et al., 1991).

Mapping the Dark Matter in Clusters of Galaxies

It is well known from observations of multiple QSOs that the deviation angle due to the gravitational lensing by a typical galaxy of $10^{11}\ M_\odot$ is of the order of a few arcseconds. For a cluster of galaxies with a velocity dispersion larger than $\sigma = 1000$ km/s the distorted images (whose size depends on σ^2) fall inside a radius of typically 1 arcminute around the cluster centre, a size comparable with the cluster core radius at intermediate redshift.

After the first redshift measurement of the giant arc in A370, it immediately followed that the mass responsible for the large arcs corresponds to $M/L_R \sim 90$ for the cluster. It was a confirmation of the guess that at least 90% of the matter is unseen in rich clusters of galaxies. The evaluations of masses and dark matter distribution from lensing are independent and complementary to other dynamical methods such as the virial theorem (which is questionable in some clusters) and constitute a new powerful tool for mass diagnostics over large scales, provided we are able to constrain the parameters by a statistical study of clusters.

Two main approaches are used simultaneously for the modeling of the arcs. First, since giant arcs are located on the critical lines of the image plane, it is possible to constrain the cluster potential using the position and the shape of the largest arcs (Kochanek et al., 1989). However such models suffer from a large number of free parameters, usually larger than those observable. The redshift of the arcs is essential though not sufficient to limit the space of the solutions since it only fixes the linear scales of the problem. For such an approach, high resolution imaging in good seeing conditions is particularly important because it can strongly constrain the shape of the source and the cluster potential. Due to the large tangential magnification effect, image reconstruction can provide a super resolution in the direction where the source stretches out (better than 0.1 arcsecond if seeing is smaller than 1 arcsecond).

Second, compared to galaxy-lenses, cluster-lenses strongly distort many background galaxies and form a lot of arclets in the same cluster. The efficiency of the lensing mainly depends on the projected mass density along the line of sight. So using the uniform projected distribution of background galaxies, one can derive the shape and the profile of the projected potential from the "distorsion map" outlined by the arclets (see Fig. 3), with a resolution of about 20 arcsec. This can be done either by using ray-tracing modeling (Grossmann and Narayan, 1989) or from purely analytical calculations with simple models such as a pseudo-isothermal sphere with possibly an elliptical term and a core radius. A statistical approach has been developed by our group (Mellier, Longaretti, in preparation) which uses the whole set of arclets to reconstruct the map of the dark matter in clusters without any assumption on the shape of the potential. All these modelings provide good constraints on the gravitational potential distribution and the total mass, but in order to derive a complete assessment of the matter content in clusters (visible matter, hot intracluster gas, and unseen mass) it is highly desirable to get X-ray maps for these cluster lenses. A proposal has been submitted in collaboration with the MPE (Max-Planck-Institut für Extraterrestrische Physik, collaborators H. Boehringer, M. Pierre and R. Schwarz), to survey the best cluster candidates with ROSAT.

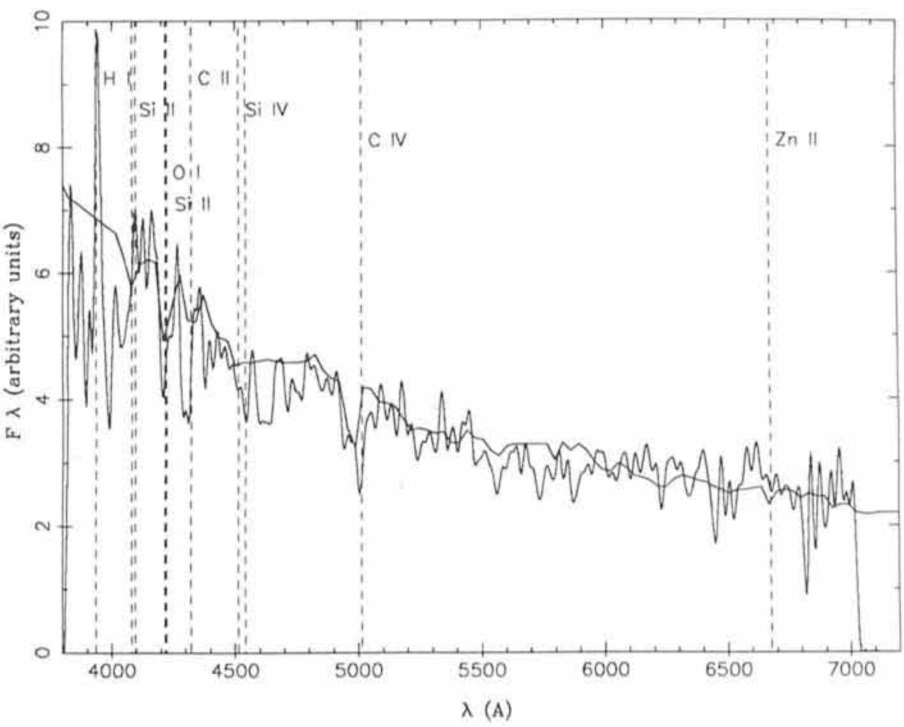

Figure 2: *Integrated spectrum of the arc in Cl2244-02 obtained at ESO with the B300 grism (exposure time 6 hours). The spectrum is flux calibrated in* F_λ (arbitrary units) and a synthetic spectrum of a non-evolved Im galaxy (Guiderdoni and Rocca-Volmerange, 1987) redshifted at $z = 2.237$ is superimposed. Some of the best identified lines at this redshift are overplotted. One should especially note the emission line at 3938 Å identified with Lyα redshifted at $z = 2.237$. This spectrum represents the most distant field galaxy presently known.

Giant Natural Telescopes to Probe High Redshift Galaxies

Since the sources of the arclets are lensed only because they happen to lie serendipitously behind a totally unrelated cluster, selection effects are kept to a minimum and the family of the arclets represents a large sample of a-priori very distant field galaxies.

For any given distribution in redshift of these galaxies, the number of arclets produced by a very rich cluster will depend strongly on the cluster redshift (or the distance lens-source). If most of the background galaxies lie closely behind the cluster the convergence of the lens will not be large enough to create large distorsions. Thus the multi-colour photometry and the number counts of arclets will be a new way to estimate the redshift distribution and the colour-evolution for these very faint objects (Ellis, 1990). Note however that the number of arclets can also change dramatically with the dynamical state of the distant clusters (Fort, 1990) and can be used as a critical test for the dynamical evolution of clusters.

For the luminous arcs in which a redshift was measured, it is difficult but possible to perform a large spectral survey from the UV to the near IR. The large tangential magnification increases the S/N ratio of the data either for spectroscopy or IR photometry, for a few objects which would be unobservable without this gravitational telescope effect. The IR data are crucial to characterize the oldest stellar population of the galaxy and they can constrain the epoch of formation of such a galaxy. That is why IR data are taken at UKIRT in collaboration with the Durham group, complementing our survey in the visible. It is likely that the study of arclets could reveal some distant and more primeval galaxies (Mellier et al., 1991).

Other Cosmological Consequences of the Arc Survey

Gravitational lensing is sensitive to the curvature of the universe. In principle one should obtain some constraints on the cosmological parameters from the study of lensing. For example, the distribution of several arcs in the same cluster is sensitive to q_o through the

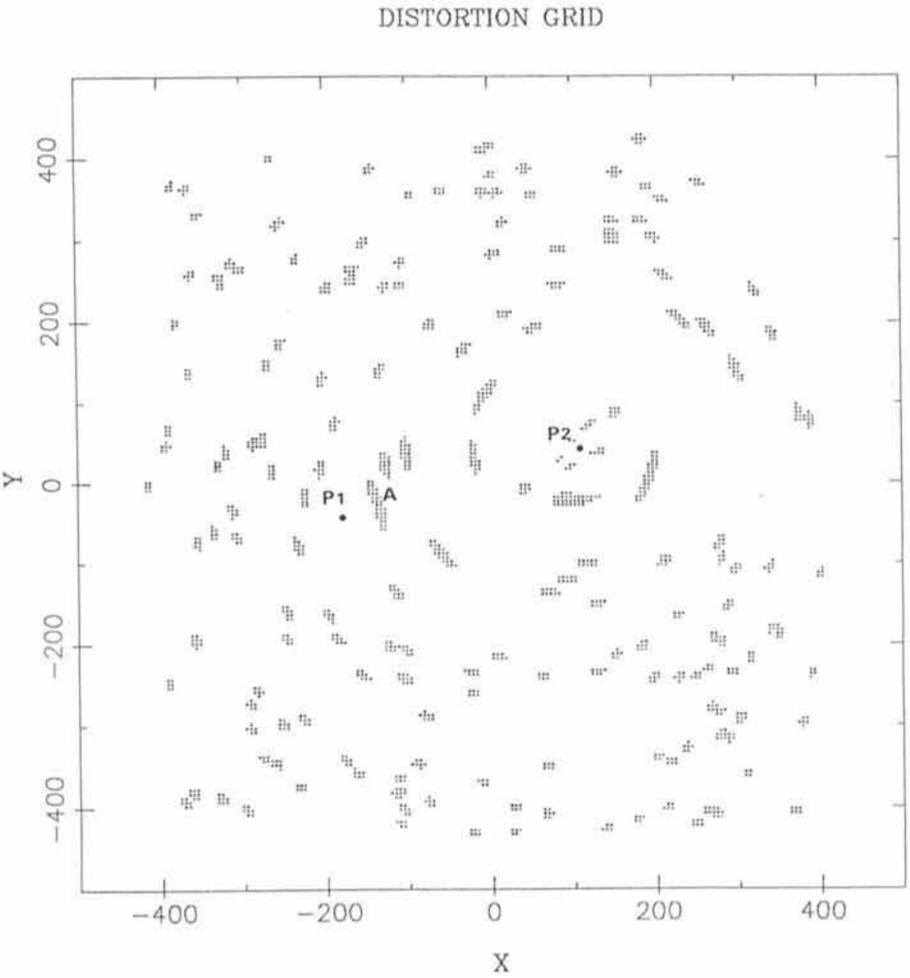

Figure 3: *Simulation of the gravitational distorsion of a population of galaxies randomly distributed at z=1.2. The cluster-lens is at redshift 0.23 with standard structural and dynamical parameters as expected for a rich cluster of galaxies. The cluster is composed of two potential wells located at P1 and P2. One should note the simulated "straight arc" located in A.*

ratio D_{ol}/D_{ls} where D_{ol} is the angular-diameter distance between the observer and the lens and D_{ls} is the distance lens-source. This ratio is independent of H_o and slowly varies with q_o. But a large number of arclets in the same cluster could possibly constrain the deceleration parameter. On the contrary, constraints on H_o are not evident. As was suggested by Kovner and Paczynski (1988), one should wait for a supernova occurring in the source, and measure the short time delay between the event in the two or three images in the arc. Another possibility was suggested recently (Soucail and Fort, 1991). A velocity gradient was detected along the giant arc in A2390 (Pello et al. 1991), and was interpreted as an intrinsic rotation of the source. Applying the Tully-Fisher relation on this galaxy, they deduced an absolute magnitude of the source and consequently determined H_o for a large distance modulus.

It is clear that this observational programme calls for large telescopes with sub-arcsecond seeing. It is extremely time-consuming, both for ultra-deep imaging in multi-band photometry (B, V, R, I, K) and for the spectroscopic follow-up of the most luminous arcs. The future European VLT will give new insight into the domain opened by this Key Programme. Observations with the VLT of the images produced by these Very Large Natural Telescopes are likely to open a completely new window to the early Universe.

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PROFILE OF A KEY PROGRAMME

High Resolution Studies of Quasar Absorption Lines

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The Key Programme described here intends to study the physics, chemistry and chemical composition of diffuse gas clouds between a redhift z ~ 0.6 to redshifts beyond z=4. With long integration times, it is now possible with CASPEC, and, for the first time, EMMI (1), to observe quasars fainter than 17.5 mag with a spectral resolution of 10 km s^{-1}, and signal-to-noise ratios as high as 50 from the UV to the near IR. High quality spectra of a selection of bright quasars will probe several long cosmic sight lines. This will permit detailed astrophysical analyses of the diffuse gas in intervening galactic disks and halos, gas clouds in the intergalactic medium and, for those clouds in the physical vicinity of quasars, it will be possible to study the interactions between the quasar radiation and the absorbing clouds.

The immediate first goal of the research will be an understanding of the ionization conditions, cloud temperatures, velocity structures, ionic abundances, and dust content for those clouds with sufficient column density that they produce observable absorption lines from enough metallic ion transitions that these cloud parameters can be constrained.

Past attempts to study the narrow line clouds relied on low-resolution spectra and curve of growth analyses. Since these earlier spectra achieved only comparatively poor S/N ratios, or had limited wavelength coverage, it was often difficult to produce definitive, accurate results. High S/N ratio spectra are required in order to model convincingly the weak absorption lines and determine the b values and wavelengths of the principal clouds in a redshift system. Once the weak lines are modeled it is possible to extend the model to the stronger lines in the system and determine the column densities with fair confidence. The strong line column densities are needed to determine the abundances of the prevalent C, N, O group of elements relative to those of the less abundant metals. If the metal line clouds have low velocity dispersions (as a few radio studies of the hydrogen 21-cm line in particularly strong clouds and isolated high resolution optical studies have shown to be the case) then data from transitions with a wide range of oscillator strengths will be needed before the physical and chemical properties of the clouds are clearly understood. Careful measurements of lines with different λf values for the same ion and the investigation of the relative abundances of the elements as a function of their grain volatilities are required before the chemical composition of these distant clouds can be settled. Observations of several ionization stages for key elements, such as N, C, Si and S can lead to accurate models of the ionization structure of the clouds. It is important that the spectra have sufficient wavelength coverage that many spectral lines of different strengths are available for analysis.

When the observations have sufficient spectral resolution, it is possible to measure the gas kinetic temperature for metal line clouds with low turbulent velocities by comparing the doppler widths of the metal lines to those of the hydrogen lines. For low ionization clouds that have damped hydrogen Lyman lines, fine structure excitation of low ionization metal ions often produces measurable fine structure lines that, in addition, can give an excitation temperature. CASPEC spectra of UM-402 gave very different temperatures for different cloud systems (2). In the $z=2.523$ redshift complex C II fine structure lines suggest an excitation temperature $T<15$ K, a typical temperature for cool interstellar clouds in our Galaxy. At high redshift this temperature provides a useful check on the Cosmic background temperature, since theory predicts that the background temperature will scale as $1+z$. Other metallic fine structure lines and measurements at other redshifts can sample the background radiation at different wavelengths relative to the peak of the Planck curve. In marked contrast to this low temperature cloud, a second cloud in a high redshift complex seems to be interacting with the radiation field of UM-402, and gives a doppler temperature for one hydrogen Ly-α cloud that exceeds 5×10^5 K.

The dust content of the high redshift clouds can be estimated by comparing elements with small (Si, Mn, Zn) and high (Cr, Fe, Ni) depletion factors onto grains in Galactic interstellar clouds. Absorbing clouds with large H I column densities, i.e. the damped Ly-α systems, are the best candidates to estimate abundances because their H II content is frequently negligible, as shown by the low ionization level of the gas (3) and from photoionization model calculations (4). When the hydrogen Ly-α line is damped, the estimate of N(H I) is independent of the velocity dispersion b, of the gas. Absorption lines from elements with low cosmic abundances are optically thin, even in clouds with high column densities. Since their transitions are unsaturated, the corresponding ionic column densities are then also independent of b. At high redshift ($z \sim 2$) the important ions to be studied are Cr, Ni and Zn. At lower redshift ($z \sim 0.8$) Ca and Mn can be used, or the more abundant Fe^+ ion if the Fe II $\lambda\lambda$2366, 2373 lines which have very small oscillator strengths are used. The dust grain depletion factors in the Galactic interstellar medium are of order unity for Zn, 10^{-1} for Mn, 10^{-2} for Cr, Fe and Ni, and a few 10^{-4} for Ca. There is presently no damped Ly-α system known at $z<1.3$, but such systems will be detectable with the HST (one of us, J. B., is Co-I in the HST key programme on "Quasar Absorption Line Survey"). Dusty clouds should also show detectable amounts of H_2 absorption; molecular hydrogen absorption has now been reported in PKS 0528-250 (5). For this study the maximum spectral resolution was 5000, 1/6 the resolution now achievable with ESO instrumentation for this quasar.

In several cases with $z<1$ metal line absorbing clouds are clearly associated with an identified host galaxy (6, 7, 8). We therefore know that at least in these cases the absorbing clouds are part of very extended gaseous halos associated with the intervening galaxies. Cir-

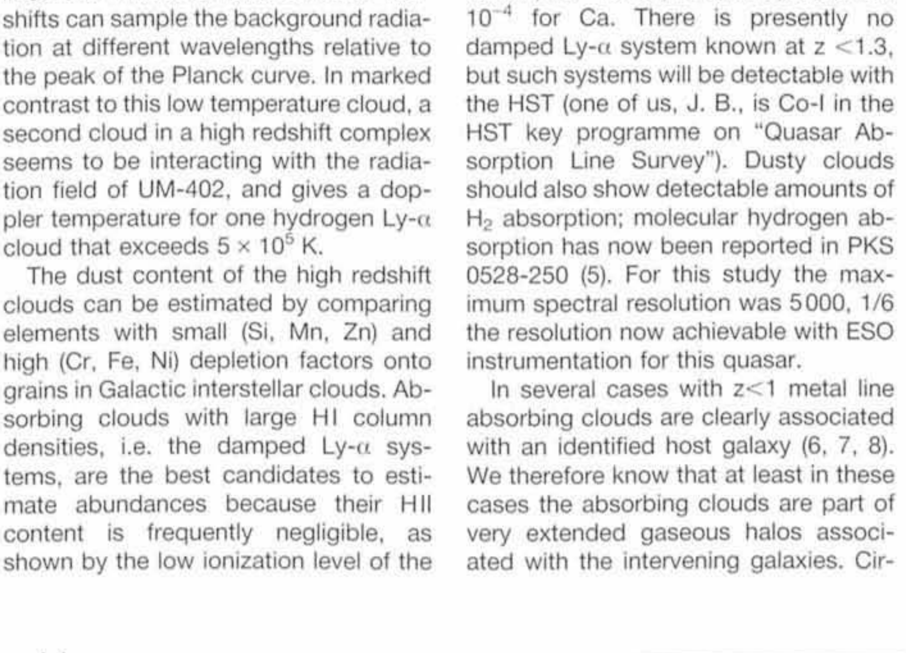

Figure 1: *A portion of the CASPEC spectrum of UM-402, showing lines from the low ionization z=2.523 system (C II lines) and the high ionization z=2.88 system (Ly-α line with broad thermal wings). The thin line shows a model fit.*

cumstantial evidence suggests that most of the dense clouds, those having absorption systems with damped Ly-α lines, are also galactic disk complexes, despite their surprisingly frequent occurrence in high redshift quasar spectra (9). The study of the conditions and evolution of these cloud systems can tell us much about the evolution and conditions in the host galaxy itself. The ionic abundances and dust content in disks and outer gaseous envelopes of moderate to high redshift galaxies are important parameters for the study of primeval galactic evolution. Also, the dust content of distant galaxies strongly affects the opacity of the early Universe.

CASPEC observations of the BL Lac object 0215+015, aimed at studying the ionization level of absorption systems with $N(HI) \sim 10^{18}-10^{20}$ cm^{-2}, have permitted an estimate of the column densities of Mg II, Mn II and Fe II in the $z=1.345$ absorber (10). In this system the derived abundances of Mg, Mn and Fe are all equal to 0.15 (± 0.5) times the solar values, implying no depletion onto dust grains. The abundance of Ni II has been derived in the $z=2.811$ system toward PKS0528-250 (11), suggesting that much less Ni is depleted in this system than in Galactic interstellar clouds. In these two absorbers the abundances are about 0.10 and 0.05 times the solar values and the dust-to-gas ratio is approximately one order of magnitude lower than the Galactic value. In contrast, the damped Lyα ($N(HI) \sim 10^{19}$ cm^{-2}) system at $z=2.523$ toward UM-402 has metal abundances close to solar. Obviously, while there is a spread in the abundances in these high redshift clouds, some high redshift galaxies are able to process hydrogen into heavy metals in short cosmic time scales.

Often the high column density, damped Ly-α line, clouds are accompanied by much lower column density satellite lines (2, 12).These satellite lines may arise from clouds in a turbulent halo phase or in an accompanying galaxy cluster. The total velocity spread of the individual components of the damped Ly-α line rarely exceeds one hundred km s^{-1}, appropriate for a galactic disk, while the satellite lines span a velocity range of several hundred km s^{-1}, and in a few cases up to one or two thousand km s^{-1} comparable with velocity dispersions in galaxy clusters. The evolution of such complexes of lines with z (if any) may give insight into the beginnings of galaxy clusters.

The brighter high redshift quasars can now be studied with high spectral resolution using ESO telescopes and echelle spectrographs. For these studies ESO has some important advantages over its competitors. These include: (a) the EMMI spectrograph is somewhat more efficient (1) than comparable instruments at other observatories and (b) the observing conditions at La Silla are quite good. Furthermore, the Barbieri Key Programme and the Hamburger Sternwarte Key Programme will increase the number of bright, Southern Hemisphere quasars that will be available for study. Together, these advantages represent a significant capability that should be exploited. The experience gained in these initial studies will point the way to future work and give valuable experience in the extraction of the peak performance from the telescopes, their instrumentation and the data reduction facilities. European astronomers will then be in a good position to fully exploit the revolutionary possibilities represented by the future availability of the VLT and its powerful complement of instruments.

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Discovery of the Most Distant "Normal" Galaxy

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Normal galaxies at epochs about one third or less the present age of the universe, t_H, are extremely difficult to detect directly since they are very distant from us and thus have very faint apparent luminosities. However, it is crucial to search for young normal galaxies at high redshift for understanding the formation and evolution of galaxies. The existence of high redshift gas-rich galaxies has already been inferred from the absorption signatures that their interstellar and halo gas imprints on the spectra of more distant objects which may happen to lie on the same line of sight. Such absorption features, due to hydrogen atoms and heavier elements, have been detected in the spectra of distant quasars (see e.g. the first surveys of Weymann et al., 1979, Sargent et al., 1980 and Young et al., 1982). In these studies, quasars are used as background candles to probe all the intervening matter between us and them.

The first identification of a galaxy giving rise to a MgII absorption system, at a redshift $z = 0.430$ or about $\frac{2}{3}$ t_H, was obtained in 1985 at the ESO 3.6-m (Bergeron, 1986). This first identification has been followed by a dozen of others for similar redshifts in a survey done by Bergeron and Boissé (1990). These galaxies have huge gaseous halos, roughly three times larger than the extent of the stellar components and their centres are separated from the quasar image usually by 5 to 10 arcsec. Comparing these observed impact parameters, an average close to 3 Holmberg radii R_H ($R_H = 22$ kpc with $H_o = 50$ km s^{-1} Mpc^{-1}), to those predicted from statistics of MgII absorption line samples, Bergeron and Boissé conclude that all field galaxies at $z \sim 0.4$, brighter than 0.3 L^* should have extended gaseous halos of roughly spherical geometry. Furthermore, there is also a similar level of [OII] λ 3727 emission, thus of star formation activity, in the absorbing galaxies and in those of faint (field) galaxy surveys at $z \sim 0.3$ (Broadhurst et al., 1988, Colless et al., 1990) which is higher than that observed in local galaxies (Peterson et al., 1986). Consequently, the study of galaxies giving rise to absorption lines in quasar spectra is giving information on the overall field galaxy population. The presence at z ~ 0.4 of extended galactic gaseous halos, which no longer appear to exist today, and of enhanced star formation activity suggest a strong evolution in recent times, and these halos could be the remnants of the initial huge gaseous clouds whose collapse led to galaxy formation.

Encouraged by this successful search for "absorbing" galaxies at z ~ 0.4, J. Bergeron, S. Cristiani and P. Shaver submitted a proposal for an identification survey of intervening galaxies at higher redshifts z ~ 1.0 to 1.5, or $t < ⅓ t_H$, which was accepted as an ESO Key Programme. Observations have been conducted in March and September 1990 at the ESO New Technology Telescope, and in the September run the first identification of an "absorbing" galaxy at z ~ 1 was obtained. Last March, several candidates have been detected by deep broad-band imaging in the red, but the spectroscopic search for their redshift was then inconclusive due to the faintness of the objects and the absence of strong emission lines in the selected wavelength range for the spectroscopic follow-up. The identified "absorbing" galaxy, G 0102–190, has a redshift $z_g = 1.025 \pm 0.001$, as measured from a strong [OII] emission line detected in a red spectrum of total exposure time of 4.5 hours. The redshift of the MgII absorption doublet present in the quasar (UM 669, $z_Q = 3.035$) spectrum is $z_a = 1.0262$ and, given the accuracy of our galaxy redshift determination, $z_g = z_a$. As shown in Figure 1, the absorbing galaxy lies 4.8 arcsec south of the quasar. The linear separation between the galaxy centre and the line of sight to the quasar gives a lower limit for the radius of the gaseous halo, which is of 53 kpc (adopting $q_o = 0$) or 2.4 R_H. The galaxy has a magnitude in the r band of 23.2 which, at the time of our observations, corresponds to an intensity of 2% that of the sky. Close to the quasar sightline, there are two other galaxies at 12 arcsec south-east and 14 arcsec south-west with measured redshifts of ~ 0.9 and 0.6 respectively. Therefore, contrary to conclusions which could have been derived based solely on imaging data, the absorbing galaxy does not belong to a cluster or tight group. Our pencil-beam observations appear to sample different sheets of galaxies as observed in the large scale distribution of local galaxies (see e. g. Geller et al., 1987).

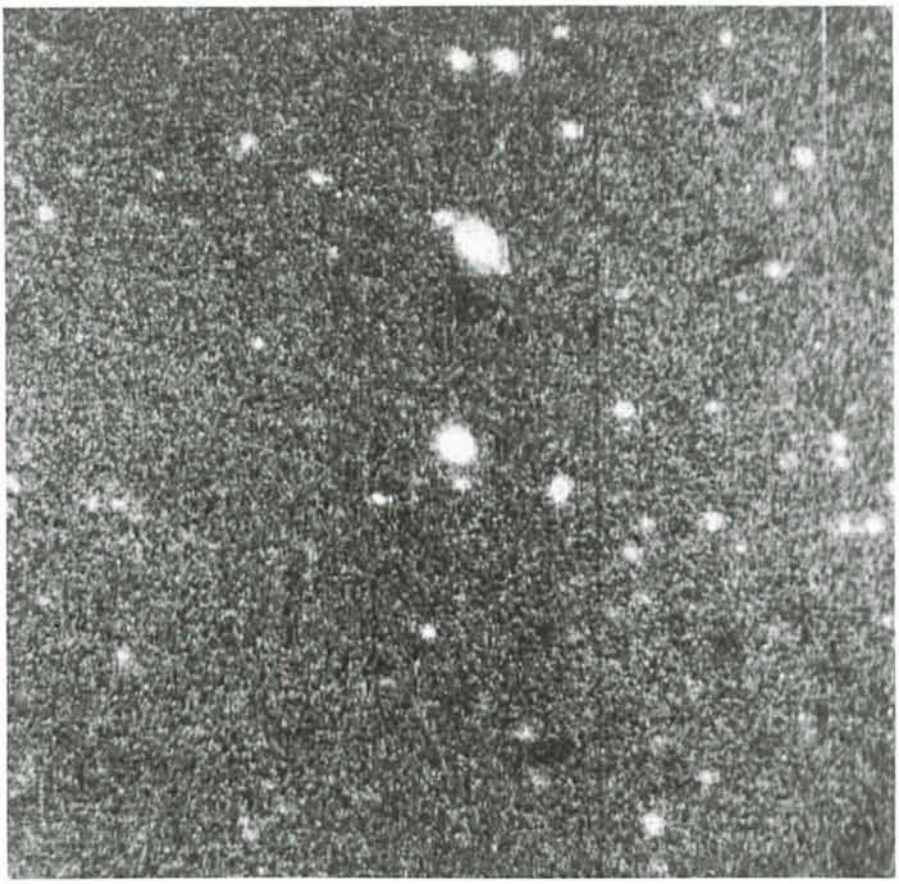

Figure 1: *Broad-band r image of a 120 arcsec square centred on the quasar UM 669. North-east is at the top left corner. The $z_g = 1.025$ absorbing galaxy is the faint resolved object 4.8 arcsec south of the quasar.*

This first identification of a z ~ 1 absorbing galaxy suggests that galactic gaseous halos were at least as extended at $t \sim ⅓ t_H$ than at later times, $t \sim ⅔ t_H$, and confirms the validity of our approach for detecting "normal galaxies" at early epochs $t \lesssim ⅓ t_H$. The identified galaxy has an absolute luminosity $M_r = -21.6$ similar to those of z ~ 0.4 absorbing galaxies and this is also true for our candidate absorbers assuming that they are indeed at $z_g = z_a$. This points towards a lack of strong evolution for the luminosity of galaxies. Since deep photometric surveys of very faint field galaxies suggest that there is an increase with redshift either in the comoving density or in the luminosity of galaxies, our identification survey will help clarifying this problem.

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ESO Mini-Workshop on Quasar Absorption Lines

A mini-workshop will be held at ESO Garching on 20-21 February 1991 to discuss recent developments in studies of the absorption lines in quasar spectra. Those wishing to attend should contact the Secretariat of the Science Division for further information.

European Astronomical Society Founded

The 12th European Regional Astronomy Meeting of the IAU "European Astronomers Look to the Future", organized jointly with the Astronomy and Astrophysics Division of the European Physical Society, took place from 8 to 11 October 1990 in Davos, Switzerland. Some 300 astronomers from all over Europe attended. The scientific programme included presentations on Neptune, Solar Irradiance Variations, Supernova 1987A, the Neutral Interstellar Medium in Galaxies, and Prospects in Cosmology. The status of the astrometry satellite Hipparcos, of HST, and of a number of other projects was discussed. The programme also included thesis presentations, unpublished discoveries, and more than 150 poster papers. Very successful panel discussions took place on "Cooperation in Astronomy in the New Europe", and on "Instrumentation Beyond the Year 2000".

On 10 October, the European Astronomical Society was founded in Davos. The idea of an EAS has been around for a long time, but only during the last few years have its form and aims been more specifically defined. The constitution of the EAS foresees a society of individual members who will determine its activities and elect its ten-member Council. The Society aims at fostering the progress of, and the cooperation in, astronomy in Europe, and at serving as a forum where specific issues of common interest may be discussed. The constitution foresees that existing national or language-based societies can become "affiliated societies" so as to ensure a smooth and cooperative interaction with the EAS.

By 25 October, already 681 astronomers had signed up as Founding Members of the EAS, and an additional 111 persons had announced their intent to become regular members.

For the coming several months, the EAS will be run by a small committee composed of A.A. Boyarchuk, M.C.E. Huber, J.P. Swings and L. Woltjer (Chairman). In the meantime, a nominating committee composed of present and past General Secretaries of the IAU (chaired by R. West, ESO) is preparing the nomination of the first Council of the EAS.

L. WOLTJER

Professor L. Woltjer announces the foundation of the European Astronomical Society in Davos, Switzerland, on October 10, 1990. (Photo: B. Shustov)

Report on the 12th European Regional Astronomy Meeting

Davos, Switzerland, October 8–11, 1990

When this meeting was planned in September and October 1989, nobody could foresee under which totally different conditions it would take place. But early in the planning state it was clear that 1990 is really the "Year of Europe" and no better time could be found for the long planned founding of the European Astronomical Society: Travel restrictions were abolished and many scientists from Eastern states were, after many years, or even for the first time in their life, able to travel to Western countries. Above all, younger astronomers were eager to make use of these new possibilities.

Within months the organizers of the conference were swamped with hopeful applications – and with requests for financial help. Travelling was possible, but the economic situations of many countries was – and still is – so difficult, that there were no financial means to make use of the new possibilities. So it was clear for the Organizing Committee that its main task was to make available as much financial support as possible. This has luckily been possible to a rather large amount.

Among the 300 participants were about 170 from countries of Eastern Europe. Many were young astronomers who could for the first time take part in such a meeting, eager to present their work to the international community and to listen with interest to the plans which were developed in the panel sessions about the future of European cooperation in research in astronomy. A lunchtime excursion under a cloudless sky to the mountaintop restaurant at Pischahorn and a reception celebrating the formal founding of the "European Astronomical Society" made informal contacts easy.

In addition to the two Panel Discussions on
- "Cooperation in Astronomy in the New Europe" and
- "Instrumentation beyond the year 2000" (see page 19)

there were reports on the newest developments:
- "Neptune" (A. Brahic, Paris),
- "Supernova 1987A" (I. Danziger, ESO, and N. Chugai, Moscow),
- "Prospects in Cosmology" (I. Novi-

kov, Moscow, and M. Rees, Cambridge),
- "The Neutral Interstellar Medium in Galaxies" (R. Genzel, Garching),
- Assessments of the satellite projects Hipparcos and Hubble Space Telescope (M. Perryman, ESTEC, and F. Machetto, STScI),

and, besides more than one hundred poster presentations, a substantial number of shorter communications.

U. W. STEINLIN,
Astronomisches Institut
der Universität Basel, Switzerland

New ESO Preprints

(September – November 1990)

Scientific Preprints

725. J. Breysacher and C. Perrier: Decoding of the Light Changes in Wolf-Rayet Eclipsing Binaries: An Application to HD 5980 in the Small Magellanic Cloud. Invited contribution – IAU Symposium No. 143 on "Wolf-Rayet Stars and Interactions with Other Massive Stars in Galaxies". Denpasar (Bali), Indonesia, June 18–22, 1990.
726. G. Zhao and P. Magain: Abundances of Neutron Capture Elements in Metal-Poor Dwarfs. I. Yttrium and Zirconium. *Astronomy and Astrophysics.*
727. G. Piotto: Properties of the Globular Cluster Mass Functions. M. Stiavelli et al.: Disk-Shocking and the Mass Function of Globular Clusters.
S. Djorgovski et al.: Color and Population Gradients in Globular Clusters.
S.R. Zaggia et al.: Central Velocity Dispersion Measurements in M30 and Five Other Centrally Concentrated GGCs.
To appear in *Formation and Evolution of Star Clusters* (ed. K. Janes), A.S.P. Conference Series, in press (1991).
728. P. Londrillo et al.: Dissipationless Galaxy Formation Revisited. *M.N.R.A.S.*
729. D. Bencivenni et al.: The Young Magellanic Cluster NGC 2004. *Astronomical Journal.*
730. E.A. Valentijn: Opaque Spiral Disks: Some Empirical Facts and Consequences. Invited paper presented at the IAU Symposium No. 144: "The Interstellar Disk-Halo Connection in Galaxies. Leiden, the Netherlands, June 1990. To be published in the Conference Proceedings. Ed. J.B.G.M. Bloemen, Kluwer, Dordrecht.
731. J.I. González-Serrano and E.A. Valentijn: A Rotation Curve Study of the Dwarf Sc Galaxy UGC 2259. *Astronomy and Astrophysics.*
732. D. Bettoni et al.: Stellar and Gas Kinematics of NGC 4546, the Double-Spin SB0. *M.N.R.A.S.*
733. R.M. West: A Photometric Study of (2060) Chiron and its Coma. *Astronomy and Astrophysics.*
734. R.M. West et al.: Commission 20: Positions and Motions of Minor Planets, Comets and Satellites (Positions et mouvements des petites planètes, des comètes et des satellites). To be published in IAU Transactions, Vol. XXI A, 1991.
735. A. Bragaglia et al.: Double Degenerates Among DA White Dwarfs. *Astrophysical Journal.*
736. R. Morganti et al.: The Nature of the Optical Filaments in Centaurus A: Evidence for a Beamed Ionizing Continuum. *M.N.R.A.S.*
737. A. Moneti and H. Zinnecker: Infrared Imaging Photometry of Binary T Tauri Stars. *Astronomy and Astrophysics.*
738. P.A. Patsis et al.: Self-Consistent Spiral Galactic Models. *Astronomy and Astrophysics.*
739. T. Zwitter et al.: Photometry of SS433 and its Implication on the Nature of the System. *Astronomy and Astrophysics.*
740. P. Bouchet et al.: The Bolometric Light Curve of SN 1987A. II. Results from Visible and Infrared Spectrophotometry. *Astronomy and Astrophysics.*
741. H.E. Schwarz: Discovery of a Nebula Around AS201. *Astronomy and Astrophysics.*
742. M. Capaccioli et al.: Empirical Correlations Between Globular Cluster Parameters and Mass Function Morphology. *Astronomy and Astrophysics.*

Technical Preprint

26. L. Noethe: Use of Minimum Energy Modes for Modal Active Optics Corrections of Thin Meniscus Mirrors. *Journal of Modern Optics.*

Cooperation in Astronomy in the New Europe

Report on a Panel Discussion at the XII ERAM in Davos[1].

The initial interest for a discussion on this theme was much stimulated by the exceptional attendance from Eastern Europe. Clearly, the frame of this discussion was shaped by the opportunities offered by the new situation in the East, as well as by the increasing interest of the European Community in fundamental science, mobility and University programmes. Free circulation of people has now been achieved over nearly all of Europe (although some visa limitations still remain in force); English has emerged as a common language in astronomy, and while "all astronomers are born equal", it is only now that equal opportunities progressively become a reality. It is the responsibility of the astronomical community to recognize its privileged life and to optimize the use of its costly resources in the most efficient manner, taking into account not only scientific, but also economic aspects. In the USSR, the difficulties related to the non-convertibility of currency creates problems, also for remote observatories, but the number of new projects (Radio-Astron, X- and Gamma-ray, 1.7-m EUV Telescope), which are open to international collaboration, should offer new opportunities.

The *mobility of people* is first addressed as a key issue in the construction of the new Europe. G. Setti underlines the existence of exchange programmes at the post-doctoral level, most often bilateral, sometimes within international agencies (ESA, ESO). He pleads for a vigorous extension of these programmes, suggesting a goal for the astronomical community of 200 fellows per year, with a price tag of about 10 MDM/year. The most likely agent for a corresponding action is the European Community, which currently discusses its new Science programme (and especially the Line 6 – Human Resources and Mobility). One could envisage that Societies as the newly founded EAS may become partners of the EEC for such action, in order to reduce bureaucratic overloads. Exchanges must be balanced within Europe. To further this goal, it is suggested to create a limited number of focal points in Eastern Europe, which could channel the international exchanges. Reference is made to the virtue of a broad post-doc programme in the United States, since no tenured position is achieved without some exposure to mobility and to a context distinct from the one where the PhD was prepared.

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[1] The Panel members were: A. Boksenberg (Cambridge), A. Boyarchuk (Moscow), P. Léna (Paris), R. Lüst (ESA), G. Setti (Bologna), J. Smak (Warsaw), R. West (ESO). F. Sanchez (Tenerife) and P.O. Lindblad (Stockholm) were unable to attend. In this short summary, opinions or comments are not necessarily referred to their actual author. The Chairman (P. Léna) takes the responsibility for his summary of the discussions, including remarks from the audience.

A. Boksenberg underlines how modern science, born in Europe, has a cultural richness which can be recognized by all Europeans acting in cooperation.

J. Smak makes a passionate plea for a balanced development where the "superpowers", in the astronomical sense, do not neglect the work which can be carried out in smaller institutes. All the best students should not leave the smaller institutes or countries, and a properly organized system of Visiting Professors or Lecturers could help to maintain the vitality of the smaller centres, given the present facilities of communication and decentralization. Small may remain beautiful!

R. Lüst points out how lucky the postwar generation has been to get postdoctoral opportunities in the United States on a broad scale, and how important this has been for the renaissance of science in Europe. H. van der Laan emphasizes the opportunities offered by the ESO Research Student Programme.

N. Bochkarev (Moscow) introduces the newly founded Soviet Astronomical Society, a professional society which intends to foster cooperation by disseminating information on fellowship programmes, evaluate projects, sponsor a new English-language publication, organize meetings, etc.

The second part of the discussion focuses on *Mobility of ideas and data*, in the framework of easier and faster communications. R. West describes the considerable changes that have taken place between "yesterday" when people went to the telescope to observe, and today, when the data come to the people, either from the telescope (remote observing) or from centralized data banks. An E-mail connection is a most important link to the rest of the world which any institute must ensure today; the recent, very positive experience in Warsaw is reported by J. Smak.

A key issue is data archiving. Data obtained on the ground are now coming at rates comparable to the ones obtained in space missions. And yet, their formatting is usually not so well defined, their archiving is of dubious nature or even absent, the right of access to astronomers not belonging to the observing teams is uncertain or with undefined rules. Defining formats, archives and rules of access in a professional way is an urgent task, especially in view of the advent of large, new telescopes and powerful detectors. Even existing data banks may not be sufficiently documented to offer an easy access to the non-specialist.

R. Lüst underlines the recent actions taken by the European Space Agency to accept as coinvestigators on space missions scientists from Hungaria, Poland, Czechoslovakia. P. Léna recalls a number of comments received during the Panel preparation phase, which all concern the high cost of scientific books, and express the hope that some efforts will be made to produce cheap (paperback), up-to-date fundamental books in astronomy for European students.

The available and future *Observing resources* in Europe constitute an important chapter. A. Boksenberg reads a letter from F. Sanchez, who outlines the exceptional opportunities offered by the Canarian site for long-term development of optical astronomy in the Northern Hemisphere and suggests the creation of an institution, similar to ESO, in the North. This view is challenged by several panel members, who would rather favour the development of ad-hoc cooperations, and not put available resources into monolithic schemes, which may then lose efficiency and slow down the emergence of new ideas. The cooperation within the VLBI may be taken as a good example of such flexibility. Some form of flexible association ought to be invented, which would allow the optimum sharing and use of observing resources, data and talents, but without leading to infinite extension of the membership in existing organizations. Funds provided by international structures, such as the EEC, could help to create this type of partnerships. On the individual basis, the status of "co-investigator" in a programme could also be extended to scientists who do not belong to a "member state" of a given programme.

It is suggested that the new EAS may trigger an effort analogous to the regular Reports to the National Academy of Science in the US (the current Bahcall Report), in order to provide guidelines for the future plans. The other view is also expressed, that one should keep flexibility and not necessarily provide a unique plan for Europe, where the sources of funding are much more diverse than in the USA. Naturally, this must not restrict the absolute need for optimization of resources in the global sense. In this connection, A. Boyarchuk recalls that the USSR projects are open to participation to all European scientists.

The last item on the Panel agenda is *Communication of astronomy to the public*. Time prevents an extended discussion on this, but R. West briefly outlines how much work is to be done: planetaria, proper school education, clubs, TV programmes. He stresses the great differences from country to country, and the urgency for appropriate channels to be created for the transfer of public information across the borders as well as the desirability that "culture" as well as "astronomy" properly develop new interactions. He mentions the current agreement between ESA, ESO, CERN, EMBL to create a joint scientific exhibition that will tour Europe in the coming years.

P. LÉNA, Panel Chairman

ESO Guesthouse in Snow!

Many visiting astronomers remember the ESO Guesthouse in Santiago as a warm and sunny place to rest after a hard observing run or a long flight from Europe. Few, however, have witnessed snow on the ground. The photo was made in July 1990 by K. Fuhrmann (Munich).

Hundreds of Rock Engravings Around the La Silla Observatory

D. BALLEREAU, Observatoire de Paris, DASGAL, Meudon, France
H. NIEMEYER F., Sociedad Chilena de Arqueología, Santiago, Chile

Astronomers on observational trips to the La Silla Observatory and the permanent staff can combine work and pleasure by making the most of the sunny days to take long walks on the mountains.

During these walks, they often discover strange rock engravings, sometimes very numerous, spread over the basaltic rock faces or on granitic blocks scattered on the soft slopes.

There are rock engravings all around La Silla, mainly on the eastern slope of the mountain, towards the locality called El Cementerio Indio, and in particular on the southern slope, on both sides of the Quebrada Los Tambos whose head is directly below the 3.6-m telescope. There are small groups of engravings on the western and northern slopes, but as yet little research has been done in these areas.

In early February 1990, we carried out a complete photographic and topographic survey of the engravings of the Quebrada Los Tambos and we partially explored those on the eastern slope. We compiled a photographic atlas of over 1000 black-and-white pictures and hundreds of colour slides. Several sets of contact prints were made, one of which was deposited at the library in La Silla, with an explanation of how the enlargement of the photos were made.

This article begins by giving a general idea of the geography and the history of this area, to help to situate the rock art and prehistoric sites of La Silla in relation to the ancient history of the Norte Chico. We then follow the paths in search of these hundreds of engravings, in order to look at them, describe them, define their specific style, identify their particularities, determine their distribution and attempt some interpretations. Finally, we compare the La Silla style with that of other known rock art sites in the region and elsewhere.

The Geographical and Historical Context

In this semi-arid region of Chile where the European Southern Observatory has been set up, four major physical features can be distinguished from east to west: the high cordillera, the mid-altitude mountain range (where Cerro La Silla is situated), the wide valleys which cross them, and the coastal plain (1).

Cerro La Silla is situated in the basin of the Río Los Choros, which does not originate in the high cordillera, unlike the two major adjoining river basins, the Río Huasco in the north and the Río Elqui in the south. This explains why there is no permanent watercourse in the bed of Río Los Choros. However, it may be presumed that in the first millenium of our era, rainfall was more abundant than it is now. The presence of prehistoric sites around La Silla and in the surrounding area supports this hypothesis, and the flora was certainly more varied.

Chronologically, from the beginning of our era until 700 or 800 AD, the first culture in the semi-arid north was *El Molle*, named after the village of the same name in the Elqui valley (2). During this period, agriculture was carried on and pottery was produced. Then the El Molle complex was superseded by another culture, perhaps technically more advanced, called *Animas* (3). This lasted until about 1200 AD and gave place to the *Diaguita* culture (4). This culture reached its height towards the middle of the XVth century, when the Inca conquest came from Peru. The symbiosis of these two cultures resulted in the *Inca-Diaguita* period until the Spanish conquest led to wholesale destruction from 1535–1540 onwards.

The archaeological sites of La Silla have not yet been excavated, but based on similarities between the rock art styles, it is generally accepted that the signs of human occupation at La Silla can be attributed to the El Molle complex. The Archaeological Museum of La Serena most attractively displays each of these cultural periods of prehistoric Norte Chico with many photographic documents and innumerable objects discovered during the archaeological excavations.

The Rock Art Sites of La Silla

We begin our exploration of the east slope of Cerro La Silla at the dormitories near the Hotel. This is a gentle downward slope and we take the direction of El Cementerio Indio. After a few hundred metres, we come across two solar figures about 20 cm in diameter carved on a block of basalt. Turning to look back towards our point of departure, we see a beautiful string of white domes silhouetted against the deep blue sky.

Further down, at an altitude of about 2000 m, we admire a magnificent set of engravings on a vertical panel in three parts, facing south-east (Fig. 1). This triptych was obviously carved by a single artist and over a short period of time, because the patina is uniform. There are two scenes showing men and animals together and strange geometrical figures whose meaning escapes us.

Arriving at El Cementerio Indio, some

Figure 1.

Figure 2.

engravings are visible here and there, not far from a spring. The soil has been considerably disturbed by many illicit excavations. Following the quebrada downwards, we reach the Río Los Choros.

The site richest in engravings is beyond doubt that of the Quebrada Los Tambos. Almost all of this vast and gently sloping region can be observed from the outside catwalk of the 3.6-m telescope. Some years ago, this area was difficult to reach because of the steep slopes below the 3.6-m which had to be negociated. Now the new road to Cerro Las Vizcachas saves time and energy. Figure 2 shows that the first groups of rock engravings are only one hundred metres or so below this road.

The higher part of the Quebrada Los Tambos follows a southerly direction and then gradually veers towards the east. A few hundred metres further down, it passes through a series of basaltic outcrops where some terraces have been formed. Various stone tools can be found here (Fig. 3) with other signs of human occupation. From this level, the talweg of the quebrada again veers towards the east and gently slopes down to El Cementerio Indio which we have described earlier.

The majority of the rock engravings in this quebrada are seen on the thousands of granite blocks scattered over the western slope. Engravings are also found on the eastern slope, which is steeper and basaltic. The largest engraved surface in the region is on this eastern slope. Dozens of varied motifs cover the surface of a stone slab measuring several square metres. However, it is difficult to move back sufficiently to be able to photograph all of it.

On both slopes of Quebrada Los Tambos, we have identified and photographed a total of nearly 800 engravings. Continuing our path towards the south and east, we found other groups of rock art which we hope to be able to explore in the future. The engraving technique used by the Molle is direct picking out using a blunt point. The outline is sometimes clumsy and superficial, sometimes deep and carefully done. Unlike many sites in the United States and Mexico, no longitudinal lines produced by a repeated abrasive movement are found.

We continue our route towards Cerro Las Vizcachas beyond the area shown in Figure 2. Up to the right, we pass the SEST of our Swedish friends and one kilometre further on, to our left, we observe some dark blocks of stone one hundred metres lower down. Here we discover one of the most beautiful groups of engravings of La Silla, and perhaps the one which is most familiar to weekend walkers (Fig. 4). This could be termed a coherent set of engravings, since as in the case of the triptych on the eastern slope the work appears to have been carried out at one and the same time. The delicate central spiral symbolizes a serpent, while the rest of the space is taken up by strange little figures, together with some simple geometric motifs and quadrupeds.

From this group of rocks, it is no longer possible to give a detailed itinerary, because engraved granitic rocks, isolated or in groups, are found in all directions. If we follow the contour line to our left, we come across the important site whose highest elements are shown in Figure 2. Heading directly east, we come to the important outcrop of basaltic walls of the bed of the Quebrada Los Tambos where the engravings are so numerous and so densely crowded that our heads spin! Almost every stone has an engraving and most of them have engravings on all their sides. The only advice we can give to the tourist is to follow a zigzag path and in groups to cover the area with a minimum of "misses".

Continuing our path towards the east, following the talweg, we come back to El Cementerio Indio. This path is also scattered with carved blocks of stone.

The La Silla Rock Art Style

Above all, a rock engraving is a thing of beauty which gives pleasure to the eye. Their great variety, their size and the diversity of themes of which they are composed often make them authentic works of art, which are admired in the same spirit as paintings in a museum. Here at La Silla the passing of centuries can be felt at the site. Some rocks have been fissured by weathering, in others the surface has flaked due to thermal or chemical action and the drawings have been lost for ever. Over the centuries, the sedentarized population of the area, whose domestic life was based on agriculture and cattle rearing, carved new rocks or did new carvings over older ones. The differences in patina indicate that this practice was spread over long periods in time. As for the fundamental

Figure 3.

Figure 4.

Figure 5.

Figure 6.

purpose of this art, this is difficult to define. But there is no doubt that it is the most familiar elements of daily life that are represented here.

The engravings of La Silla can be divided into two well-defined groups, abstract and figurative designs. In the first group, which is by far the most numerous, a large quantity of geometrical signs are encountered, endlessly repeated: plain circles or circles with rays (internal or external), isolated, concentric or in series, plain rectangles or rectangles with internal parallel lines, spirals, stars, ovals, isolated or parallel undulating motifs, Greek patterns, maze-like designs. Figure 5 is a fine example of the geometric use of the undulating motif. The central element is a closed undulation which is often seen at La Silla (see also Fig. 2). Figure 6 is different in conception as it shows numerous surface elements, isolated from one another, and with internal parallel lines.

One particular type of engraving is very common here. The surface of the rock is covered with a maximum of details so as to leave no free space. A fine example of this form of graphic expression, which could be termed an "integral structure" is shown in Figure 7, where it is difficult to determine any guiding principle in this jumble of circles, curves or segments. This rock is situated very near the road to Las Vizcachas, at level with the SEST.

The figurative drawings, fewer in number, mainly depict human outlines and animals. The anthropomorphs generally have a simple structure, a few lines representing the limbs and a dot for the head, but sometimes the style is more elaborate. The body is marked by thick lines, feet and hands are portrayed with toes and fingers, the head has a mask and bears a large ceremonial head-dress. This type of figure can be seen on the right in Figure 8. Its head is framed by four large dots and is surmounted by a feathered structure. The rest of the surface bears a tortuous network of irregular lines. Figure 9 is extremely interesting as it shows a highly stylized human form, identifiable by its two small eyes and the two hands with five fingers. Stylized representations of this kind are very rare at La Silla. This carving is located on the eastern slope of Quebrada Los Tambos.

Animal shapes are very numerous and camelidae can be identified by their long necks. Often, the animal is depicted near a human figure and we are in presence of a domestic scene. The extreme abundance of such motifs is an argument in favour of the essentially pastoral nature of the Molle populations which occupied these sites at the beginning of the modern era. The very pretty scene in Figure 10 has the most plentiful animals of the entire site, nearly 25 animals and some human figures, very certainly shepherds. In other engravings, animals follow each other quietly in line . . .

Another animal frequently represented is the serpent, depicted as a wave-like form ending in a large dot. Curiously, one never now comes across serpents when walking in this area.

We will end this description of the La Silla rock art style with the two anthropomorphs shown in Figure 11. Two figures can be seen, whose morphology is distinguished by a "thick" body, i.e. a certain area of the rock has been hollowed out by repeated impacts. They have neither hands nor feet, but on their heads they bear respectively 6 and 3 rectilinear or curved ornaments, perhaps feathers. Their style is unique at La Silla and they bring to mind representations of shamans. Such figures are common throughout pre-Colombian America. This scene is located near the road to Cerro Las Vizcachas, not far from the cerro, on a small mound a few

Figure 7.

Figure 8.

Figure 9.

Figure 10.

dozen metres away on the right. We would like to thank Mr. Scardia for taking us there. We also walked around the mound and saw that the two shamans enjoyed a splendid isolation, untroubled by the presence of any other engraving . . .

Rock Art in the Norte Chico

Between Río Copiapó to the north and Río Choapa to the south, 200 archaeological sites belonging to the El Molle complex have been identified (5). Rock art is in evidence at 43 of these sites. This indicates the importance of this art form, which by its very nature withstands the passage of time.

The greatest El Molle rock art sites are found in the basin of the Río Limarí, in particular along the Río Hurtado in the north and around the town of Combarbalá in the south. The *Limarí* style is characterized by the wide variety of heads wearing masks or extravagant ceremonial head-dresses. Only one example of this type of engraving is seen at La Silla. The most representative site of the *Limarí* style is the El Encanto valley, 19 km from the town of Ovalle in the province of Coquimbo. Some of the most beautiful examples of rock art in Chile can be admired there. The representations of gigantic human heads, rectangular in shape, bearing wide and complex adornments, are deeply engraved in regular furrows obtained by a remarkable longitudinal buffing.

The La Silla style thus seems to be well delimited in semi-arid Chile, between latitudes 27° S and 32° S, with some perceptible differences between the north (Copiapó and Huasco) and the south (Elqui and Limarí).

Another well-known rock art site gives an opportunity for more detailed comparison of styles and symbols. This is the site in Quebrada Las Pintadas de Marquesa, a northern tributary of Río Elqui, where over 500 engravings have been recorded (6). Comparison with La Silla leaves no doubt as to the similarity between the styles: the same invariants, the same human and animal figures, the same engraving technique. However, decorated heads are relatively numerous. This important symbol of rock art thus shows a distinct progression from north to south, between La Silla where it is practically absent, the Quebrada Marquesa where it becomes more frequent, and the Limarí basin where it is omnipresent.

Acknowledgements

We wish to express our thanks to Professor van der Laan, Director General of ESO, who gave his agreement to our proposal of archaeological prospection around the Observatory. We are also happy to take this opportunity to thank Mr. Daniel Hofstadt and Miss Armelle Cabillic who did everything possible so that our work could be carried out under the best possible conditions. We are also grateful to Jacques Breysacher, who was responsible for liaison between Meudon and Garching for the preparation of the mission. Dr. Roland Paskoff carefully read the text and added useful improvements.

Figure 11.

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Report on ESO Workshop on Rapid Variability of OB Stars

Waves or Spots?

D. BAADE, ESO

Highlighted by some of the most beautiful days which this year's autumn had to offer, a workshop on the rapid variability of OB stars took place on October 15–18 at ESO's Headquarters in Garching. Seventy people had come from twenty countries (as the Director General, H. van der Laan, pointed out in his welcoming address, this number also reflects the rapid political variations in Europe) on five continents to participate in the meeting. Fifteen ESO staff members attended at least part of the workshop.

Over the past ten years, it has become clear that a very large fraction of stars in the upper left of the Hertzsprung-Russell diagram show weak but significant variations in light, colour, line profiles, etc. In some cases, the patterns seen are complicated; but generally they are surprisingly similar over a range of more than 30,000 K in effective temperature and 8 magnitudes in bolometric luminosity. In a number of cases, nonradial pulsation (NRP), mostly travelling waves, is the widely accepted explanation although the driving mechanism(s) is (are) not finally identified.

In other stars, the evidence for NRP is more disputed and especially for stars whose probable rotation periods are statistically indistinguishable from the observed periods, corotating surface features ("spots") might offer a rather different explanation.

The primary aim of the workshop was to provide the basis for a structured discussion of the large and complex observational material which had often led to only partial explanations. A secondary aim was an early reconnaissance of the diagnostic value, if any, of the phenomena. Especially pulsation may provide interesting insights into the internal structure of rapidly evolving OB stars which often is veiled by substantial mass loss. The workshop was fortunate in that it succeeded in gathering a very large fraction of at least the observers engaged in the field.

The Scientific Organizing Committee (SOC; H. Ando, D. Baade, C.T. Bolton, H. Henrichs, L.B. Lucy) had invited nineteen reviews in order to form the scientific backbone of the meeting. The first day was devoted to observations of line profile and photometric variations in various sub-classes of OB stars. The second day started with presentations of other variables, e.g. δ Scuti, magnetic, and cool spotted stars, where models also considered for OB stars are more firmly established. In the afternoon, papers on possible relations between variations at the photospheric level and in the radiatively driven winds of hot luminous stars were followed by summaries of some of the main models competing for the explanation of the observations. This latter part of the programme was continued on Wednesday morning. The remainder of the agenda addressed the more long-term question whether the study of variabilities can provide information about OB stars which cannot otherwise be obtained. The topics covered included the modeling of stellar atmospheres, chaos, driving mechanisms, the interaction between NRP and rotation, and the connection between stellar evolution and pulsation.

Thirty-three poster papers were shown during two poster sessions. Together with the ten orally presented contributed papers, they brought the ratio of papers to participants relatively close to the ideal (provided neither number is too large) value of unity.

Upon invitation by the SOC, A.G. Hearn, J.M. Marlborough, and J.R. Percy gave brief, personal summaries of the workshop. Apart from rounding off the workshop, their remarks were also intended as nuclei for the special discussion session in the morning of Thursday, October 18. The SOC had asked participants ahead of time whether they would be interested in a more extensive discussion which, contrary to the other sessions, would not be recorded in the proceedings. In fact, nearly two-thirds of the participants came and a lively discussion developed. The inherent risk of a session without predefined agenda was ably compensated by the careful chairmanship of C.T. Bolton. So, the obvious advantage of this concept, namely to re-assess the main topics in a broader context after all observed facts and inferred arguments had previously been put on the table, could be fully exploited. A general consensus seemed to be that the main problems are now seen much more clearly. A very encouraging observation was that inspite of the necessarily controversial character of the discussion, participants tried very constructively to identify the areas of agreement. These may be larger than could realistically be expected before the workshop: Nonradial pulsations are the most widespread phenomenon. But there are certain phenomena which cannot in any straightforward way be explained by standard NRP eigenfunctions. In the co-rotating frame their phase velocity is very small, if not zero, but may nevertheless include velocity fields. Viable driving mechanisms of nonradial pulsations may be within reach.

Workshop participants have been asked to provide their manuscripts in camera-ready form by November 15. The proceedings will be published in the ESO Conference and Workshops Proceedings series and are intended to appear early in spring, 1991.

Many participants commented on the smooth organization of the workshop. It is my pleasure to pass these compliments on to those colleagues who actually deserve them: Hans-Jürgen Kraus, Harry Neumann, Britt Sjöberg, Rebonto Guha, Francesco Ferraro, to name only a few, and especially Christina Stoffer who gave an instructive example of Swiss precision.

ESO Exhibitions in a European Frame

This autumn, the ESO Exhibition visited the Council of Europe in Strasbourg, France, during sessions of the Council, as well as of the European Parliament. Following the festive opening on September 26 by the ESO Director General, Professor van der Laan, it was seen by a large number of delegates from most European countries in the course of the next 18 days. The exhibition was permanently manned by staff from ESO and/or the Strasbourg Observatory (our thanks are due to the Director, Michel Crézé and his staff!) and the astronomers had plenty of opportunity to inform politicians and other specialists about what is going on in the Universe. Quite a few delegates from countries which are not members of ESO wanted to know why this is so. Who knows, perhaps some seeds have been sown in the minds of influential people!

Just two days later, another ESO exhibition was opened in Porto by the Portuguese Secretary of State for Science and Technology, Professor José Pedro Sucena Paiva, in the old market hall, newly transformed into a splendid frame for exhibitions. The arrangements were perfect, due to the excellent preparations by Professor Teresa Lago of the Porto Astrophysical Centre and her corps of dedicated astronomy students, headed by Natércia Lima, who all put in a lot of work. It was visited by nearly 15,000 persons during less than four weeks, including many school classes from Porto and the surrounding country.

In the beginning of November, the exhibition moved on to the capital, Lisbon, where it will be on display until mid-December, at the Science Museum. The local arrangements were handled by Professor F. Duarte Santos and the opening on November 7 was attended by more than 100 persons, including many representatives of the media. The event was widely reported in the press and on TV with favourable comments about the new association between ESO and Portugal.

Figure 1: *A view of the ESO Exhibition at the Council of Europe in Strasbourg.*

Figure 2: *The Portuguese Secretary of State for Science and Technology inspects a model of an 8-metre VLT mirror at the ESO exhibition in Porto.*

IAU Executive Committee Visits ESO

At the invitation of Professor Harry van der Laan, Director General of ESO, the IAU Executive Committee visited ESO on September 7, 1990.

The Executive Committee, headed by the IAU President, Professor Yoshihide Kozai, held its annual meeting at ESO's neighbour institute, the Max-Planck Institute for Astrophysics, whose director, Professor Rudolf Kippenhahn, is also Vice-President of the IAU. After a hard day's work, the EC members and the IAU Secretaries walked over to ESO and were shown around the various facilities, including the Image Processing Centre and the Remote Control Centre.

At a subsequent buffet dinner in the new Council room, the EC members had the opportunity to meet with ESO scientists and visitors, and there was plenty of time for renewal of personal links and exchange of new astronomical information.

The Editor

ESO'S EARLY HISTORY, 1953–1975

IX. The 3.6-m Telescope Project Division; ESO Collaborates with CERN*

A. BLAAUW, Kapteyn Laboratory, Groningen, the Netherlands

> *"– – – practically everyone [on the CERN Committee of Council] – – – emphasized the scientific importance of the collaboration between astronomy and high-energy physics and common technical developments – – –".*
>
> From a letter of C.J. Zilverschoon (CERN) to the author of November 27, 1969.

In the second half of 1969, Council and ESO Directorate changed course in the effort to realize the 3.6-m telescope. Within the ESO management, but in close consultation with Council members, collaboration with other scientific organizations or with industry was contemplated as an alternative to relying entirely on the engineering bureau of Strewinski.

ESO Approaches CERN

For several reasons, ESO tended to turn first of all to CERN. CERN developed powerful and sophisticated instrumentation; the scientific, non-profit aims of the two organizations were similar; CERN's Rules and Regulations for personnel and its administrative procedures had served as a model for those of ESO, and as we saw in article I, the ESO Convention had been shaped to a large degree after that of CERN. An interesting and important circumstance was also that for three of the six ESO member states, government delegates in the CERN and the ESO Council were the same person: from the time of the ratification of the ESO Convention in 1964 till the early 1970's, this had been the case for Denmark (O. Obling), the Netherlands (J.H. Bannier) and Sweden (G. Funke). Moreover, the ESO Council members for the Federal Republic of Germany and for France, C. Zelle (from 1970) and A. Alline (from 1969), respectively, had been members for several years of the CERN Finance Committee. Thus, there was much common ground between the governing bodies of the two organizations and ample possibility for informal consultation [1].

Deliberations cristallized at a meeting at CERN on October 21, 1969. Present were from CERN: its Director-General Bernard P. Gregory, the Director of Administration George H. Hampton, and C. ("Kees") J. Zilverschoon, Head-Engineer associated with the construction of the Intersecting Storage Rings. ESO was represented by Heckmann, Ramberg, Blaauw and Bloemkolk of the Directorate, and Fehrenbach as Chairman of the Instrumentation Committee. An extensive report on the meeting, dated November 10, 1969, was written by Ramberg [2]. After introductory presentations on general CERN procedures for handling large instrumentation projects and on the current situation of the 3.6-m Telescope Project, possible ways of collaboration were explored. Not only the case of the 3.6-m telescope was considered; reference was also made to the recent proposals of the SPC for three powerful telescopes described in article VII (a large photometric telescope, a "big Schmidt", and an astrometric telescope).

The most attractive arrangement appeared to be what we shall call the "incorporation proposition": ESO would create the staff positions that would be required according to CERN experience for a project of the (financial) size of the 3.6-m telescope, and make these available for an ESO set-up at CERN. The group would follow CERN rules and grades and salary scales, and be under the jurisdiction of the Director General of CERN, whereas the ultimate scientific responsibility for the project would remain under the Director General of ESO. The draft organigram proposed at the meeting is reproduced in Ramberg's report. Even farther reaching collaboration was briefly discussed, including the possibility of common research projects and close physical neighbourhood of the two Headquarters. A time schedule was drawn up leading to completion of the telescope project on La Silla about six and a half years after the beginning at CERN. An essential feature of the proposed arrangement would be the continuous availability of CERN expertise – technical and administrative – and even CERN making personnel available to ESO "on loan" for limited periods.

As a first step following the meeting, Ramberg on behalf of the ESO Directorate sent on November 12, 1969 the following telegram to the President of the CERN Council [3]:

"In view of the recent informal discussion between the Director General of CERN and the Director General of the European Southern Observatory, on which occasion a mutual interest in exploring a collaboration between the two organizations was expressed, we respectfully submit for your meeting of the Committee of the CERN Council a request to explore the possibilities for such a collaboration within CERN."

As the President of the CERN Council, G. Funke, also was a member of the ESO Council (and had been its President over the years 1966–1968!), understanding for the situation could be taken for granted, and the matter was duly submitted to the CERN Committee of Council in its meeting on the next day, November 13. The reaction was very encouraging. In a letter of November 27, 1969 addressed to myself, Zilverschoon informally reported as follows (in translation by me from the Dutch text):

"As you may have heard from Bannier, our Committee of Council has very favourably received the proposition of collaboration with ESO.

It was remarkable that practically everyone – – – entirely lost sight of the original aim, the construction of the telescope, and rather emphasized the scientific importance of the collaboration between astronomy and high-energy physics [and] common technical developments such as data handling and the political aspect: formation of a "Communauté scientifique européenne", in which there would be room also for other organizations for fundamental science. England, too, was quite positive. We expect that our Council in December will approve continuation of the discussion. – – –."

In my reply of December 9, apart from expressing appreciation for the reaction of CERN, I elaborated especially on the prospect of wider scientific collaboration on which I may return in a later article [4]. Kees Zilverschoon, the author of the above letter, would in subsequent years become a devoted counseler to ESO's TP Division.

Consultation with ESRO

CERN was not, however, the only sister organization approached by ESO. The other one was ESRO, the European Space Research Organization, predecessor of the European Space Agency. On November 14, 1969 I visited its Director General H. Bondi at ESRO Headquarters in Paris [5]. Bondi, too, reacted quite positively. However, as

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* Previous articles in this series appeared in the *Messenger* Nos 54 to 61.

MEETINGS OF COUNCIL, COMMITTEE OF COUNCIL AND FINANCE COMMITTEE, 1970 – 1974

COUNCIL and COMMITTEE of COUNCIL				
COU No.	*C. of C. No.*	Date	Place	President
	1	*1970 May 6*	*Hamburg*	*J.H. Bannier*
15		1970 June 11	Hamburg	J.H. Bannier
	2	*1970 November 17*	*Hamburg*	*J.H. Bannier*
16		1970 December 9	Hamburg	J.H. Bannier
	3	*1971 May 18*	*Hamburg*	*J.H. Bannier*
17		1971 June 9–10	Hamburg	J.H. Bannier
	4	*1971 November 12*	*Geneva*	*J.H. Bannier*
18		1971 Nov. 30/Dec. 1	Hamburg	J.H. Bannier
	5	*1972 May 19*	*Geneva*	*A. Alline*
19		1972 June 8–9	Geneva	A. Alline
	6	*1972 October 31*	*Bergedorf*	*A. Alline*
20		1972 November 17–18, 21, 24	Santiago, La Silla	A. Alline
	7	*1973 March 29*	*Paris*	*A. Alline*
	8	*1973 May 18*	*Geneva*	*A. Alline*
21		1973 June 5–6	Hamburg	A. Alline
	9	*1973 November 28*	*Geneva*	*A. Alline*
22		1973 December 13–14	Hamburg	A. Alline
	10	*1974 March 26*	*Geneva*	*A. Alline*
	11	*1974 May 9*	*Bergedorf*	*A. Alline*
23		1974 June 19, 20	Hamburg	A. Alline
	12	*1974 November 1*	*Amsterdam*	*J.H. Bannier*
24		1974 December 5–6	Hamburg	J.H. Bannier

FINANCE COMMITTEE			
No.	Date	Place	President
17	1970 March 10	Hamburg	C. Zelle
18	1970 May 22	Hamburg	C. Zelle
19	1970 October 28	Hamburg	C. Zelle
20	1971 May 17	Hamburg	C. Zelle
21	1971 October 5, 6, 8	La Silla, Santiago	C. Zelle
22	1971 November 16, 17	Hamburg	C. Zelle
23	1972 April 11	Hamburg	C. Zelle
24	1972 October 17	Bergedorf	C. Zelle
25	1972 December 18	Geneva	C. Zelle
26	1973 April 26	Bergedorf	M. Fehrm
27	1973 November 12, 13	Bergedorf	M. Fehrm
28	1973 December 12	Bergedorf	M. Fehrm
29	1974 June 6	Bergedorf	M. Fehrm
30	1974 October 31	Amsterdam	M. Fehrm

space-engineering differs quite a bit from ground-based work in that the requirements for space-proof products make them considerably more expensive than those that, if needs be, can be reached by a ground-based technician, cost estimates soon pushed this perspective for collaboration into the background.

The Documents Cou-59 and Cou-60 of December 1969

Parallel to these talks between ESO and CERN ran consultations between Council and myself as a candidate for the succession of Heckmann in the General Directorate. I had been approached by Council on this matter early in 1969, and this led to a formal offer by the President of Council, J.H. Bannier, of June 30, 1969, containing the following passage: "Council considers the successful construction and erection of the 3.6-m telescope as a priority task of the Organization for the next few years, and would be happy to hear how you think that you can best discharge your responsibility in this respect. The Council is willing to discuss with you any proposals you would like to make, even if these would imply changes in the structure of, or a different division of responsibilities within, the Organization. Council would be pleased to receive such proposals early enough to be able to discuss them in the meeting of 15 and 16 December 1969." [6].

Half a year later, for this meeting Council had at its disposal two documents for discussing its policy. One was "The Present State of the 3.6-m Telescope Project" (Doc. Cou-59), compiled by the Technical Director J. Ramberg [7], the other the "Memorandum on Further Development of the 3.6-m Telescope project and on Possible Collaboration with CERN or/and ESRO" (Doc. Cou-60), by myself [8].

Document Cou-59 summarized the situation by the end of 1969, including a breakdown of the cost estimates for the

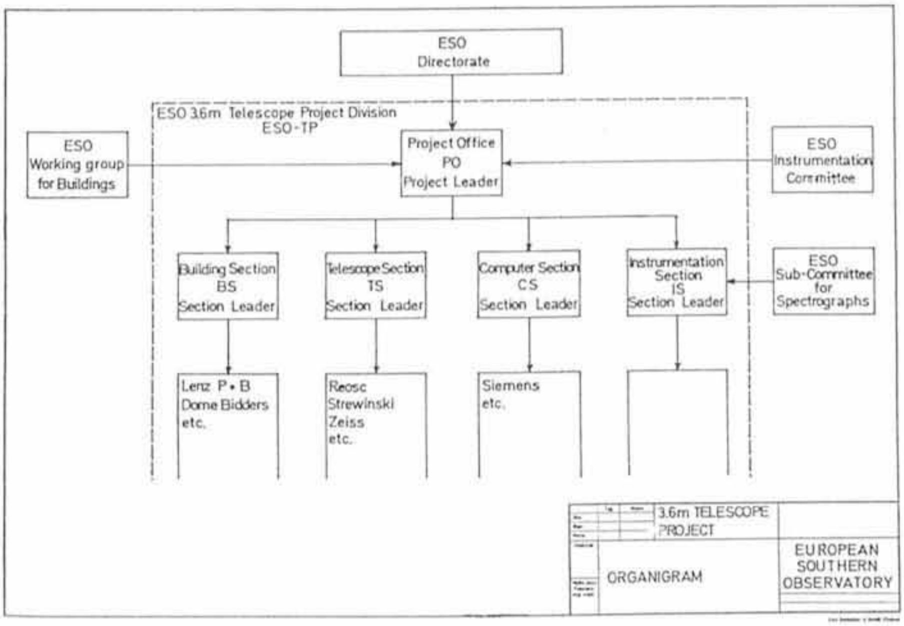
MEETINGS OF THE INSTRUMENTATION COMMITTEE, 1970 – 1974

No.	Date	Place	President
30	1970 June 2	Hamburg	Ch. Fehrenbach
31	1970 December 1	Geneva	Ch. Fehrenbach
32	1971 March 8	Geneva	Ch. Fehrenbach
33	1971 September 21	Geneva	Ch. Fehrenbach
34	1972 March 28	Geneva	J. Borgman
35	1972 June 6	Geneva	J. Borgman
36	1972 October 3–4	Geneva	J. Borgman
37	1973 February 13–14	Geneva	J. Borgman
38	1973 October 3–4	Geneva	J. Borgman
39	1974 March 27–28	Geneva	J. Borgman
40	1974 October 15–16	Lyon	J. Borgman

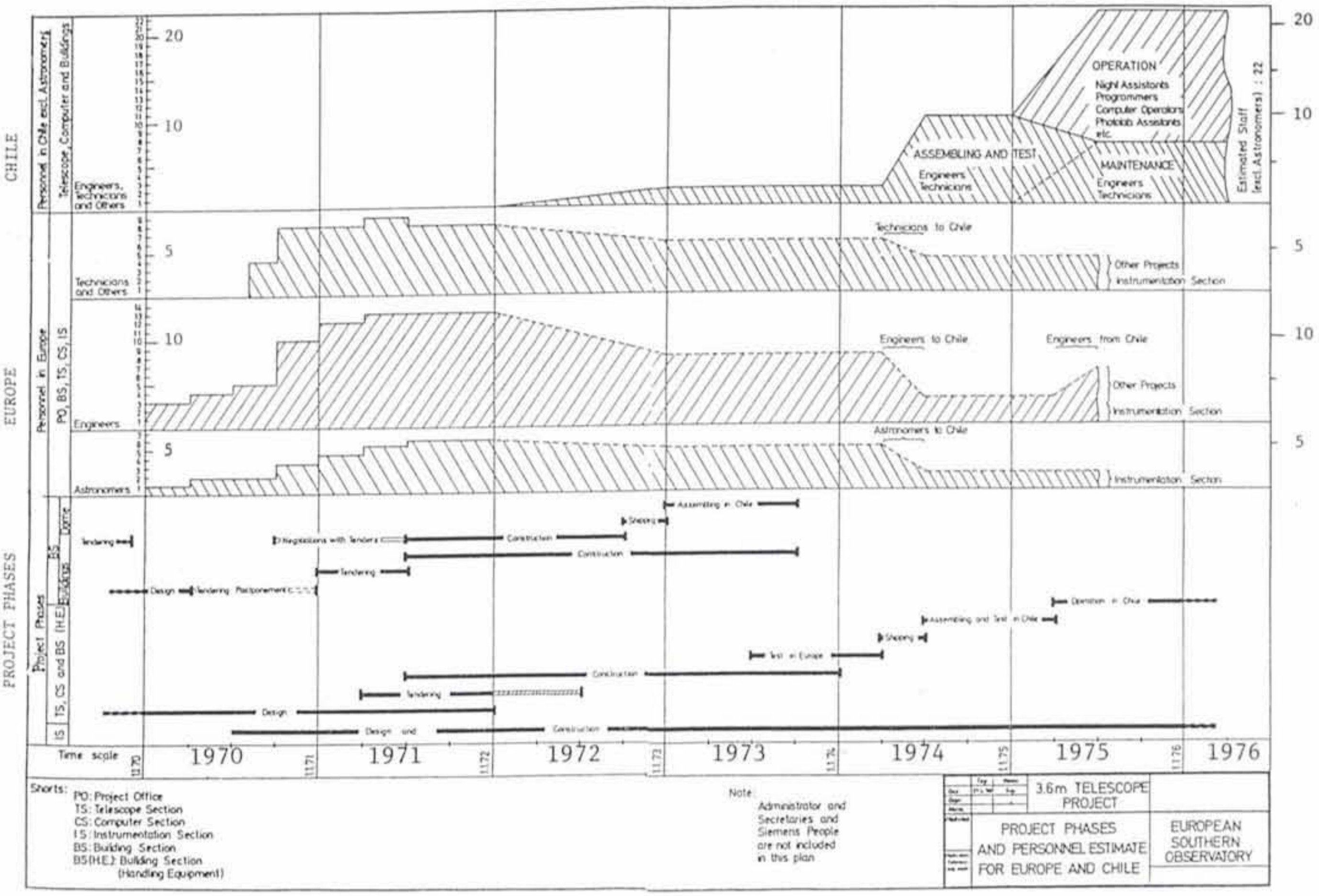
various components of the project. As this situation has been reviewed in the previous article, we need not present here again Ramberg's summary. I shall return to the cost estimates of Cou-59 in article XI.

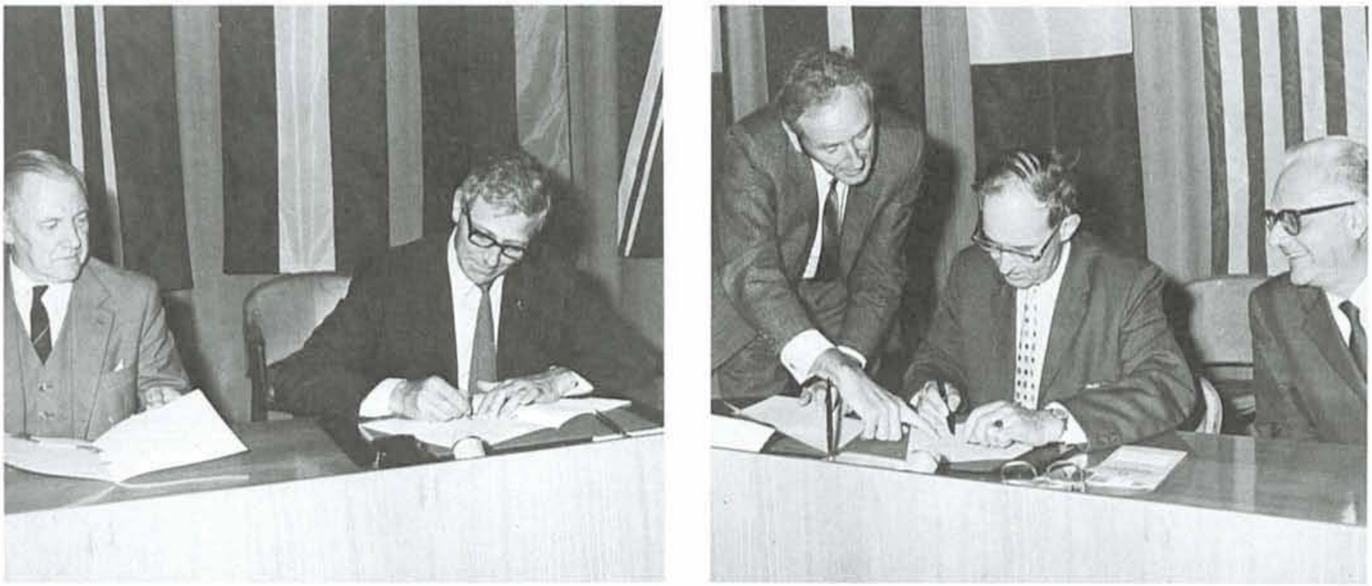
Cou-60 consisted of three parts. The first part discussed ways of proceeding with the project with special reference to the possible collaboration with CERN, the second part discussed further aspects of the collaboration with CERN including the proposition that the ESO Headquarters should move from Bergedorf to Geneva, and the third one briefly dealt with concern about the position of the ESO project relative to certain national projects in astronomy. In the present context I shall only refer to the first part; in article XI I expect to return to the other two.

Starting point for part I was a compilation, prepared by Heckmann, of possible ways one might chose from in the case of involvement of industrial firms, with varying degrees of participation by Strewinski's bureau. A solution of this kind would have been preferred by Heckmann, but none of those suggested seemed attractive in comparison with the prospect of collaboration with CERN. With reference to the growing internal technical group headed by Laustsen and described in the previous article, the document elaborated on how this Group might operate in conjunction with CERN, and it expressed preference for the "incorporation proposition", the

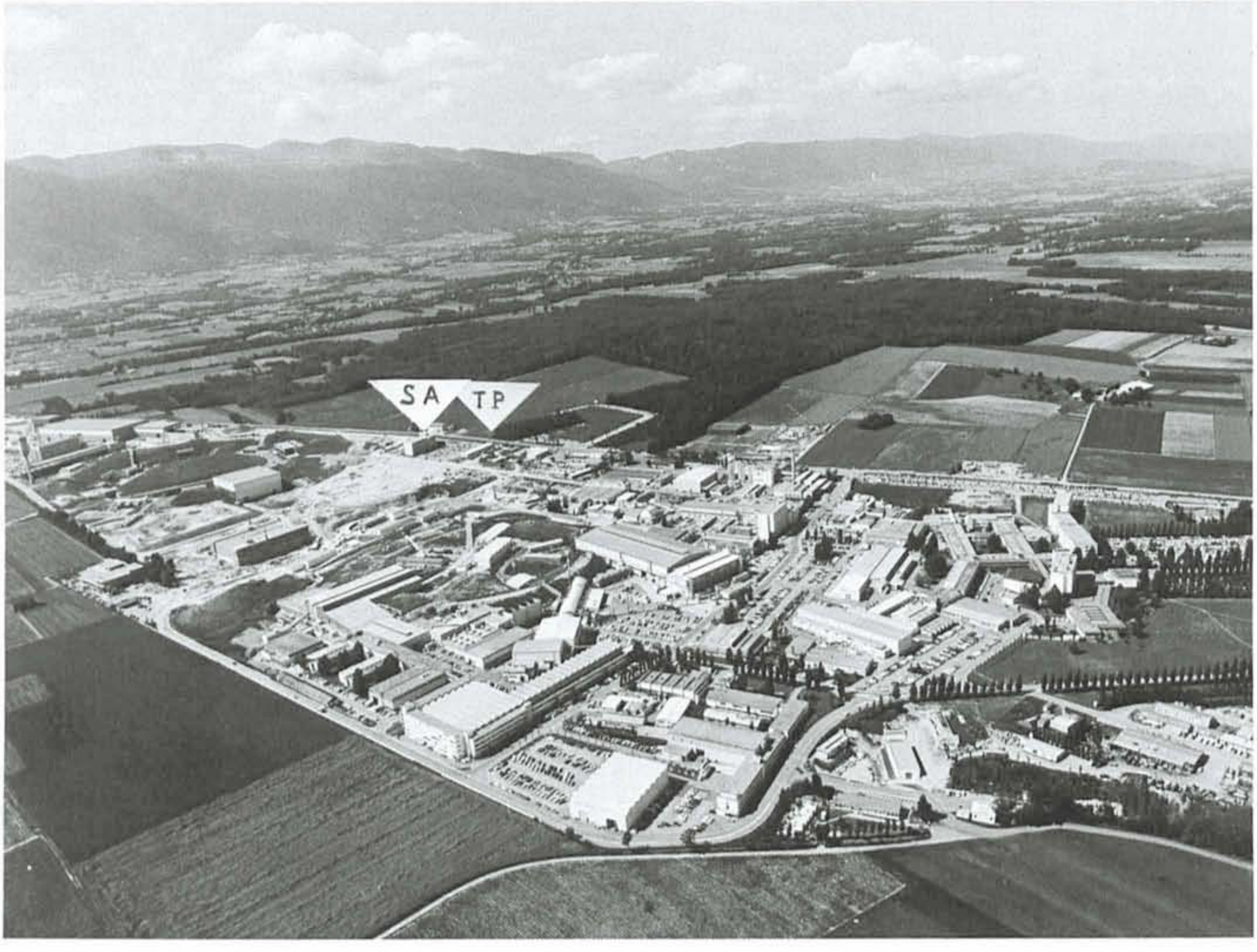


In May 1970, the ESO Directorate submitted to Council a proposal (Doc. Cou-66) for the structure, the constitution and the time schedule of an in-house group for the realization of the 3.6-m Telescope. It was endorsed by Council in its meeting of June 11, 1970, and provided the starting point for the execution of the project by the ESO TP Division in the next six years in collaboration with CERN. The two diagrams reproduced here from Cou-66 present the proposed administrative structure of the Group and the estimated time schedule for the period 1970–1976; the latter diagram illustrates the varying degree of involvement of engineers, techniciens and astronomers and the shift of their activities from Europe to Chile towards the end of the period.





On September 16, 1970 at CERN, the contract was signed between ESO and CERN for collaboration in the realization of the ESO 3.6-m Telescope and its auxiliary equipment. The two photographs show, from left to right: J.H. Bannier, President of the ESO Council, B.P. Gregory, Director General of CERN, G. Hampton, Head of Administration of CERN, A. Blaauw, Director General of ESO, and E. Amaldi, President of the CERN Council.
From photographs in the EHPA.



ESO's establishments on the premises of CERN.
By the end of 1970, a few months after the collaborative agreement between ESO and CERN had been signed, the Telescope Division had established itself in the building made available by CERN and marked in the above photograph by TP. The photograph shows the extensive complex of CERN's laboratories, technical facilities and administrative services, located at Meyrin near Geneva as they were in 1970.
A few years later, as will be described in the next article in this series, ESO's Sky Atlas Laboratory also was established on the CERN premises; it was housed in the building marked SA, facing the TP Division.
From photograph in the EHPA.

The southern part of La Silla, early 1970. *At that time, the intermediate-size telescopes were in regular operation; of these, we show here, at left, the 1-m Photometric Telescope and next the Grand Prism Objectif (GPO). Next to this, in the background, the dome of the Schmidt telescope, at that moment still waiting for the telescope's arrival (this happened at the end of 1971). In the far background, beyond the hill with the water tanks, the flattened summit prepared for the 3.6-m telescope. This one, however, would have to wait longer . . .; early 1970 was the time of the renewed planning of the realization of the telescope.*
This photograph is one of a set taken for the firm of Hochtief that constructed the buildings of the first construction phase on La Silla and the Headquarters in Santiago. These photographs together with rather detailed descriptions of the buildings have been published in the July 1971 issue of the magazin Hochtief Nachrichten (in EHA-I.C.3.2.).

closest of the forms of collaboration sketched at CERN on October 21. It recognized, though, that besides the many advantages of this solution (notably CERN's established experience in non-profit scientific instrumental development), there was the danger that the negotiations with CERN might lead to longer delays than negotiations with private firms. In the most favourable case they might lead to complete clearance at the June 1970 CERN Council meeting. A complicating, uncertain element in the discussions were the financial implications of the two forms of collaboration, with CERN or with industry.

The ESO Council meeting of December 1969 reacted by creating a number of staff positions required for the work of the Laustsen Group and encouraged the (future) Director General to further pursue the negociations with CERN, although more information on industrial participation remained desired.

Most outspoken in its preference for CERN was the French delegation. Let me quote part of the statement of its member, the astronomer André Lallemand:

"La réalisation de ce grand télescope est à la limite de nos possibilités techniques, toujours parce que l'expérience à cette échelle nous manque en Europe.

Ce que je vais dire n'est aucunement une critique de l'excellent travail fait par le Comité des Instruments et par les ingénieurs qui ont travaillé au projet, mais il suffit de lire le document Cou-59 du 8 décembre 1969, pour être persuadé de cette inexpérience. – – –

Ceci montre que l'ESO a un besoin impérieux de l'assistance d'un organisme expérimenté, ayant l'habitude de traiter des questions semblables et de même envergure, et d'un organisme n'ayant pas des fins et des activités à caractère commercial et lucratif. Cette assistance nous l'avons trouvée au CERN et devant l'ampleur des difficultés que nous allons rencontrer, je souhaite qu'elle soit la plus large possible. – – –

On peut rêver à ce que pourra être l'ESO dans le futur, il est agréable de penser que non seulement l'ESO pourra fournir des moyens d'observation extrêmement puissante, mais qu'elle pourra être aussi un centre culturel où les astronomes européens pourront travailler en étroite collaboration, et où les théoriciens et les observateurs pourront échanger leurs idées et leurs résultats, mais – – – Il faut d'abord réaliser vite et bien notre grand télescope, cette réussite est l'enjeu de l'existence même de l'ESO."

The German delegation, on the other hand, insisted strongly on exploring more extensively industrial participation.

Pursuing the In-House Group Concept: Doc. Cou-66

After the December 1969 Council meeting, parallel to pursuing external participation, the ESO Directorate worked out a scheme for realizing the telescope by means of a powerful in-house technical group. This led to the important document Cou-66 "The ESO 3.6-m Telescope Project" that became the basis for further policy decisions. It was prepared at the Bergedorf office by the working group for the development of telescope operation and auxiliary instrumentation (of which I mentioned the creation at the end of the previous article): Laustsen and his associates Blichfeldt, Malm and Scharnweber, with the advice of the Technical Director Ramberg. It was presented to the Committee of Council for its meeting of May 6, 1970 and had three points of departure:

"A. ESO must form its own group of astronomers, engineers, etc. which group shall be able to conduct the project through all its phases including the first period of operation of the instrument in Chile.

B. The group must at any time have all parts of the project under firm control. But --- a major part of the design work and all construction work will have to be done by consulting and manufacturing firms.

C. --- For its task in Europe [the group] should be located in a scientific and technological milieu and be offered good service facilities."

The various sections of the document dealt with Administrative Structure, Project Office, Building Section, Telescope Section, Computer Section, Instrumentation Section, Personnel Plan for Design Phase, and Long-Term Schedule and Personnel Plan. Throughout, there was reference to the possibility – but not necessity – that the group might be established at CERN, and the document was inspired by consultations with staff of CERN.

Starting point for the planning was the situation at the end of 1969, laid down in Ramberg's Status Report Cou-59. Making optimal use of what had been done so far on the project was a natural point of departure, although this was hampered by reluctance of Strewinski's bureau to provide documentation beyond the design drawings already delivered to the Instrumentation Committee. The long-term time schedule foresaw completion of building and dome on La Silla by October 1973, completion of assembling and testing of the telescope on La Silla around April 1975, and hence first operations in the course of that year.

No financial schedule was given, but much attention was paid to the detailed personnel planning which should be one of the principal bases for budget planning. For astronomical and technical staff – but not including administrative and secretarial help – the following personnel complements were foreseen: per January 1971, 24.5; per July 1971, 29; per January 1972, 27; and approximately that same level for the following years. At the time of submission of the report, Laustsen's group counted 5.5 members. The steep growth to some 25 or 30 members represented what had been expected from comparisons with large telescope projects elsewhere; it also underlined one of the serious shortcomings of the previous arrangement: the shortage of staff of the bureau of Strewinski. The personnel development plan given in Cou-66 is reproduced here in the accompanying diagram.

For the sake of comparison with projects elsewhere of comparable scope, Council was also presented with data obtained from AURA's Large Telescope

On December 31, 1971, Jöran Ramberg resigned as Technical Director after having been associated with ESO since November 1963 and having essentially contributed to its building programme and to putting the 3.6-m Telescope Project on the new track. These photographs, taken at his farewell party, show:
upper left: *Jöran Ramberg, Mrs. Bloemkolk, and Johan Bloemkolk (Head of Administration).*
upper right: *Mrs. Ramberg, Jöran Ramberg, and Mrs. Bloemkolk.*
lower left: *H.W. Marck (accountant), Mrs. Bachmann, G. Bachmann (Head of Finance), Mrs. Behr, and A. Behr (consultant astronomer).*
Photographs from EHPA.

Division, from the large radio telescope projects of the Max Planck Foundation at Bonn and of the Westerbork Project, and of the large optical telescope project of the Max Planck Foundation at Heidelberg.

First ESO Committee of Council Meeting, May 6, 1970

On May 6, 1970 the ESO Committee of Council held its first meeting. As mentioned before, it had been created – following CERN practice – for discussing informally in advance of Council meetings items requiring consultation between ESO management and governments, or between the government delegates mutually, and it thus would help avoiding controversial situations at the Council meetings. The accompanying tables show the meetings of Council, Committee of Council and Finance Committee, and those of the Instrumentation Committee for the years 1970–74. Committee of Council consisted of the Council President and the Presidents of the IC, the FC and SPC, plus one Council member of those states not represented among these. It proved to be a very useful instrument; its meetings were held sufficiently in advance of the Council meetings that in the intervening period also advice from the IC or FC could be obtained. The proposal for collaboration with CERN was typically one to benefit from such preparatory activity.

Basic documents for this meeting were Cou-66 mentioned before, and a draft contract with CERN that meanwhile had been prepared by the administrative departments and legal advisors of the two organizations. Nucleus of the draft contract – based on the assumption of establishment of the Telescope Group on the CERN premises – were the services to be rendered by CERN: administrative, technical and professional. The Committee of Council meeting decided to submit a somewhat amended draft to the ESO Council, to be supplemented with the advice of the IC, the FC, and the SPC. Alternative solutions by collaboration with major industrial firms, like MAN, had meanwhile been further explored, mainly by Ramberg, but it turned out that these firms were at best interested in realizing the construction of the telescope once the project would be well defined – and not in participating in the design work.

Council Resolves to Collaborate with CERN

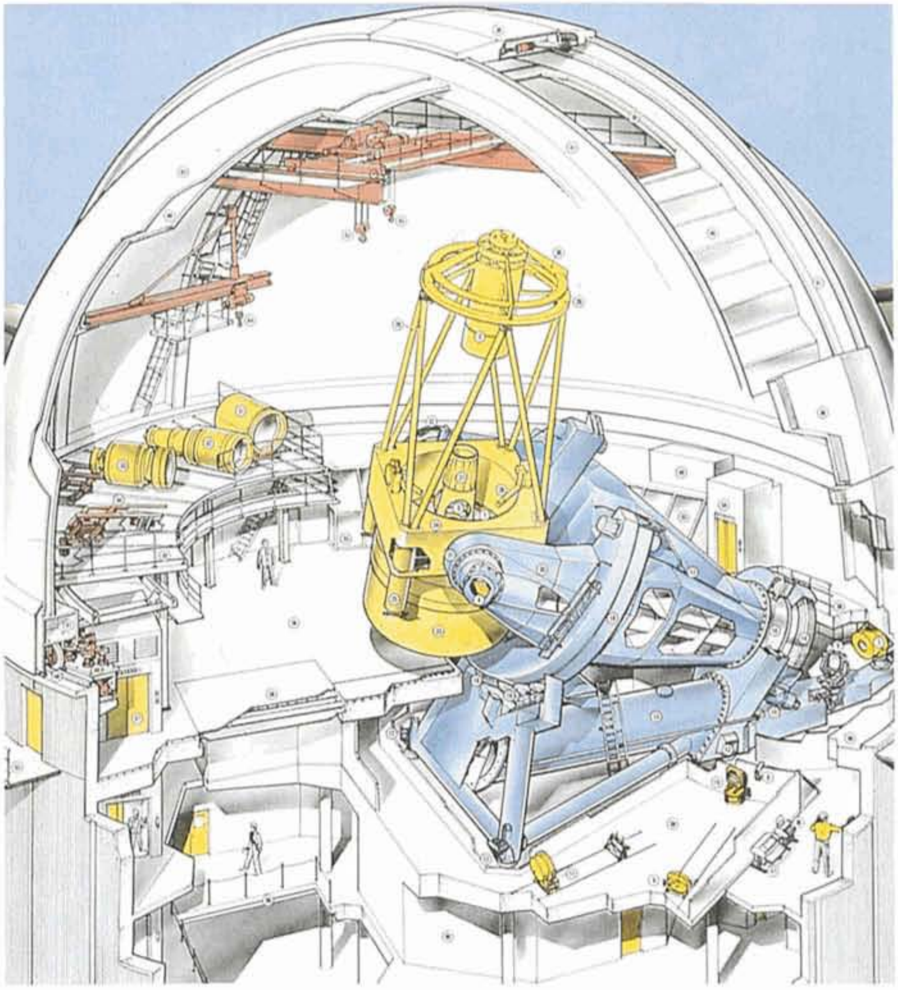
The Instrumentation Committee in its meeting of June 2, 1970 following that of the Committee of Council, after first endorsing the establishment of the Telescope Group as described in Cou-66, strongly supported the proposed collaboration with CERN. The FC, in its meeting of May 22, had remained faced with uncertainty as to the financial implications, but this was inherent to a situation in which reliable cost estimates could be obtained only after the telescope group would have started its work.

The Chairman of the SPC, Strömgren, was prevented from attending the forthcoming Council meeting, but provided the Council President with a written statement of June 4 along the lines of his advice expressed verbally at Committee of Council. The following passages are quoted from this letter:

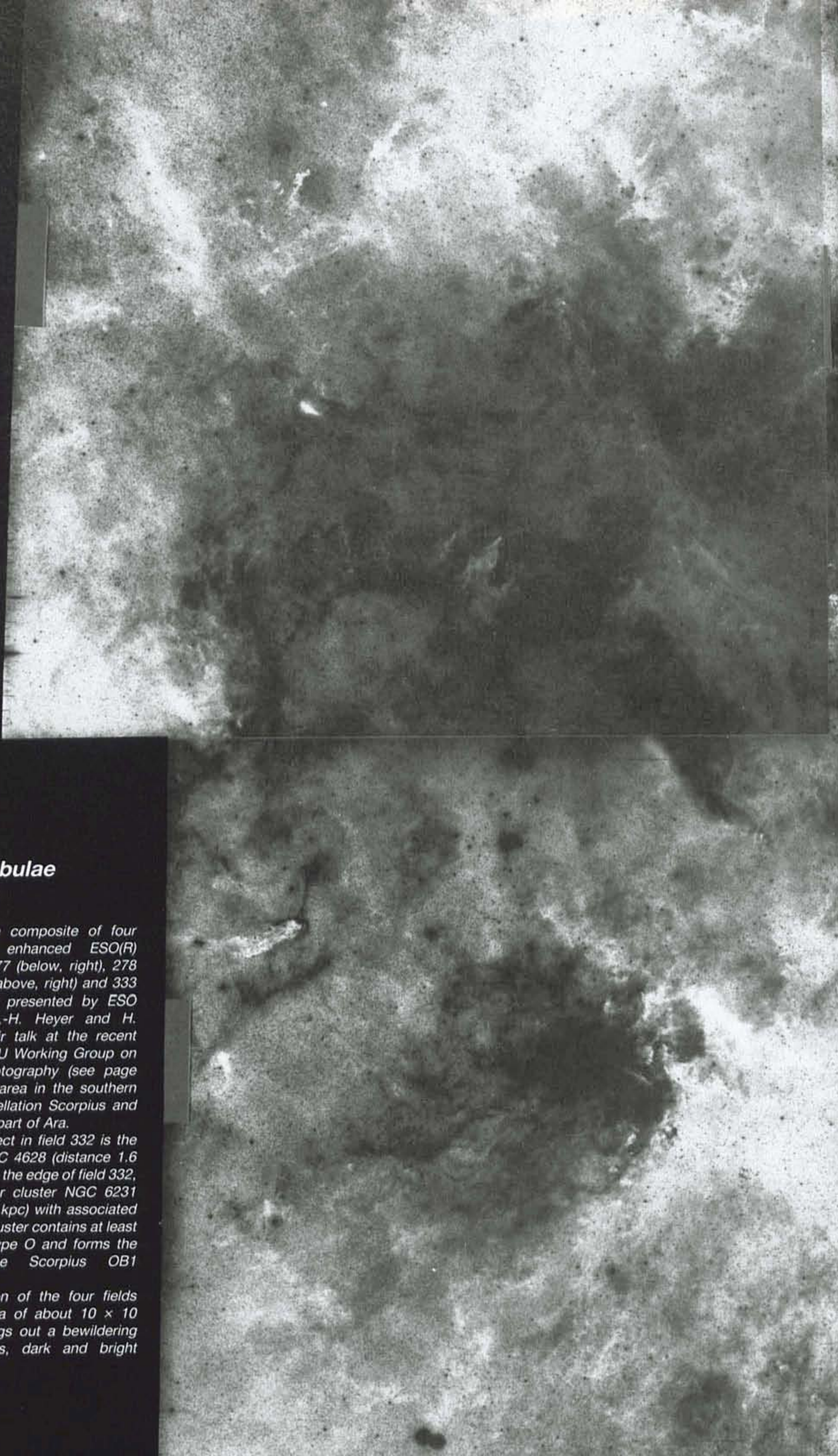
"I wish to emphasize the urgency of the situation regarding the construction of the 3.6-m telescope, and the necessity of reaching a decision soon on the questions of the Telescope Development Group as well as the agreement with CERN – – –. I must emphasize the difficulty of the ESO situation: We do concentrate on the 3.6-m telescope, but we do not now consider the proposals that were made by the SPC to supplement the instruments already agreed on with instruments for other purposes, of intermediate size. Therefore, the way it looks is that during the period when ESO is constructing the 3.6-m telescope, there will be at the disposal of the whole ESO community of astronomers only the 152 cm and the 100 cm Telescopes, some smaller telescopes, and the Schmidt Telescope. – – –. The conclusion is, that any further delay that would lengthen the lead-time – indeed any postponement regarding the 3.6-m Telescope – would endanger the future of ESO. – – –" [9].

At the Council meeting of June 11, 1970, concensus of opinion was definitely in favour of both, creating the Telescope Development Group and collaboration with CERN, and Council accordingly resolved to submit a corre-

(continued on page 36)



Once the work of the TP Division was well under way, the expected appearance of the telescope-to-be was presented in a colourful poster. A black-and-white reproduction of the poster, designed by Tony Lofthouse in 1973, appeared in the ESO Annual Report of 1974. The section reproduced here shows the main features of the telescope, the design reflecting the early ideas of Strewinski described in the previous article.

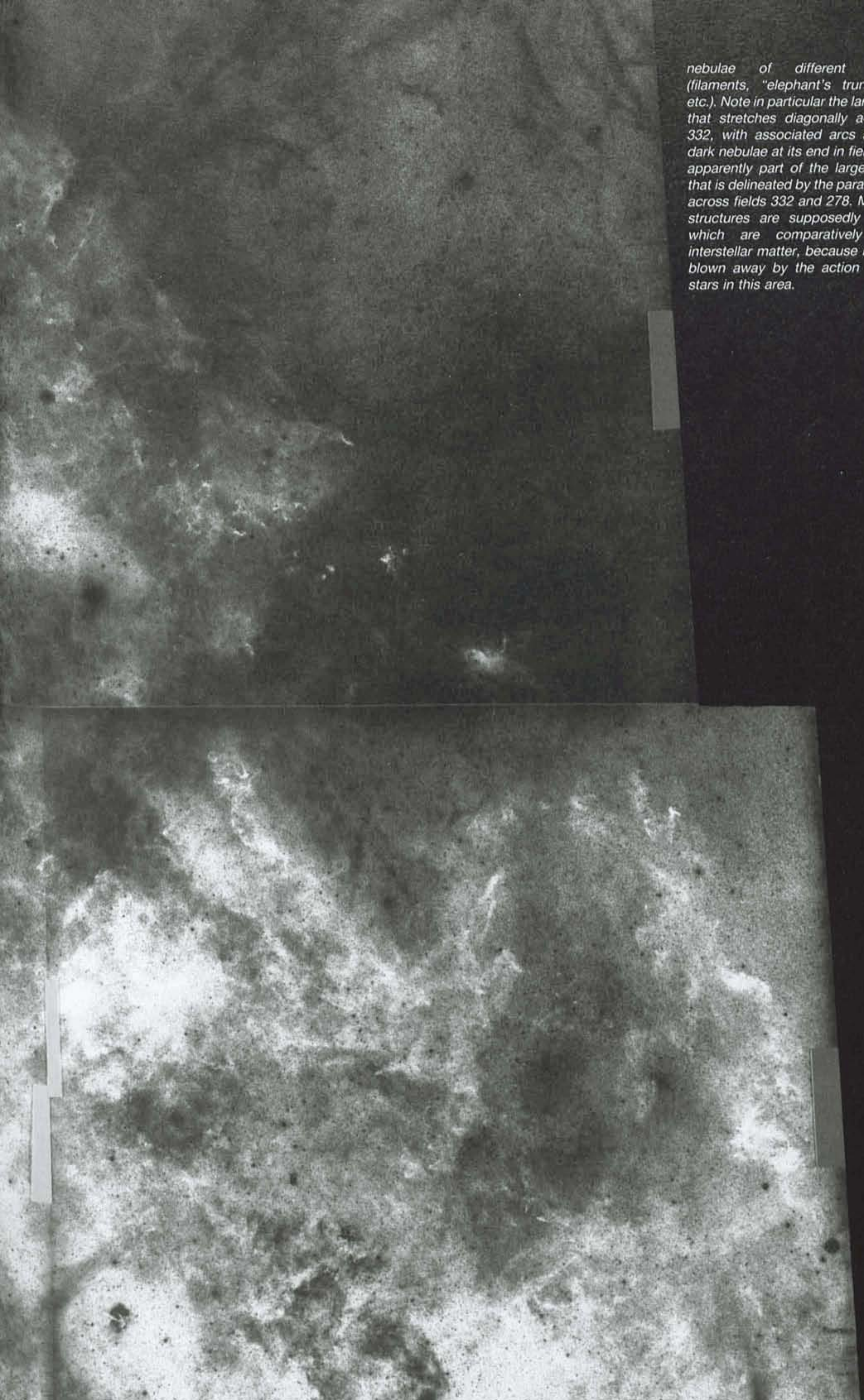


Galactic Nebulae in Scorpius

This impressive composite of four photographically enhanced ESO(R) plates of fields 277 (below, right), 278 (below left), 332 (above, right) and 333 (above, left) was presented by ESO photographers H.-H. Heyer and H. Zodet during their talk at the recent meeting of the IAU Working Group on Astronomical Photography (see page 50). It shows an area in the southern part of the constellation Scorpius and also the northern part of Ara.

The central object in field 332 is the emission nebula IC 4628 (distance 1.6 kpc); south of it, at the edge of field 332, lies the open star cluster NGC 6231 (distance about 2 kpc) with associated nebulosity. This cluster contains at least 70 hot stars of type O and forms the nucleus of the Scorpius OB1 association.

The combination of the four fields covers a sky area of about 10 × 10 degrees and brings out a bewildering complex of stars, dark and bright nebulae of different structures (filaments, "elephant's truncs" bays, etc.). Note in particular the large "finger" that stretches diagonally across field 332, with associated arcs and radial, dark nebulae at its end in field 277. It is apparently part of the larger structure that is delineated by the parallel borders across fields 332 and 278. Many of the structures are supposedly "cavities", which are comparatively void of interstellar matter, because it has been blown away by the action of the hot stars in this area.



sponding request to the Council of CERN. This met one week later, on June 18 and 19, and agreed to enter into the collaboration.

September 16, 1970: the ESO-CERN Agreement Signed

The contract between the two organizations was signed on September 16 at CERN by the Directors General, Gregory and Blaauw.

Let me quote a few parts from the 21 articles of the contract:

from art. 2.1.a: *"toute la connaissance et l'expérience scientifique acquises par l'une des parties au présent Accord, et susceptibles d'affecter le travail de l'autre, seront librement communiquées et lesdites Organisations mettront à la disposition l'une de l'autre des solutions et méthodes utilisées dans les techniques de pointe de leurs domaines respectifs;"*

from art. 3.2: *"La responsabilité scientifique et technique du projet incombe entièrement à l'ESO, tandis qu'il incombe au CERN de fournir les installations et les services, dans toute la mesure du possible et dans la limite des moyens existant au Laboratoire du CERN."*

from art. 4.1.b: *"– – – le CERN fournit, dans des limites à convenir entre le CERN et l'ESO, les services administratifs nécessaires à l'exécution du projet sur le domaine du CERN, y compris les services des Divisions des Finances et du Personnel, ceux de la Division des Services techniques et Bâtiments qui ont trait à l'exploitation et à l'entretien du domaine et des bâtiments qui s'y trouvent, les services de transport habituels, les services de sécurité du travail et l'utilisation d'installations de caractère général, telles que les cantines, salles de conférence et bibliothèques;"*

from art. 10.1: *"L'ESO nomme un Chef de la Division ESO-TP, dont l'autorité et les compétences, notamment en matière de décisions financières, sont comparables à celles d'un Chef de Division du CERN."*

Already a month later, in October 1970, the small group of Laustsen – who was appointed to this post of Division Head – and collaborators moved to Geneva and started setting up the Telescope Project Division in a building made available by CERN on its premises. By the end of 1970, the group consisted of 12 people, six of whom were ESO employees. The TP Division was ready to realize the most important one of the instruments for which ESO had been created, the 3.6-m Telescope.

A Few Further Milestones

Whereas a detailed account on the further developments would be beyond the present historian's task, mentioning of a few milestones in the further work of the TP Division seems in order here.

By February 1971 the TP Division had drawn up a new project description, an estimate of the financial implications, and a time schedule for its realization. By the end of 1971 the staff strength of the Division had grown to a total of 22, of whom 13 were ESO staff, 6 CERN staff and 3 belonged to agencies. A drastic decision had been taken in the course of that year, when it was deemed desirable to abandon the original design for the rectangular telescope building and to start from scratch for one adapted to new ideas developed through the IC, in spite of the considerable investments that had been made for the early design.

By the end of 1972 the Division was in a position to award contracts for the major construction programmes – the building, the dome, and the main structure and main gears for the telescope. The staff complement had risen to a total of 29, of whom 17 ESO staff and 6 CERN staff. The year 1973 saw the first assignment of TP Division staff on La Silla for setting up the building site. At the end of that year the staff strength had risen to 40 of whom 30 ESO and CERN staff, and by the end of 1974 still farther, including 36 from ESO and CERN. For the telescope the main substructures had then been completed and tested at the manufacturer; the concrete structure of the telescope building was virtually finished.

The year 1975 saw further shifting of staff from Europe to La Silla and the erection of the dome, and in Europe the successful conclusion of the testing of the telescope with its optics. The mechanical assembly ot the telescope on La Silla was completed about August 1976, and finally, in the night of 7 to 8 November 1976 the telescope saw "first light": its first actual performance by presenting astronomers and technicians with its first stellar image in the prime focus. This happened six years and seven weeks after the signing of the contract with CERN. The TP Division had marvelously stuck to the time schedule drafted early 1970.

References and Notes

Abbreviations used:

EHA = ESO Historical Archives (see *The Messenger* of December 1988).

FHA = Files Head of Administration at ESO Headquarters.

EHPA = ESO Historical Photographs Archives.

[1] I am indebted to Mrs. Helga Schmal, associated with the Council Secretariat of CERN, for providing me with data on the membership of the CERN Council and Finance Committee over the years 1960–1973, and to ESO's librarian Edith Sachtschal for her intermediary in this matter.

[2] In FHA, Section 1.1.1./1.2.1., Circular Letters Council and FC.

[3] In FHA, Letter 00/3217/69 in File Cou-2, FC-2.

[4] Both letters in the author's private archive; copies in EHA-I.C.5.

[5] According to a note in the author's diary for 1969; no written report is left of this meeting.

[6] Copy of this letter in EHA-I.C.5.

[7] FHA-Cou Documents.

[8] FHA-Cou Documents.

[9] The letter is quoted in full in the minutes of the meeting, contained in FHA.

"Des Hommes, des Télescopes, des Etoiles"

A book with this title has just appeared at "Editions du CNRS" (15, quai Anatole France, F-75700 Paris, France; ISBN 2-222-04459-6, 528 pages, 220 FF). The author is the well-known French astronomer Charles Fehrenbach, who has been closely associated with ESO from its very early beginnings – as documented in the current series about ESO's history – and to whom younger generations of European astronomers owe a large debt of gratitude. Professor Fehrenbach's memoirs recount the story of French astronomy from the years between the two World Wars and also deal extensively with the early developments of ESO, in Europe as well as in Chile. They contain a wealth of personal anecdotes about contemporaries and will be of interest to all who want to learn more about this decisive epoch for European astronomy. The book has a foreword by Professor Hubert Curien.

STAFF MOVEMENTS

Arrivals

Europe:

DUCROS, Thierry (F), Coopérant
ESCHWEY, Jörg (D),
  VLT Project Civil Engineer
JORISSEN, Alain A. (B), Fellow
MØLLER, Palle (DK), Associate
PADOVANI, Paolo (I), Fellow
RUIZ LAPUENTE, Maria (E), Student
THEUNS, Tom (B), Student
VERNER, Dmitrii (USSR),
  Visiting Scientist

VIEGAS, Suela (BRA), Associate
VON DER LÜHE, Oskar (D), Experimental Phys./Astrophysicist
WARREN, Stephen (GB), Fellow

Chile:

BOURLON, Fabien (F), Coopérant

Departures

Europe:

COUDE DU FORESTO, Vincent (F), Coopérant
LAGRANGE-HENRI, Anne-Marie (F), Fellow
OCHSENBEIN, François (F), Astronomer/Data Archivist
ORIGLIA, Livia (I), Associate
PIOTTO, Giampaolo (I), Associate
SACHTSCHAL, Edith (D), Librarian
WINTER, Susan (GB), Secretary

Chile:

AUGUSTEIJN, Thomas (NL), Student
VAN DROM, Eddy (B), Coopérant

New Items from ESO Information Service

One of the more than 800 images of Halley's CO^+ tail, shown in the new ESO video film.

Among the new items prepared by the ESO Information Service, the following may be of particular interest to the readers of the *Messenger:*

- A video film: "The Tails of Comet Halley" which includes one of the most spectacular sequences ever obtained of the development of a cometary ion tail. From February 26 to May 12, 1986, more than 800 CO^+ images were obtained by ESO astronomer Holger Pedersen with a wide-field CCD camera at La Silla. Duration: ~ 13 min.; Price: 70 DM; available in VHS, S-VHS, Betacam, MII; English commentary.
- "Discoveries at ESO". A collection of the ~ 60 ESO Press Releases (and associated pictures), issued during the first five years of the ESO Information Service. Useful as reference and also for educative purposes. Approximately 200 pages; Price: 25 DM. Available from mid-January 1991.

Orders should be placed with the ESO Information Service (address on last page). Please note that the delivery time will be about 4 weeks.

Red Supergiants in Magellanic Cloud Clusters: a Step Towards Modeling Starburst Galaxies

D. ALLOIN, Observatoire de Paris/Meudon, France
E. BICA, UFRGS, Porto Alegre, Brazil

For the purpose of developing a new population synthesis technique (Bica, 1988) we collected integrated spectra for a sample of populous and concentrated star clusters in our Galaxy and in the Magellanic Clouds.

In the course of this study, we noticed that one blue cluster, NGC 2004 in the LMC, was displaying a peculiar near IR spectrum with strong TiO absorption bands and CaII IR triplet. Having in mind the M supergiant phase, well known from stellar observations and studied in stellar evolution models, we wondered about its possible occurrence on a large scale and its signature in the integrated spectrum of NGC 2004. Because M supergiants represent a time-peaked evolutionary stage, they would obviously offer an interesting opportunity to date starbursts in composite populations. Therefore, we decided to investigate further this possibility.

M Supergiants in Star Clusters

The LMC and SMC being particularly rich in blue populous clusters (Hodge, 1961), we chose 39 of their brightest members. As an example, a digital recording of NGC 2004 from an ESO sur-

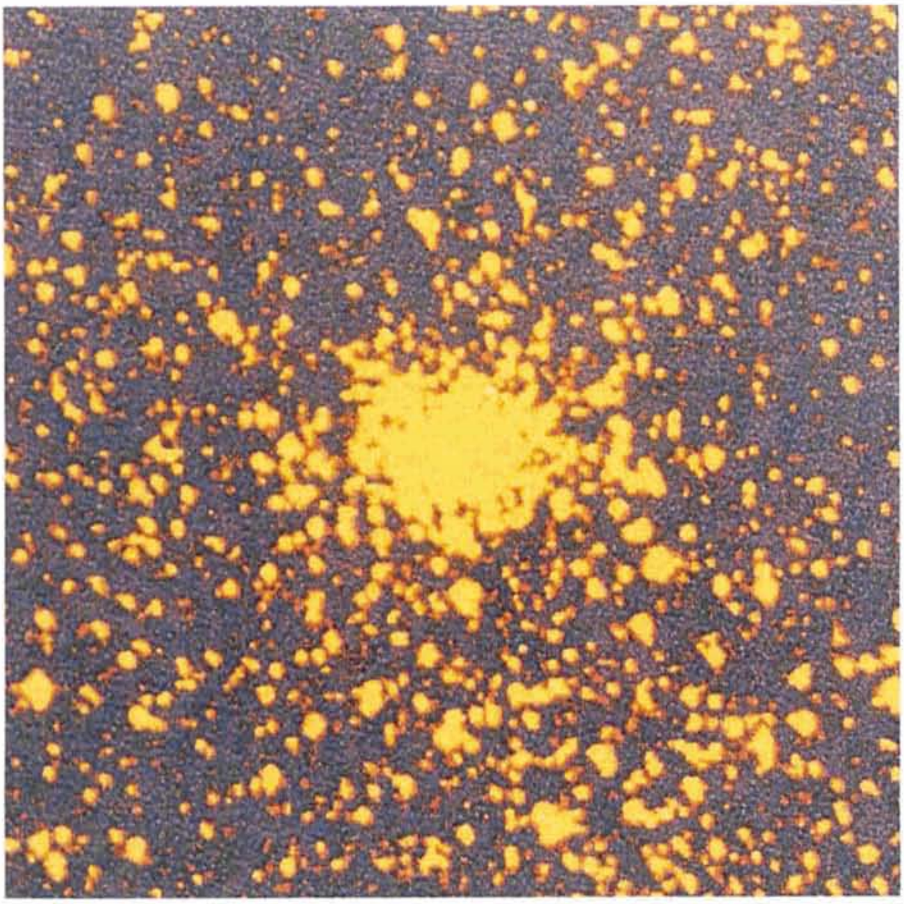


Figure 1: *Digital recording of NGC 2004, from an ESO survey B plate, to illustrate the concentrated globular appearance of our blue Magellanic cluster sample (after Bica and Dottori, 1990).*

vey B plate is shown in Figure 1 : notice the concentrated globular appearance of the cluster, quite suitable for obtaining integrated information.

We have performed spectroscopic observations of the 39 cluster sample at the ESO 1.52-m and 2.2-m telescopes, with a CCD. We used an E-W oriented long slit and we scanned the slit across the star cluster in the N-S direction, over a spatial extent 15″ to 60″, according to the cluster size. The surrounding background was extracted towards the edge of the slit and subtracted from the star cluster spectrum in a standard way. The data covered a spectral range from 5600 to 10000 Å, at a 14 Å resolution (Bica, Alloin and Santos, 1990).

The age calibration of the clusters, described in detail in the latter reference, was worked out from the relationship between blue-violet colours and turnoff ages deduced for a subsample of blue Magellanic clusters for which an HR diagram was available (Van den Bergh, 1981; Searle, Wilkinson and Bagnuolo, 1980; Hodge, 1982, 1983). Remember that the blue-violet range is essentially not contaminated by the flux from cool stars and is very sensitive to age through the Balmer jump.

The observed spectra in the near IR show indeed a spectacular change with age, illustrated in Figure 2 for LMC clusters. We identified two red phases at around 10 and 100 Myr. In Figure 2, each spectrum, at a given age, represents in fact a mean of about 5 clusters so as to minimize eventual stochastic effects related to the very large luminosity and limited number of M supergiants. The cluster grouping has been done following the age bins delineated in Figure 3 which displays the evolution of the equivalent width of strong TiO bands in the near IR.

Regarding the late red phase around 100 Myr, it is certainly related to luminous AGB stars already identified in the LMC field and in individual LMC blue clusters (Frogel and Blanco, 1983). Their quantitative contribution and exact age range of occurrence remain to be modelized in detail in the integrated light of star clusters.

As to the first red phase at 10 Myr, it is quite prominent and we interpret it as being caused by late M supergiants (Alloin and Bica, 1989). Previous JHK photometry independently showed the need for red supergiants to explain the colours of very young clusters (Persson et al., 1983). A theoretical support to the interpretation of the 10 Myr red phase in terms of M supergiants comes along two different lines: (1) evolutionary tracks for 15 to 30 $M_\odot$ stars demonstrate that these stars are good candidates for becoming, at some stage, late M supergiants (Maeder and Meynet, 1988), and (ii) evolution of the integrated light from model star clusters shows a conspicuous red phase around 10 Myr if a small enough time step is used in the computation (Arimoto and Bica, 1989; Prieto, 1990; Schmidt, 1990).

Although the age dependence is dominant in Figure 2, we cannot ignore some metallicity dependence as well, in particular for molecular absorption bands like TiO which are sensitive to Z squared. And indeed, of the three star clusters observed in the SMC, globally less metal rich than the LMC, one cluster NGC 299 appears to be in the red supergiant phase from its flat continuum and strong CaII IR triplet. Yet, its W(TiO) value is far from being as strong as that observed in LMC star clusters going through the same phase (Fig. 3).

We wish to underline the difference between the precise reference to M supergiants and the use of a general red supergiant term which often refers to earlier spectral types. Prior stars correspond to the effect we discuss here as a phase in the integrated spectrum of some LMC clusters and are observed as a well-defined clump of stars at (B-V)

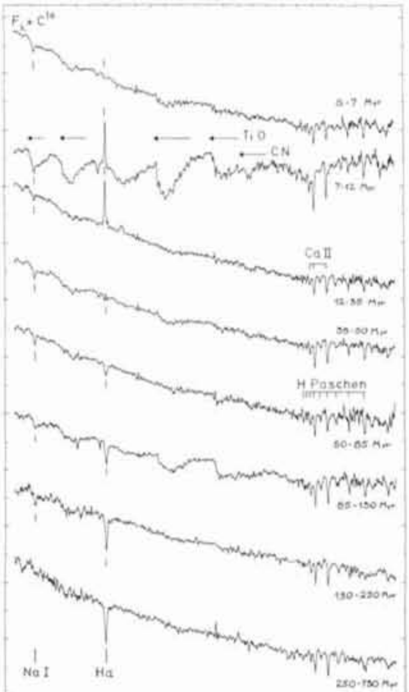


Figure 2: *Age sequence of the LMC blue clusters showing their spectral evolution in the near IR. Notice for the two red phases at 10 and 100 Myr, the enhanced W (TiO) and W(CaII) as well as the continuum slope changes (after Bica, Alloin and Santos, 1990).*

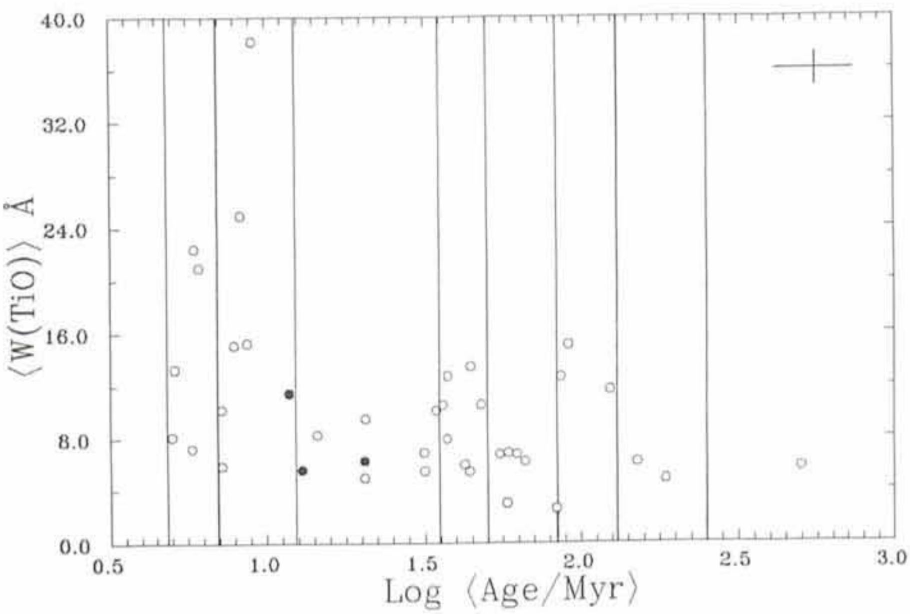


Figure 3: *Evolution of the equivalent width of TiO absorption bands in the near IR. Open circles refer to LMC blue clusters and black dots to the 3 SMC blue clusters. The age bins for grouping cluster spectra, as shown in Figure 2, have been drawn.*

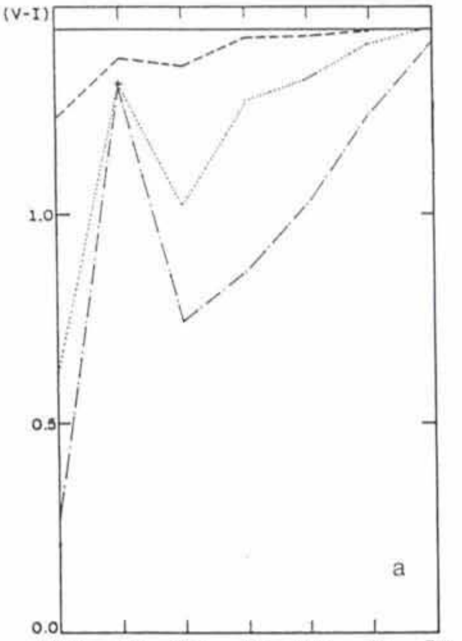


Figure 5: *a. The I magnitude change with time for a series of 0.1, 1 and 10% burst to galaxy mass ratios. Dashed line: mass ratio of 0.1%. Dotted line: mass ratio of 1%. Dash-dotted line: mass ratio of 10%. Notice the strong luminosity increase, up to 5 magnitudes, at the supergiant phase, with respect to the underlying old population. ΔI = I(B+G) – I(G). b. Colour evolution of the composite system, in the V and I filters. Same symbols as in part a. The solid line represents the old population colour.*

~1.7 in the HR diagram of NGC 2004 and NGC 2100 (Robertson, 1974). This clump is also present in Galactic open clusters of similar age at (B-V) ~ 1.8 like those in Mermillod's composite groups NGC 884, 457 and 3766. Such stars are certainly the product of the evolution of stars in the mass range 15 to 30 $M_\odot$, depending on mass-loss rate (Maeder and Meynet, 1988). It is interesting to see that stars more massive than 40 $M_\odot$ do not reach, along their evolution, effective temperatures low enough to produce M supergiants. Consequently, eventual red supergiants in star clusters with ages less than 5 Myr, still associated with emitting gas, are not expected to exhibit M-type spectral features. This would explain why the recently detected HII region with strong absorption at the CaII IR triplet, in NGC 3310 (Terlevich et al., 1990) has no signature of molecular bands.

Towards Starbursts in Galaxies

Starbursts in galaxies might be quite complex and their spectral appearance could depend on many factors such as: the burst strength relative to old population of the underlying galaxy, its metallicity, its age, its duration, the possibility of having a superposition of successive bursts. It is clear from the previous discussion about star clusters that a detailed population synthesis will be necessary to extract all this information. Such a synthesis should not only use the TiO and CaII triplet in the near IR, but also other age and metallicity discriminators like the Balmer jump and Balmer lines, and metallic lines in the far UV.

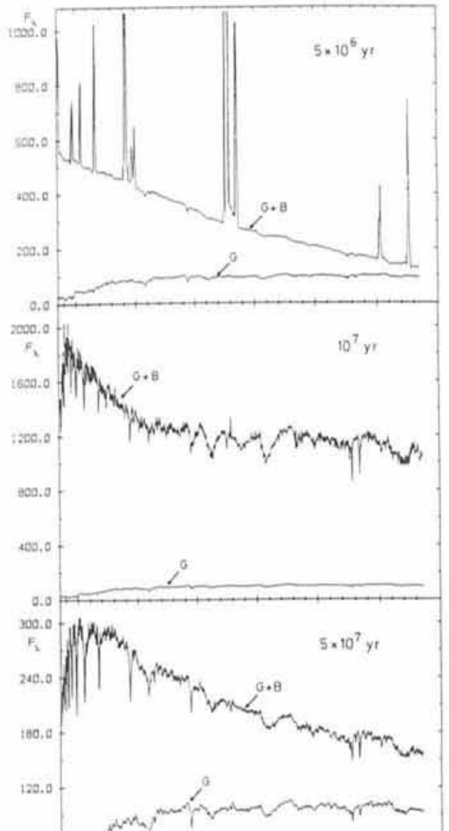


Figure 4: *Spectral evolution from 5 Myr to 50 Myr of the composite light (B+G) in the near IR, of a starburst (B) superimposed on an old population galaxy (G). The mass ratio of (B) to (G) is 1% in that case (after Bica, Alloin and Schmidt, 1990).*

We have been prompted by the possible use of the M supergiant signature for interpreting composite stellar populations. As a preliminary study, we have performed simulations of a starburst occurring on top of an old population galaxy and followed the spectral evolution of the composite system (Bica, Alloin and Schmidt, 1990). We have considered various mass ratios of the burst with respect to the old population: 0.1%, 1% and 10%. The burst is represented by a star cluster at a given age and the old population by a red, metal-rich nuclear galaxy spectrum. The burst duration, implicit in these simulations, is that of a single generation star cluster, hence, amongst the shortest. Consequently, we could explore in this work only the dependences on the burst strength and age. For illustration, we provide in Figure 4 the early evolutionary stages from 5 to 50 Myr, of the composite spectrum. Notice the rapid spectral changes. The dependence on the burst strength is shown in Figure 5a and b, in terms of absolute luminosity increase and colour evolution of the composite light: the stronger the burst, the longer its impact on the composite system, as expected.

We are not aware that any starburst galaxy has been detected so far with TiO bands as strong as those observed in the LMC blue clusters passing through the M supergiant phase. This suggests that starbursts in galaxies are not time-peaked but rather made of multiple, successive stellar generations. Then, the absence of the M supergiant molecular signature could be understood as the result of dilution effects: the contribution from evolutionary stages outside the 7 to 12 Myr, which are free of molecular absorption, will wash out the molecular bands from the short-living M supergiant phase at 10 Myr. A weak metallicity in the starburst could contribute also to a weakening of the molecular bands. The M supergiant phase in a metal-rich composite population could be prominent only if the burst duration were quite short and the burst age were around 10 Myr. In contrast, the near IR Ca II triplet should be a conspicuous feature in most starbursts, because it is present at all evolutionary stages from 6 to 500 Myr (Fig. 2).

We are now in the process of simulating starbursts in low-metallicity galaxies such as dwarf galaxies. In parallel, we are performing direct population synthesis of a sample of 60 dwarf blue and red galaxies.

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The Planetary Nebula NGC 3132: a Three-Dimensional Ionization Model

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1. Introduction

Planetary Nebulae (PNe) are an intermediate stage in the stellar evolution from a red giant star to a white dwarf of stars with masses between 1 $M_\odot$ and about 8 $M_\odot$. Most of the light emitted from PNe consists of emission lines from ions excited by the UV radiation of the hot central star. As the PN consists of material ejected from the red giant star during the AGB Phase, investigations of the morphology and the dynamics of PNe can give information about the mechanisms that cause the mass loss from the red giant star.

The major problem investigating the morphology of PNe is the fact that there is no simple way to get the three-dimensional density distribution in the nebulae. As PNe are optically thin in the light of emission lines, two-dimensional images show the integrated flux emitted from all locations in the line of sight into the direction to the observer. Thus there are several three-dimensional density distributions leading to the same monochromatic image. But most PNe show strong evidence that a spherically symmetric density distribution cannot match with the monochromatic images. Statistical methods lead to systems assuming several PN morphologies representing different evolutionary stages in some morphological classes (Balick, 1987), in which a lot of PNe seem to fit in easily, but it is difficult to justify whether a single PN really shows a specific morphology or not.

One possibility to check at least the consistency of a given density distribution for a single PN is to compare images taken from that PN in the light of different ionization stages of several elements with artificial images calculated with three-dimensional ionization models. Assuming a given density distribution, it is possible to calculate the ionization equilibrium at each location, depending on the temperature, the UV flux from the central star and monochromatic images, that can be compared to observed monochromatic images.

The observational methods for PNe made a big progress in the last years. With the availability of sensitive CCD detectors combined with narrow interference filters it is easily possible to obtain monochromatic images of PNe with high spatial resolution. At La Silla this can be done e.g. with the 2.2-m telescope. Even images in the weak lines like O III 463.3 nm and sometimes He II 4686 can be obtained in most cases with exposure times less then 30 minutes. The extended old PNe can at least be imaged in the bright lines like O III 500.7 nm and N II 658.4 nm. With the B&C spectrographs of the 2.2-m and 1.52-m telescopes combined with CCD detectors it is possible to get spectra of different positions inside the PN. With the 22.4 nm/mm grating at the 1.52-m telescope (15 μm high resolution CCD) we obtained spectra (each in the range from about 400 nm–700 nm) with exposure times between 1 and 30 minutes. The spectral resolution of this grating is sufficient to separate the important emission lines we need for comparison with our model calculations. So the observational presuppositions are given to improve the old spherically symmetric model calculations.

2. Observations

The spectroscopic observations used in this article were performed in February 1989 at the 1.52-m telescope in combination with a Boller & Chivens spectrograph equipped with a CCD detector (pixel size = 15 μm). The slit width was chosen as 2″. The resolution of the grating was 22.4 nm/mm (0.34 nm/pix). We obtained long-slit spectra from two positions south and two positions north of the centre of NGC 3132. The slit orientation was east-west. Knowing the exact position of the spectrograph slit and knowing the total Hβ emission of the object, it is possible to absolutely calibrate the measured Hβ flux. With this local calibration at Hβ and using the also observed energy distribution of spectrophotometric standard stars, it is possible to calibrate the spectra throughout the entire range from 400 nm to about 700 nm.

The direct monochromatic images were obtained in April 1988 with the 2.2-m ESO/MPI telescope equipped with a CCD detector (pixel size = 30 μm). The images were reduced using standard MIDAS reduction procedures.

3. Model Description

Our model consists of a cartesian cube which contains about 30,000 subcubes V_{ijk}, with i,j,k ranging from −15 to +15. A local density is assigned to each volume element. The central star is positioned in the centre of the cube at (0,0,0). In all volume elements the ionization and thermal equilibrium is calculated. The absorption on the way from the central star to the volume element is taken into account. For these calculations a CONVEX vector computer of the University of Tübingen is used. A more detailed description of our model is given in Bässgen, Diesch and Grewing (1990).

One problem is to "fill" our cube with a density distribution of a real nebula. To do this for NGC 3132 we fitted an ellipsoidal shell with density n_1 which surrounds an ellipsoid with a very small density n_2 to observed Hβ-images. The exact procedure is described in Bässgen et. al (1990), too.

To obtain an idea about the three-dimensional distribution of an object, high resolution spectroscopy (e.g. CAT observations) plays an important role.

4. Results

Due to the cube structure of our model it is easily possible to calculate emission line fluxes of distinct regions of the object and to construct artificial monochromatic images. Figure 1 shows the reduced observed and the calculated spectrum of the position 8″ south of the central star. We chose a logarithmic ordinate to make the weaker lines visible. Figure 2a–2d show observed and calculated OIII 500.7 nm and NII 6584 images.

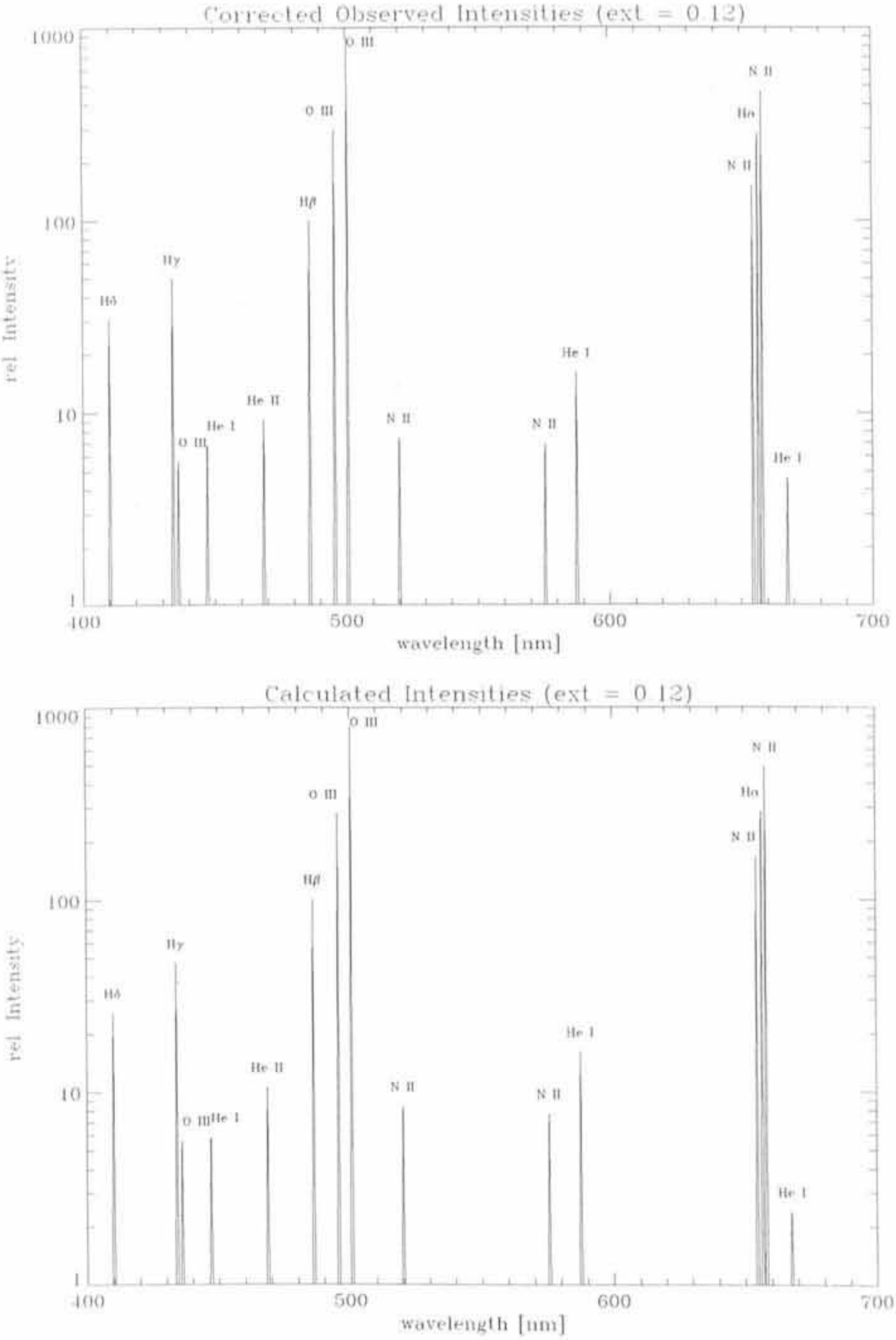

Figure 1: *Comparison of calculated and observed emission line fluxes at the position 8″ south of the central star.*

5. Conclusions and Future Work

With our new computer code we can leave spherical symmetry in modelling PNe. It is an adequate instrument to explain the spatially resolved monochromatic images and spectra available with modern sensitive detectors.

We plan to continue our work into two directions.

(a) We started to make two-dimensional cylindrical symmetric ionization models with a very high spatial resolution (= pixel size of CCD images) so that we can use CCD Hβ images directly as input density distributions after some geometrical transformations.

(b) Three-dimensional models as described above, but with a more accurate treatment of the radiation transfer. The problem is the increasing computer time. With this kind of models it would probably be possible to explain the low ionization filaments in PNe which might

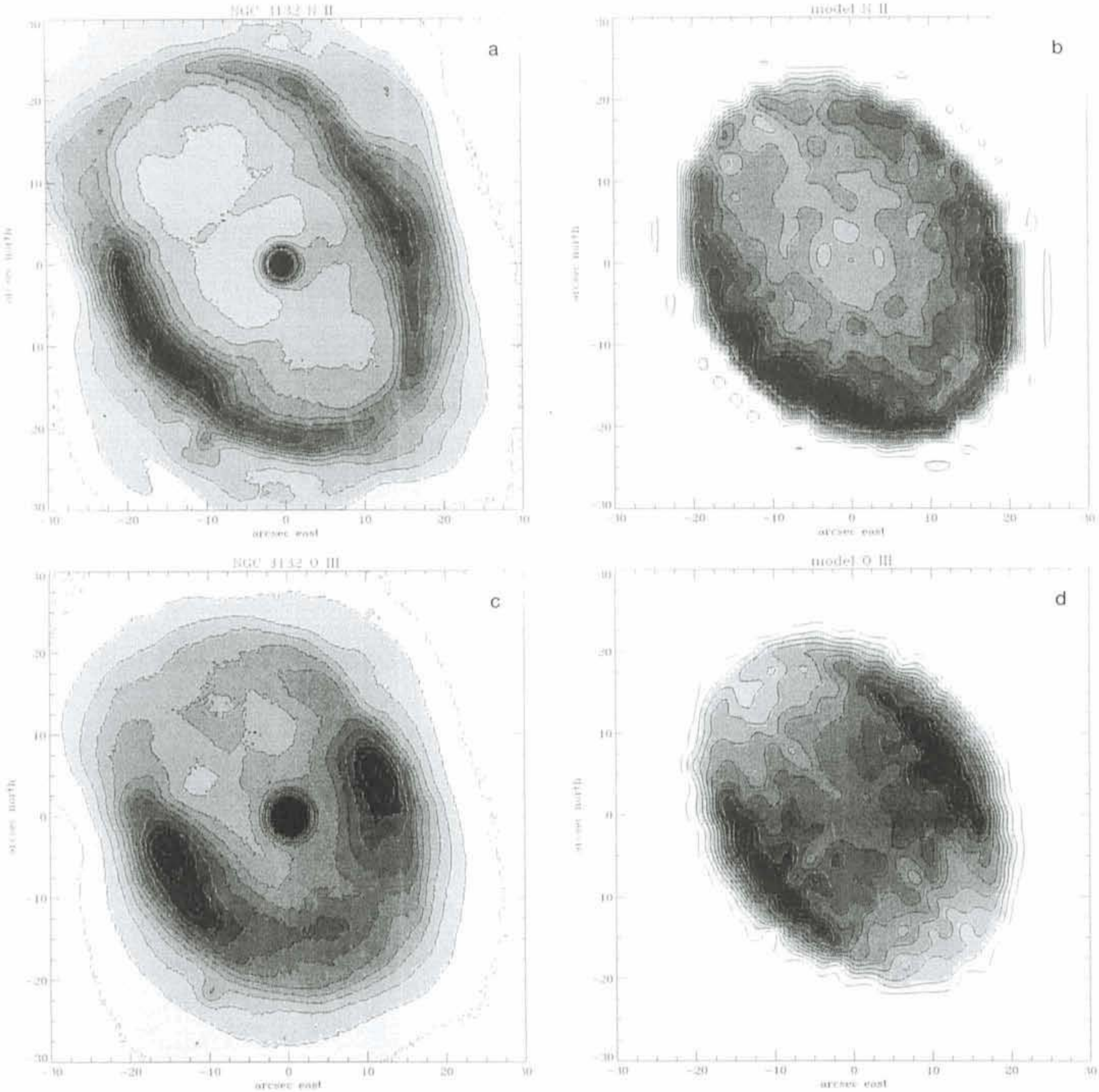

Figure 2 a–d: *Observed and calculated monochromatic OIII and NII images. The calculated images have been extended to a higher pixel number to allow direct comparison.*

be caused be shadowing effects combined with ionization by diffuse radiation of the neighbouring volume elements. It would also be possible to study the ionization structure of knots and so-called ansae. With the improved observing possibilities those features seem to be common in a lot of PNe.

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Peculiar Kinematics in Interacting Elliptical Galaxies

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Introduction

The investigation of galaxy encounters is important to understand the dynamical processes of tidal interaction between galaxies and to probe the internal dynamics of galaxies. Encounters between galaxies are not extremely rare and they cannot be neglected in the evolution of galaxies because even one efficient encounter may substantially alter their internal structures. Efficient interaction can lead to merging of galaxies.

Interactions between galaxies in the

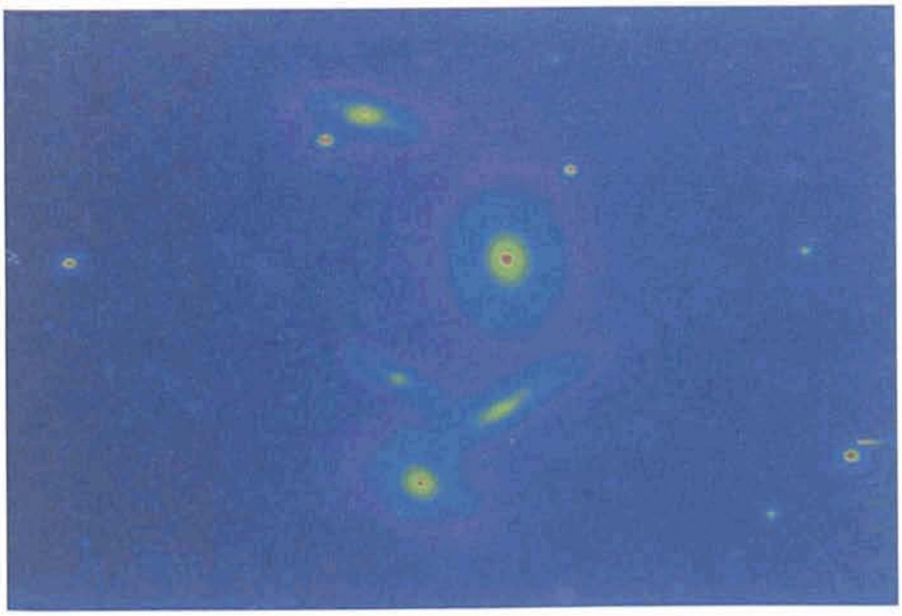

Figure 1: *Arp 321 is a group of five galaxies, which all have redshifts between 6400 and 6800 kms^{-1}. The group is composed of two elliptical and three spiral galaxies. The northern elliptical exhibits a rather regular morphology (North is up, east to the left). Note the filaments in the southern elliptical galaxy, which extend to the north and appear to be connected with the two spiral galaxies.*

early phase of galaxy formation certainly played an important role. Thereafter, the frequency of tidal interaction decayed, but still today there exists a large number of galaxy pairs, and the question arises whether they are in physical contact or just chance projections. A high fraction of the brightest cluster galaxies exhibits multiple nuclei and observations suggest that about half of these galaxy pairs are physical where both components are tidally interacting (Lauer, 1988). However, it is still unknown, whether galaxy collisions in the central parts of galaxy clusters lead to merging of galaxies. Small groups of galaxies, where the relative velocities of the galaxies are normally substantially lower than near cluster centres, are the preferred environment for merging.

Such an environment could be Arp 321 (Fig. 1), a group of five galaxies which all have similar redshifts. The morphology of the southern galaxies suggest that they are in physical contact. In the southern elliptical galaxy a tidal tail extends to the north and seems to be connected with the companion spiral galaxies.

The presence of tidal tails and major halo distortions indicates efficient tidal interaction. Normally, relatively low velocity differences and small impact parameters are required to lead to efficient, observable tidal effects. Many examples of interacting galaxy pairs can be found and the fundamental question arises whether these physical associations were formed together or whether they are recent chance encounters. Before an answer can be given, many details about tidal interaction have to be investigated. This is the purpose of the observations presented here.

Observations

We have undertaken a morphological investigation of 70 elliptical galaxy pairs mainly selected from the "Catalogue of isolated pairs of galaxies" (Karachentsev, 1972) and from the "Catalogue of southern peculiar galaxies" (Arp and Madore, 1985). For the galaxy pairs presented here, the CCD photometry was carried out with the Danish 1.54-m telescope (AM 2244-651) at ESO and the 1.23-m telescope at the German-Spanish Astronomical Centre on Calar Alto, Spain (NGC 4782/4783 and Arp 321). Typical exposure times were between 4 min in I and 20 min in V. Typical projected separations of both components of a galaxy pair are one or two half-light radii, or 20 . . . 50 arcsec, corresponding to 10 . . . 20 kpc.

According to their morphology, several obviously interacting galaxy pairs were selected for spectroscopy to determine their kinematics. All spectroscopic observations presented here were carried out with the ESO 3.6-m telescope. The B&C spectrograph was equipped with grating No. 26 which yields a spectral resolution of 0.9 Å/pixel and covered the wavelength range between 4600 and 5500 Å. In the slit direction we choose binning 4 to increase the S/N, resulting in a final spatial resolution of 2.3 arcsec. The slit width of the long slit was 1.5 arcsec and during all observations the seeing was better than 1.5 arcsec. During each night we observed several K0 III stars which were used as templates for the Fourier correlation quotient method (Bender, 1990). For each long-slit orientation we made two exposures of 90 min each. These long integration times are necessary to yield sufficient S/N. Two exposures are useful to eliminate all cosmic events after these long exposures with binning 4.

Morphology and Related Kinematics

The elliptical galaxies NGC 4782 and 4783 are the dominant members of a group of about 25 galaxies (De Souza and Quintana, 1990). Both are bright elliptical galaxies. The radial velocity difference between the two galaxies is 680 kms^{-1}. The galaxies NGC 4782 and 4783 (Fig. 2) exhibit an interesting morphology. The central parts of both galaxies are separated by 39 arcsec, corresponding to 16 kpc for H_O = 55 kms^{-1}Mpc^{-1}. Both galaxies have concentric isophotes in the innermost 7 arcsec. Further out the isophotes become nonconcentric, i.e. the central parts appear displaced with respect to the outer envelopes. Normally, the morphology in the outer parts is more strongly disturbed than near the centres. Therefore, it was quite surprising to find that the galaxy pair appears very regular at larger radii: the morphology of the envelopes of both galaxies does not exhibit any sign of perturbation. The regularity is further pronounced by the luminosity profiles, which show no deviations from the $r^{1/4}$-law for isophote radii

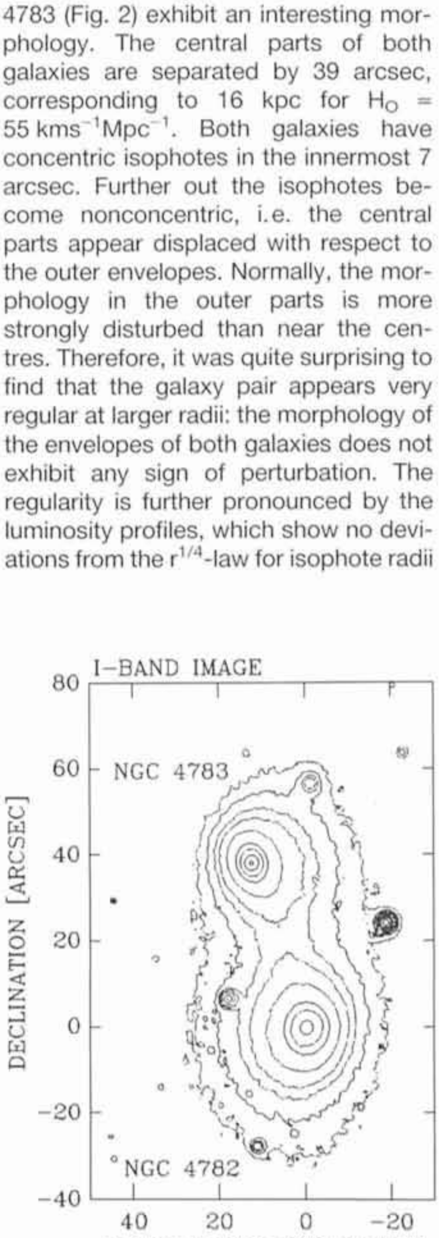

Figure 2: *This CCD image shows that both galaxies NGC 4782 and 4783 have nonconcentric isophotes. At radii larger than 15 arcsec the morphology appears very regular.*

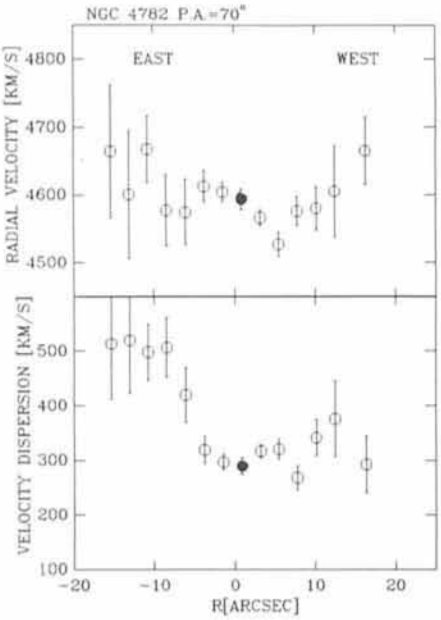

Figure 3: *The kinematical data for NGC 4782 for p.a. = 70°. In the upper part, the peculiar shape of the radial velocity is shown. A slightly U-shaped radial velocity curve is indicated in the innermost 5 arcsec. The velocity dispersion (lower part) increases from the centre of the galaxy towards the east by a large amount.*

larger than 15 arcsec (Madejsky et al., 1990). The regular morphology of the envelopes suggests that the encounter has taken place recently (2×10^7 yr ago): the stars forming the outer envolopes had not yet enough time to lead to changes of the luminosity profiles.

The kinematical data show no rotation in these galaxies (see Fig. 3). Further spectra have been obtained for other long-slit orientations, but no rotation is present at any slit orientation. However, all spectra show a drastic increase of the velocity dispersion with radius. The slight increase west of the centre can be explained by contamination from the neighbouring galaxy, while the drastic increase on the other side is real. Contamination from the neighbouring galaxy cannot account for this increase. If the observed radially increasing velocity dispersions in these galaxies are due to dynamical friction, the strength of tidal interaction can be estimated. Based on the assumption that in this high-velocity encounter the galaxy centres can be described in analogy to solid bodies while the envelopes behave like sticky bodies, we find that the galaxies lose ≈ 20% of their original orbital energies during the time of maximum interaction. The strong deceleration of the galaxies, however, is not sufficient to lead to merging of both galaxies since they have still a very high three-dimensional velocity difference. This scenario is based on the combined photometric and kinematical data. Further evidence for tidal interactions is given by the disturbed morphology of a radio jet which is centred on the southern galaxy NGC 4782 (3C 278). The eastern jet bends towards NGC 4783 (Baum et al., 1988).

Another example of interacting galaxies is AM 2244-651. The galaxies in AM 2244-651 are separated by 30 arcsec or 9 kpc in projection. From the east component a large tidal tail extends to the south (see Fig. 4); its entire length amounts to more than 20 kpc. Since the tidal tail is composed of stars, the length gives an estimate of the time elapsed since closest approach. A minimum time of $t = 2 \times 10^8$ yr is required to form the tail if the stars escape with a velocity of 100 kms^{-1}. A substantial part of the tail most probably is formed by escaping stars, i.e. they will be lost to the galaxy. In the west component, halo distortions are not easily detected. They are only seen at much fainter surface brightness levels and they appear much more diffuse.

The reason for the different morphologies presumably is the different kinematical behaviour of both galaxies (see Fig. 5). While the east component rotates rapidly, the west component rotates slowly. Stars in the rotating east component having accidentally a velocity vector parallel to the orbit of the other galaxy respond violently to the time-varying potential (the "perturbing" galaxy in this case is on a prograde orbit) and form the tidal tail. Stars with a velocity vector antiparallel to the perturbing galaxies' orbit (retrograde) experience only small tidal effects. The mean radial velocities of both galaxies are approximately the same, suggesting that we are viewing almost perpendicular onto the orbital plane of the galaxies.

Further kinematical data for the east component with slit orientation perpendicular to the line connecting both galaxy centres, are displayed in Figure 6. The galaxy shows no rotation along this axis. The velocity dispersion is obviously asymmetric. At one side, the velocity dispersion decreases to 100 kms^{-1}, at the other side the decrease levels off at a rather high value of 160 kms^{-1}. This high value is most likely due to the tidal interaction and exemplifies the strength of tidal effects even such a long time after the most efficient tidal interaction. Up to now we have only one spectrogram for the west component. Further kinematical data are required for various slit positions to model the velocity fields after the interaction. If the complete internal kinematics of both galaxies were known, their relative orbits could be determined approximately. Detailed kinematical data are necessary to probe the tides in interacting galaxies.

Conclusions

The two examples of interacting galaxy pairs presented here are in many respects complementary. The first pair NGC 4782 and 4783 is characterized by a very high velocity difference, recent closest approach (2×10^7 yr ago) and absence of internal rotation. The tidal interaction results in a disturbed but still rather regular morphology.

In contrast, the galaxies forming the second pair AM 2244-651 presumably have a low relative velocity and the time elapsed since closest approach is at least ten times as long as for the first pair. The east component of AM 2244-651 rotates rapidly, resulting in an asymmetric halo distortion. The central parts of both galaxies are rather regular, because they were not affected strongly by the tidal effects. Furthermore, since closest approach, i.e. since the moment of maximum perturbation, the central parts of both galaxies had enough time to return to equilibrium because the dynamical time scales there are shorter than the time elapsed since closest approach.

Similar relations between morphological and kinematical properties are also found for other galaxy pairs not presented here. Unfortunately, there are many parameters which are not known a priori for interacting galaxies and the different parameters may influence the ongoing interaction in a similar way, i.e. they often cannot be separated observationally. Important parameters are the relative velocities of the galaxies and the distance at closest approach. When these parameters provide the conditions for efficient interaction, the internal

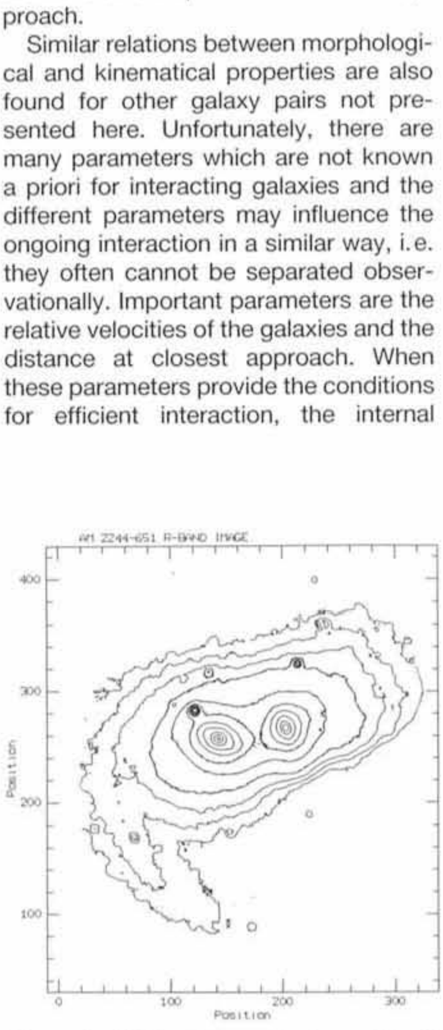

Figure 4: *While the morphology of both galaxies in AM 2244-651 is regular near the centres, the envelope of the eastern galaxy shows a large tidal tail (20 kpc in projection). The distance between both galaxy centres is 30 arcsec (9 kpc in projection).*

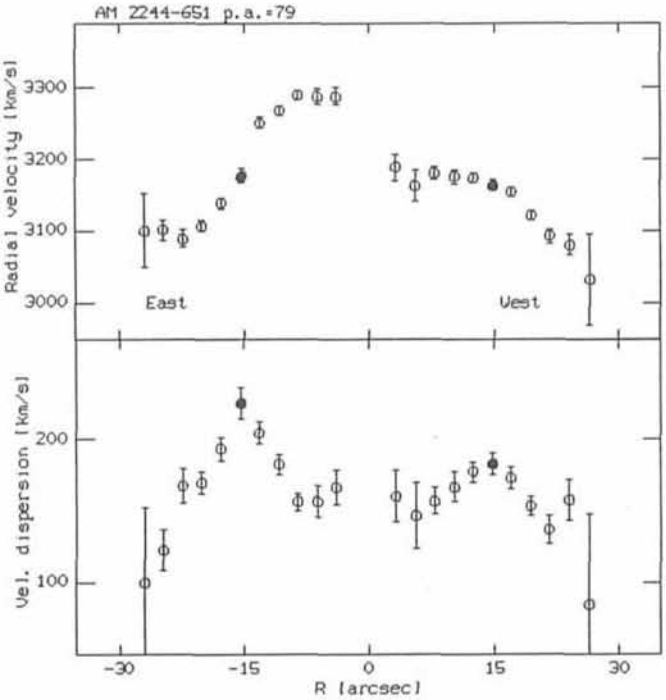

Figure 5: *The kinematical data along the line connecting both galaxy centres of AM 2244-651 show that the east component rotates rapidly. The generation of a large tidal tail as observed here requires such rapid rotation.*

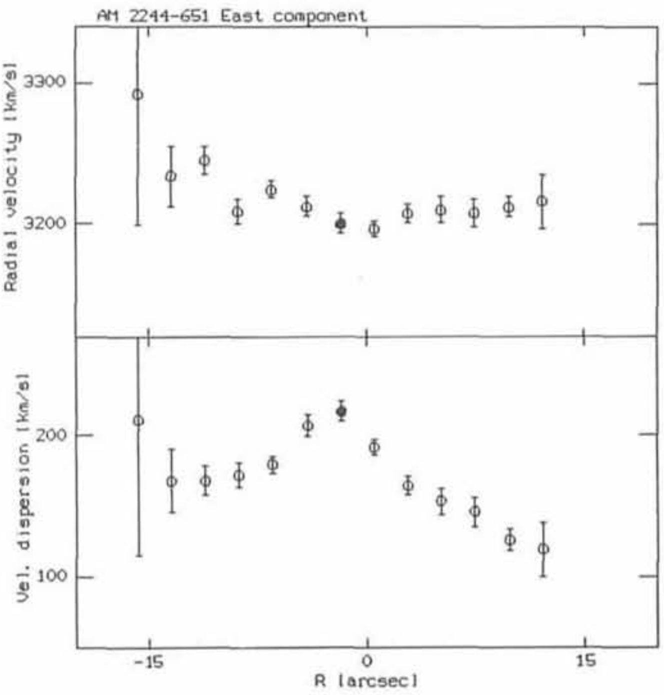

Figure 6: *The kinematical data for the eastern galaxy of AM 2244-651 perpendicular to the long-slit orientation of Figure 5. The galaxy shows no rotation along this orientation. The velocity dispersion decreases asymmetrically, probably a consequence of the tidal interaction.*

kinematics determine the strength of tidal interaction. When rotating galaxies are on prograde orbits, the interaction may lead directly to merging.

As shown, the morphology of interacting elliptical galaxies contains considerable information about the internal structure of galaxies. Only in a detailed morphological and kinematical investigation of interacting galaxies we can determine the different parameters in order to disentangle the various dynamical processes. Only then can we construct encounter scenarios and know how important are encounters in the evolution of galaxies.

Acknowledgements

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Galaxy Populations in Medium Distant and Distant Clusters

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1. Introduction

Observations of medium distant and distant clusters are of fundamental importance for the study of (a) the evolution of galaxies, (b) the evolution of clusters (c) the geometry of the universe.

Considerable efforts have been made in the past decade to understand the questions of galaxy and cluster evolution, galaxy and cluster formation but these questions are still open. Demonstrating the evolution of galaxies and clusters should be decisive for observational cosmology. Comparing galaxies and clusters of galaxies means to investigate their morphological, photometric and spectroscopic properties. The specific observations of distant clusters may also give information on the geometry of the universe. For example at $z \sim 0.7-0.9$, whether a cluster had time to form depends on the intensity of the corresponding peak in the initial density distribution, and also on H_o and q_o.

To detect evolution requires the comparison of similar clusters at various distance intervals. This means to define a local ($z \leq 0.05$), a medium distant ($z \sim 0.3-0.4$) and a distant ($z > 0.5$) sample of clusters and to investigate their photometric and spectroscopic properties.

We know that there is no detected evolution of the first ranked galaxies at $z \leq 0.4$. On the other hand, the Butcher-Oemler effect, i.e. the excess of blue galaxies in medium distant clusters in comparison with nearby clusters, is indicative of evolutionary phenomena within the last 5 Gy.

The dynamical time of galaxy clusters

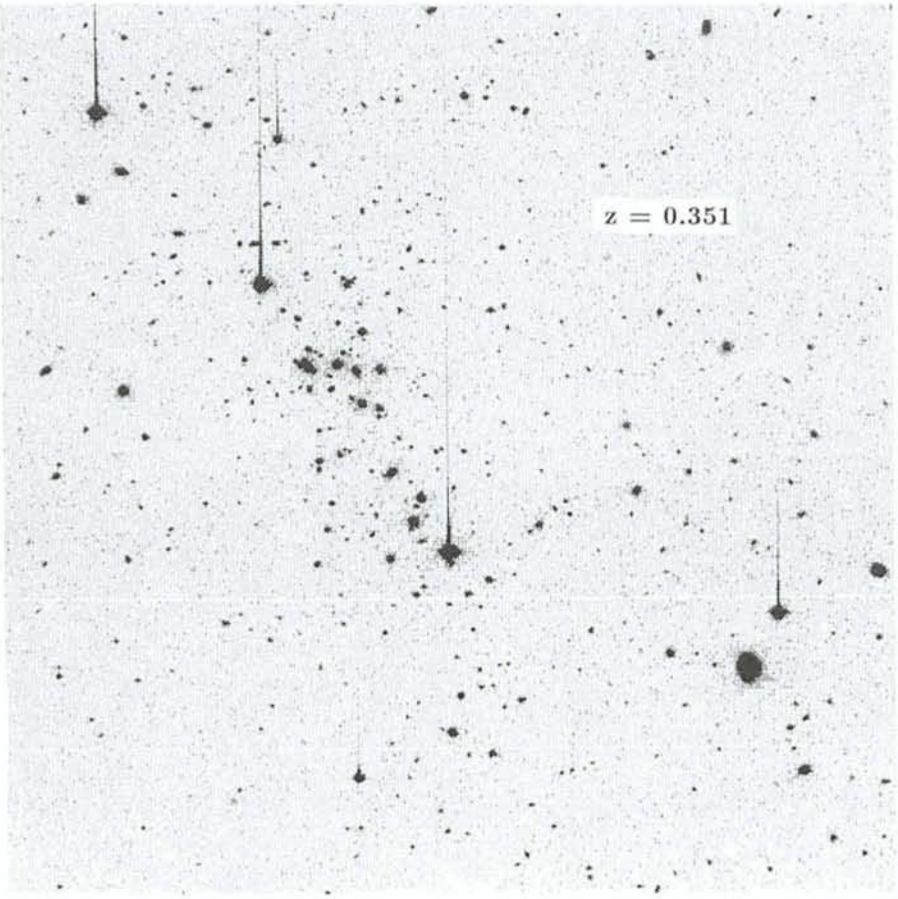

Figure 1: *A full field image of the southern cluster S 0067 at z = 0.35 obtained with EMMI and a Thomson CCD. EMMI is mounted at a Nasmyth focus of the NTT. The field is 7.5 × 7.5 arcmin. Exposure time is 10 min in R. Flat fielding was achieved using sky flats. The large field of EMMI allows to see the various morphologies of clusters and their environment. The limits of the clusters can be well defined as well as the change in colours of the objects as a function of the distance to the central condensation.*

is of the order of the Hubble time. It follows that clusters should be dynamically young. If the dynamical age and environmental effects are important, galaxies in various clusters may not be observed under similar conditions. Thus the first step before attempting to establish an evolutionary link between clusters at various distance intervals is to obtain extensive information on a variety of clusters in the same redshift range.

2. The Programme

The project is to observe 10 clusters at z=0.3 (GC3 project) and 10 clusters at z=0.5–0.6 (GC6 project). We will derive the luminosity functions, density variations and subclustering, colour distributions, colour-magnitude diagrams, and gradients of colours with respect to the cluster centre. Having a homogeneous sample is very important for testing the existence and universality of the Butcher-Oemler effect. Moreover, with the venue of the large field of EMMI it is now possible to measure colours out to rather large distances from the centres and thus to study the clusters in their environments. This means in particular that there is a possibility for testing whether clusters are linked to filaments or large-scale structures.

Multislit spectroscopy is the basic tool to derive stellar information on the galaxies of various colours and to check for cluster membership. With EMMI and low-noise CCDs it will be possible to multiply by a factor larger than 2 the number of spectra at a given exposure time (with respect to the 3.6-m) and to get spectra of some galaxies away from the cluster cores. Thus we expect to study possible variations in spectral types and eventually to follow some filaments a few arcminutes away from cluster cores. Our main project, however, is to study the populations in clusters and to search for some leading parameters whenever differences are found. For example we would like to know whether the rare clusters containing quasars have the same galaxy populations as the compact, rich clusters, or those with powerful radio sources. The GC3 and GC6 samples will be used to derive some information on the geometry of the Universe by application of the Tolman test.

The sample of the GC3 project is now well defined. Most candidates were selected from the Abell catalogue of southern clusters. Prominent structures detected near the limit of this catalogue should be at z≈0.2–0.4. Other candidates close to z = 0.4 were visually searched on CTIO 4-m plates. About 50 per cent of the candidates that we have observed look like real clusters. Most observations were done during test hours of the NTT and EFOSC 2. We give here examples of observed clusters and the redshifts that we have found (unpublished). These clusters are from the supplementary list of Abell et al. (candidates too distant for inclusion in the main catalogue): S 0067 (z = 0.35), S 0400 (z = 0.32), S 0506 (z = 0.32), S 0516 (z = 0.27), S 1115 (z = 0.34), S 1138 (z = 0.36). An image of S 0067 obtained with EMMI is shown in Figure 1. We have begun the photometric reductions using the INVENTORY context of MIDAS on one of the SUN workstations of the Astronomy Department at La Silla. We note in passing that the above clusters are rich enough to be good candidates for a specific search of gravitational arcs or arclets (cf. Key Programme of Fort et al., page 11).

The GC6 project started one year ago. The objective is to obtain photometry and a reasonable number of spectra in 10 southern clusters at z∼0.6. This redshift range has been selected because this is the limit at which spectra of normally bright galaxies can be obtained in a reasonable amount of time. At this distance rich clusters contain at least 10 to 15 galaxies brighter than V=22.5. Our search for distant clusters started with Gunn's cluster candidates and with a list obtained from visual inspection of 4-m plates. The observations were made during the commissioning period of the NTT using a 1000×1000 TH CCD camera. At this distance our identification rate dropped to less than 20 per cent. In fact most of the observed candidates look like filaments. It is not clear whether the technique of identification begins to fail at this redshift or the structure of high density regions at that time was mostly filamentary. An example of a distant Gunn cluster (z=0.57) is shown in Figure 2.

Cluster-finding at faint levels is not an easy task. The contrast with the background depends in a complicated way on the mean colour difference between the cluster and the field. Thus the visibility of a cluster varies and gets generally worse with increasing redshift. If one wants to do the work by objective criteria, it is necessary to make a deep survey and to extract a machine-gener-

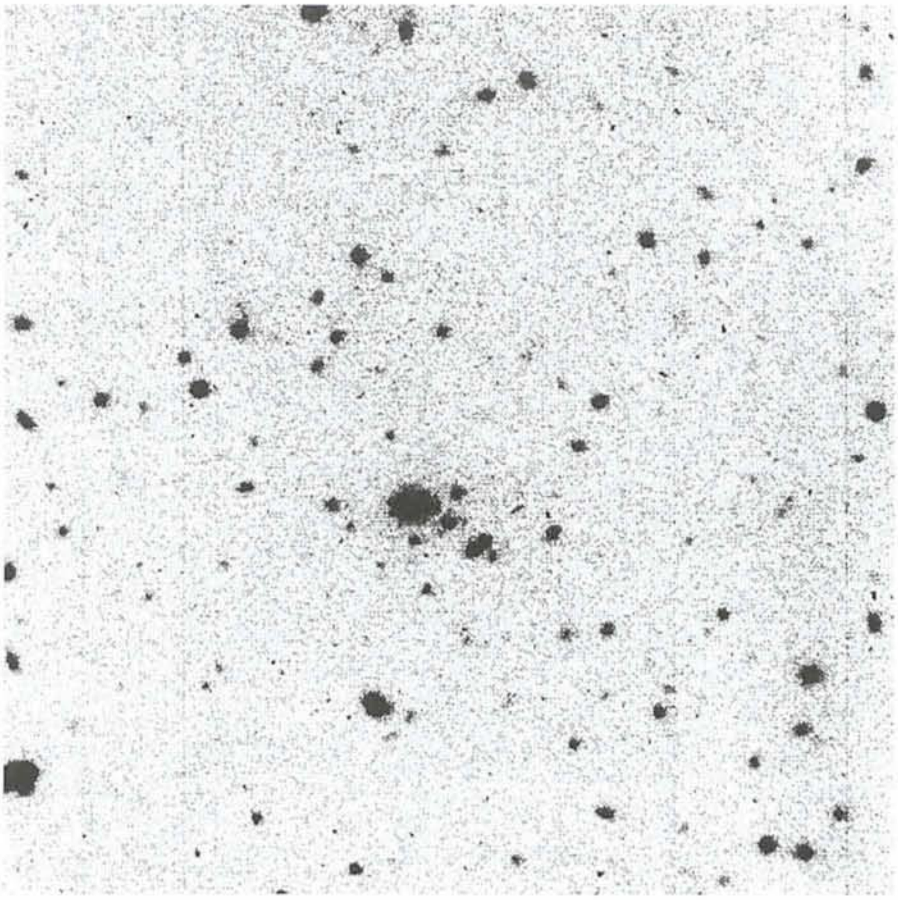

Figure 2: *An R-band image of a Gunn cluster at z = 0.56 obtained with EFOSC 2 at the NTT and a Thomson CCD. The size of the field of EFOSC 2 is much smaller (2.5×2.5 arcmin) than that of EMMI but the sampling of 0.15 arcsec/pixel gives images of higher quality when the seeing is good.*

ated catalogue such as the one being prepared by Gunn et al. at the 200″ telescope. High redshift galaxies associated with radio sources may lead to the discovery of some clusters if radio galaxies are associated with high-density peaks in the initial density distribution. A cluster at z=0.75 was discovered by this method. The cluster around the quasar PKS 0405−12 at z=0.572 was also observed.

3. First Results

For clusters at redshifts of ~ 0.3−0.4, the (B−V) colour index can be used to make a first selection between "passive" and "active" objects because, at this redshift, it is sensitive to the 4000 Å break amplitude (B is below, V is roughly above). The main result is that the B−V colour distributions present large variations from cluster to cluster. In particular there are clusters with no Butcher-Oemler effect and clusters with a very large blue population (compared with nearby clusters) as well.

All colour histograms can be described by using 3 populations: a red population (B−V ≥ 1.4−1.5) which corresponds to old-populated galaxies, a very blue one (B−V ≤ 1.1−1.2) which contains mostly emission-line galaxies, and an intermediate population which is not homogeneous, containing objects with spectra similar to those of nearby spirals and post-starburst galaxies as well. I introduced this intermediate population because I found clusters with a red and intermediate population but with a poor very blue fraction, and also clusters where the blue fraction is more important than the intermediate one (Fig. 3). The reason why there are such differences in the "active" fraction of galaxies in medium distant clusters is still unknown.

All clusters observed so far in this programme or those found in the literature belong to one of five classes derived from these 3 populations. Our spectra show that the active fraction contains galaxies with spectra typical of late-type systems, and also objects whose spectral types are very rare in nearby clusters as (a) post-starburst galaxies, with well visible Balmer absorption lines, (b) some probable Seyfert I, and (c) high-excitation narrow-line emission galaxies. Spectra representative of the various types found in S 0506 are shown in Giraud (1990). The corresponding colours vary from B−V = 1.6 for objects with large 4000 Å break, deep G band, Hβ, and Mg b, to B-V = 0.9 for emission-line galaxies.

What is new is mostly that the Butcher-Oemler effect is not universal and that there are now some indications that the whole story is more complex than a simple variation of the blue-to-red population ratio with Hubble time. An interesting result came with the observation of the cluster associated with the quasar PKS 0812 + 02 at z = 0.403. The blue-to-red population ratio in this cluster is the highest we have observed so far at medium distance. This cluster is also peculiar in the sense that bright red galaxies, which are usually found in other cluster cores, are missing there. Finding that a cluster surrounding a quasar has a very large blue population may imply that this cluster is dynamically young whereas a cluster with a large and concentrated population of elliptical galaxies might have been formed much

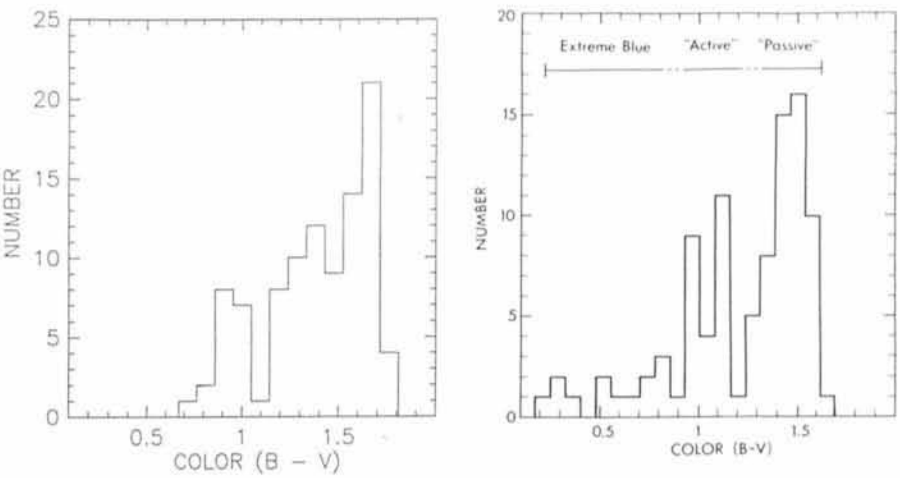

Figure 3: *The distributions of the B−V colour indexes in two medium distant clusters. These histograms show that the nature of the active population varies from cluster to cluster. There are clusters in which the active population is very blue whereas in others it is mostly yellow.*

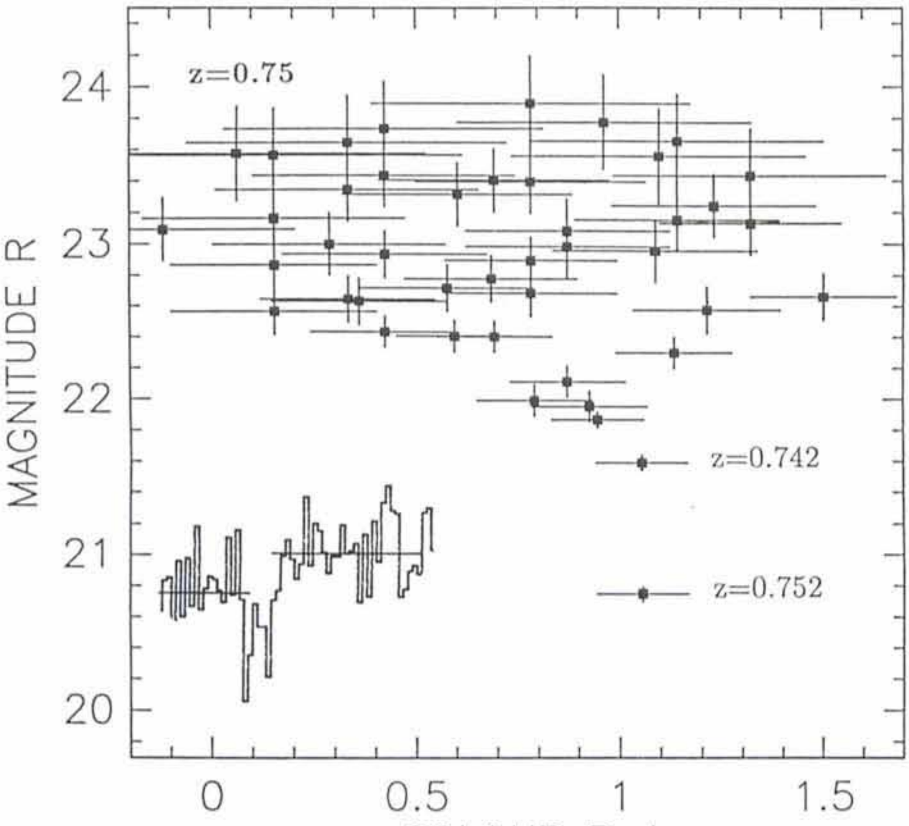

Figure 4: *A colour-magnitude diagram of a cluster at z = 0.75. We find that the blue fraction of objects is very high and that the red objects are slightly bluer than in the absence of evolution. These results should be taken with care, in particular because the contamination by field objects is very uncertain. In the left corner is the 4000 Å break of the first ranked object.*

earlier, possibly in high density peaks of the initial density distribution. In other words, a cluster with a high population of elliptical galaxies may have had high activity in the past, burning most of the gas, while a cluster found with a high degree of activity later would correspond to a slow growing fluctuation. These are the general ideas at this observational stage.

The use of the NTT, EFOSC 2 and a Thomson CCD are very important for the observations of distant clusters. The NTT, a seeing of 0.7 to 0.8 arcsec and a sampling of 0.15 arcsec/pixel made the separation of faint stellar-like objects from galaxies rather easy up to R = 22. To achieve good photometry in R and I, and obtain a spectrum far in the red, it was important to use the THCCD because it has low noise and no fringing in I.

Results on these clusters are still very preliminary. A colour-magnitude diagram of the cluster at z = 0.75, cleaned for stars and foreground objects, is presented in Figure 4. It shows that the R−I colours of red objects are somewhat bluer than if there were no evolution and that the blue-to-red ratio is of the order of 1, both properties suggesting that evolution has been detected (see also in Fig. 4 the rather low 4000 Å break amplitude in the spectrum of the first ranked object). However, the interpretation cannot be so crude for at least two reasons. First, the estimate of the real extent of the contamination by background and remaining foreground objects without multislit spectroscopy is very uncertain, and, second, we do not know if this cluster is representative or very peculiar, as it was detected by the presence of an ultra-steep spectrum radio source.

The trends presented here may be guidelines for a larger programme. Observing faint clusters of galaxies to investigate morphological and photometric evolution was one of the objectives of the wide-field camera of the Hubble Space Telescope (GTO Observing programme, October 1985). Frontier results should be within reach of the NTT and EMMI with a low noise CCD.

High-Resolution Imaging of Globular Cluster Cores

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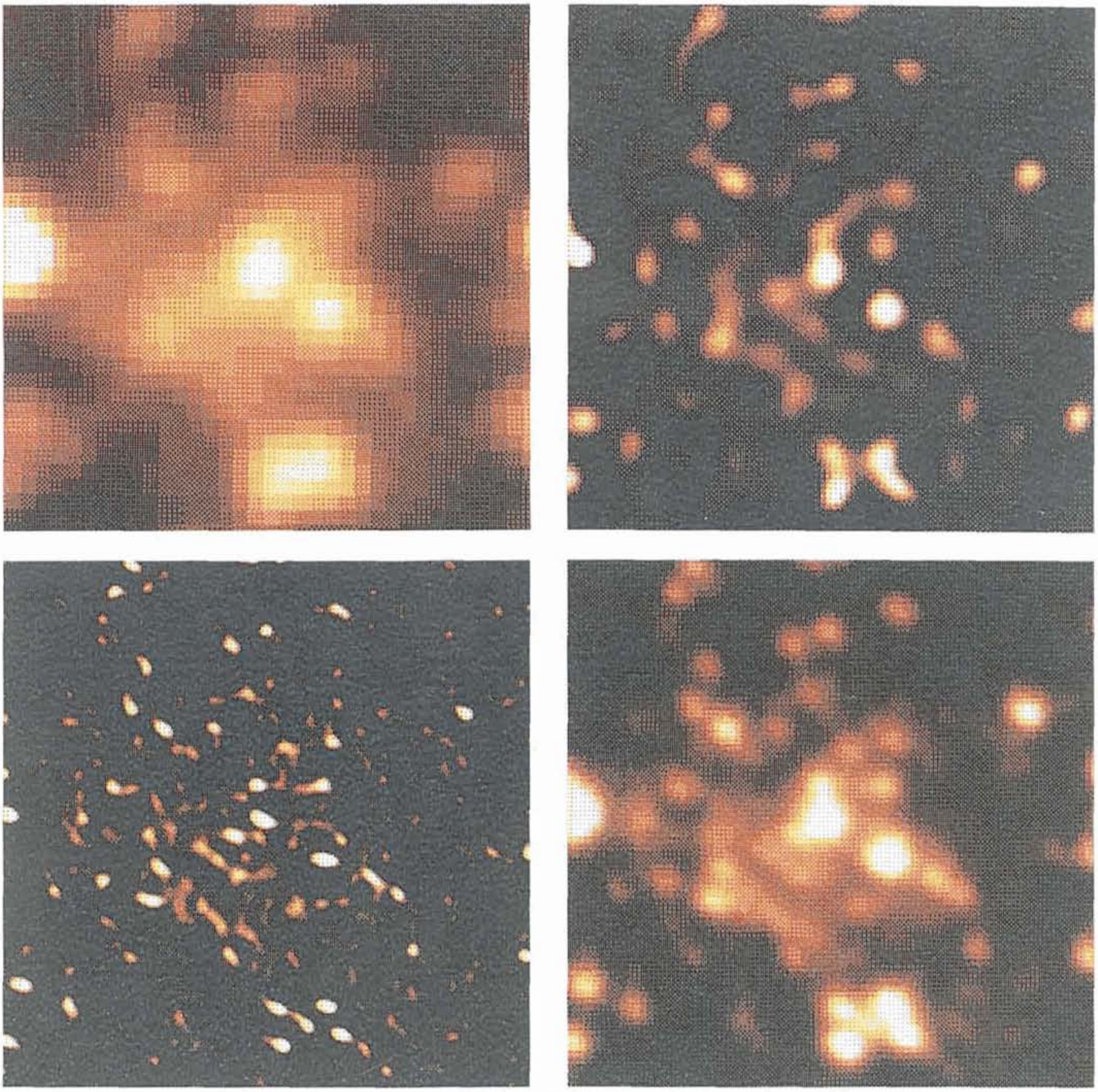
Practically all of ground-based astronomy can benefit from improved angular resolution. Whereas specialized techniques exist (e.g., speckle) or are being developed (e.g., optical interferometry), they are often limited in field size and/or by the available signal level. A significant fraction of optical work relies on CCD imagery of fields of several arcmin, and will probably continue to do so for quite some time. Recent advances in telescope technology (the ESO NTT being the foremost example), careful selection of telescope sites, etc., can do a lot to improve the seeing. But once the hardware is firmly in place, and the data are taken, the only way to improve the resolution is by some image deconvolution technique. Possibly the best among them is the *Maximum Entropy Method.*

A combination of good seeing data and a powerful and reliable seeing deconvolution technique may achieve results from the ground which were once believed to be reserved for space-based observatories. Here we illustrate just such an approach to data taken at ESO as a part of our study of globular cluster cores. There is hardly a more crowded scene than the very centre of a post-core-collapse cluster, such as M30 = NGC 7099.

The primary scientific motivation for our study is the discovery of colour and population gradients in the clusters which show the characteristic post-core-collapse morphology (Piotto, King, and Djorgovski, 1988; Djorgovski,



Old and new images of the collapsed core of M30, and their MaxEnt restorations. The field shown is about 13 arcsec square, with north at the top and east to the left. Clockwise from top left: (a) An R-band image obtained in ~ 1.2 arcsec seeing at the ESO 2.2-m telescope, from Piotto et al. (1988). (b) MaxEnt deconvolution of the image shown in (a). (c) An I-band image obtained in ~ 0.5 arcsec seeing at the ESO NTT. Note the excellent correspondence between the stars resolved in the reconstructed image (b) and this one. This comparison establishes the reliability of the deconvolution method. (d) MaxEnt deconvolution of the image shown in (c). The effective "seeing" in this image is about 0.1–0.2 arcsec.

Piotto, and King, 1988; Bailyn et al., 1989). The gradients are always in the sense of becoming bluer inwards, which is the opposite of what may be expected from seeing and crowding effects, and they occur in post-core-collapse, but *not in* King-model-type, clusters. This effect was confirmed by Djorgovski, Piotto, and Mallen-Ornelas (1991), and Djorgovski et al. (1991). Detailed star counts (which are of course limited by the seeing near the cluster centres indicate that the primary cause of the colour gradients is the difference in radial distribution of red giants and subgiants, and horizontal branch stars. It is also possible that there is an increase towards the centre of some population of faint, blue objects, perhaps blue stragglers (Aurière et al., 1990).

Since the phenomenon is clearly confined to clusters with the post-core-collapse morphology, it is likely a consequence of stellar interactions during and after the core collapse. Apparently, dynamical evolution of star clusters can physically modify their stellar populations. Theoretical attempts to understand the origin of gradients have been unsuccessful so far (Djorgovski et al., 1991). Binaries seem most likely to be part of the ultimate explanation of this phenomenon. The process may also be important for the formation of binary and millisecond pulsars in globular clusters. In any case, the key to understanding this phenomenon must be in the nature of stellar populations near the cluster centres. This calls for a substantial increase in angular resolution.

To perform our image restorations, we have implemented a shell which utilizes the Gull-Skilling (1989) MEMSYS-3 package of routines for maximum entropy (MaxEnt) reconstruction of arbitrary sets of data. The new MEMSYS-3 code, and our extensions to it, represent a significant improvement over previous MaxEnt implementations (Weir and Djorgovski, 1991).

A recent application of this system includes restorations of ESO images of the mysterious object R136 in the core of the 30 Doradus nebula (Weir et al., 1991). An especially useful feature of this software is that it allows one to solve for a restored image at subpixel spatial scales, if the S/N is high enough. This ability facilitates the detection of very high resolution structure in the restored image which otherwise might not be apparent due to the large pixel size of the original data. From simulated images and double blind tests, we have never found the method to introduce structure at subpixel scales when it did not actually exist. To restore to such levels, one must be able to adequately interpolate the point spread function (PSF) at the subpixel level. We typically use a PSF determined by the stellar photometry programme Daophot, which achieves a three times higher than nominal sampling estimate of the PSF by forming a composite of stars from the image of interest.

The pictures in Figure 1 are of images obtained (a) on the ESO 2.2-m telescope in ~ 1.2 arcsec seeing, (b) its restoration, (c) an image obtained on the NTT in ~ 0.5 arcsec seeing, and (d) its restoration. This data set provides an excellent means of assessing the power and validity of our deconvolution method by providing us with an estimate of "the truth" (the NTT image) by which to judge the restoration of the poorer quality data (a). We were pleased to find very high correspondence. Virtually all of the maxima in restoration (b), even those which may appear on the surface to be ringing artifacts or noise, actually have counterparts in the independently derived image (c). The faint fuzzy or filamentary structures in (b) are typically how the algorithm represents two or more fainter point sources which it is unable to clearly resolve in the original data. We can thus reliably detect stars at least a magnitude fainter than was possible in the unprocessed data.

From our determination of the power and accuracy of the first restoration, we are able to estimate the degree of resolution and reliability in the deconvolution of the NTT data. We estimate that we are able to reliably distinguish and resolve binaries of equal intensity down to the separations of *0.2 arcsec* or lower throughout the image. The oblong nature of some of the objects in (d) indicates that we are beginning to reach some fundamental limits in resolution, probably due to our inability to form a precise enough estimate of the PSF for all parts of the image. The PSF has been determined in the outer parts of the 2′.5×2′.5 image where the crowding is still quite severe, and the profile of the brightest and most isolated stars can still be contaminated by faint objects. Nonetheless, virtually all of the maxima detected in (d) are easily identifiable (with the proper stretch) in image (c). The principal benefit of deconvolution is in deblending the most crowded groups, to gain a better indication of the number and location of objects in the image.

The next step in our analysis is to construct colour-magnitude diagrams in the cluster centre region, and compare them with those at larger radii. The photometric results of MaxEnt restorations have long been known to be biased in the downward direction. We have found that this degree of bias can be reasonably modeled through Monte Carlo simulations, providing the possibility of statistically correcting for this effect in the image. We prefer, however, the following approach. Given that MaxEnt does an excellent job of object detection and separation, we use the restored image as a high-resolution "finding chart" by which to locate and obtain first estimates of the position and flux of all objects in the image. Next, one feeds these estimates into a least squares PSF fitting package, e.g., Daophot or Romaphot, to obtain unbiased stellar photometry from the original lower resolution images. We have only begun to experiment with this hybrid approach, but the results appear quite promising.

While we will not be able to achieve the resolution possible with speckle methods for bright objects, we do not think we have yet reached the maximum possible resolution attainable via direct imaging and subsequent deconvolution: in fact we are still largely limited by pixel size. Because of the large field of view and long integrations possible with direct imaging, we believe that sophisticated new restoration methods have real promise for providing resolution and depth previously thought achievable only from outside the earth's atmosphere, perhaps at the level of 0.1 arcsec for a broad range of objects.

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IAU Working Group on Photography Meets at ESO

On October 29–30, 1990, the IAU Working Group on Photography (within IAU Commission 9: Instruments) met at the ESO Headquarters in Garching. It was the second time a meeting of this group took place at ESO; last time was in 1978 while the ESO Telescope Division was still located at CERN.

Much has happened within the field of astronomical photography during the past 12 years. CCDs have taken over at many telescopes and to some it may perhaps appear that photography is on its way out of astronomy. However, this is certainly not yet true. Photography is still unequalled when wide fields are observed at high spatial resolution, i.e. whenever areas covering more than a few thousand pixels square are involved. Moreover, the ease of storage and data retrieval from photographical plates should not be underestimated, while the possibility of future digitalization of sky surveys (to provide easy computer access to the information) is a most interesting development. It should of course also be kept in mind that not all observatories have the necessary means to acquire state-of-the-art CCDs. For them, photographic observations will still continue to be an important activity for quite some time to come.

The 1990 WG meeting, which was moved from Nice to Garching at the last moment for technical reasons, attracted about 40 specialists, mainly from Europe and including a substantial complement from Eastern Europe. The discussions centred on a variety of subjects, in particular the extraction of information from photographical plates. There has been important progress in the accuracy and speed of microdensitometry, and image "manipulation" in the photographic laboratory allows us to see weak and/or extended structures which would otherwise not be visible.

The big Schmidt telescopes in the world continue their surveys of the northern and southern skies which will provide present and, not the least, future generations of astronomers with the possibility to learn about the past behaviour of objects with newly discovered, peculiar properties. Several "durchmusterung"-type projects are based on these surveys and provide extensive lists of selected objects for detailed studies with larger telescopes.

The Organizing Committee of the Working Group decided to study how this group can best be continued; photographic methods alone may become too narrow a delimitation in the future. The WG will meet again at the IAU General Assembly in Buenos Aires next year and expects to take the corresponding decision there.

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Lithium in Chromospherically Active Stars

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1. Introduction

The abundance of Lithium in stars is perhaps one of the least understood problems in Astrophysics. Contrary to most other elements, Li is not produced in the standard way by stellar nucleosynthesis; rather, it is believed to have largely been created at the very beginning of the Universe. An accurate measure of the present Li abundance can thus provide stringent constraints on models of the Big Bang. Unfortunately, Li is a very fragile element and its isotopes Li^6 and Li^7 are destroyed by nuclear reactions at temperatures higher than 2.2×10^6K and 2.6×10^6K, respectively. Since most of the stellar interiors are at temperatures higher than this, Li is confined to shallow surface layers. It is not surprising that a number of mechanisms exist to mix the surface Li to the hotter interior, thus changing the present abundance of Li with respect to the primordial value. To make things even worse, there are also a number of mechanisms (nuclear spallation reactions by cosmic rays, production in novae and in red giants) that can potentially increase the abundance of Li on time scales comparable to the age of the Galaxy. For all these reasons, it is extremely important to understand the mechanisms that lead to Li depletion in stars or to a possible Li enrichment of the interstellar medium during the galactic evolution.

The "classical" picture of Li depletion in late-type stars was put forward by Herbig in the mid-sixties (see Herbig, 1965). He noticed that field stars of spectral type F8 to G5 present a very large spread in the Li abundance (more than two orders of magnitude) and that the largest Li abundances were ≈ 3.0 (these are logarithmic values on a scale where $\log n(H) = 12.0$). These values were similar to those found in T-Tauri stars and in meteorites. Herbig also found that Li depletion increases towards later spectral types. It is very rare to find large Li abundances in stars later than G5. Typically, K stars do not show a measurable Li line.

The easiest way to interpret these observations was to suppose that all stars (at least those of Population I, see later) were born with the same Li abundance and that Li was progressively depleted in late-type stars under the action of convective motions that bring surface material down to deeper layers. Li is more rapidly depleted in cooler stars which have deeper convective zones and hence higher temperatures at their base. Herbig's interpretation is at the origin of the well-known use of the Li line as an age indicator for solar-type stars, a notion that has commonly been accepted for nearly two decades. There were however a number of "disturbing" effects that, although usually neglected, should have cast doubts on the simplified classical picture. For instance, a substantial number of early F stars were known to have a low Li abundance, much lower than the initial value of about 3.0. Since these stars have very shallow convective zones, it is not clear how they could have been deprived of their Li. Moreover, if Li abundance in solar-type stars were related to age, one should observe a tight correlation between Li abundance and other indicators of age, such as surface rotation or chromospheric Ca II H and K emission. This is typically not observed.

There were also problems on the theoretical side. Standard models of the interior structure of stars show that the bottom of the convective zone in solar-type stars has a temperature significantly lower ($\approx 2.0 \times 10^6$K) than the minimum temperature needed to destroy Li^7 by nuclear reactions ($\approx 2.6 \times 10^6$K). Since the lithium we observe is mostly Li^7, some mechanism other than simple convective transport is required to provide for its depletion. The larger convective zones of K stars are expected to penetrate deep enough to allow nuclear burning of Li, but in the Sun, and in general in all late F and G dwarfs, some extra mixing is definitely required. Several possibilities have been suggested: *turbulent diffusion* below the convective envelope driven by convective overshoot, *mixing* induced by radial differential rotation, *"evaporation"* of Li-rich surface layers through stellar winds, and others.

Over the past decade great advances have been made in the study of Li abundance in stars. In particular, new high-quality observations of open clusters (for a review, see Boesgaard, 1990) have revealed the existence of a "dip" at ≈ 6650 K in the Li abundance of all clusters with ages greater than $\approx 10^8$ years. In the dip, the Li abundance is reduced by at least two orders of magnitudes, while it is "normal" both a temperatures higher than ≈ 6900 K and in the temperature range 6300–6100 K (while decreasing sharply at still lower temperatures). The dip has also been identified in observations of F stars in the field. The reasons for this peculiar

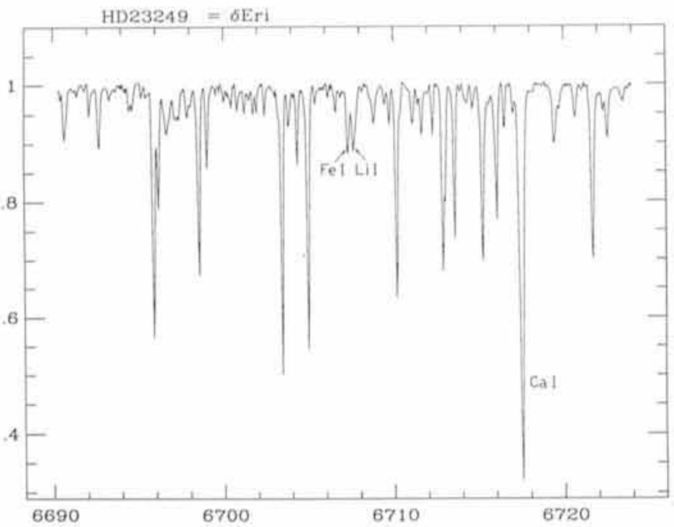


Figure 1: *CES spectrum of the comparison star δ Eri in the Li region. In this and in the following three figures the wavelength scale has not been corrected for the radial velocity of the star.*

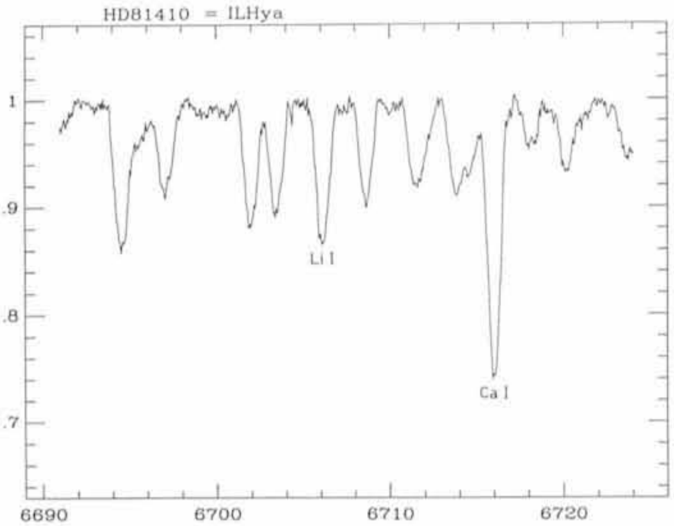


Figure 2: *CES spectrum of the RS CVn binary IL Hya. Note the strong Li line.*

behaviour are not clearly understood. Suggested mechanisms include diffusion under the action of gravity, dilution caused by meridional circulation, and rotationally induced turbulence at the base of the convective zone.

With regard to Population II stars, a real breakthrough has been the discovery of a high Li abundance in old halo stars having effective temperatures between ≈ 6300 and 5600 K (see Spite, 1990 for a recent review). Not only is Li preserved in these old stars, but its abundance appears to be remarkably constant for all halo stars over this temperature range. The approximately constant value is 2.0, a factor 10 less than the initial cosmic value for Population I stars. It has been suggested that the lower metallicity (and hence shallower convective zones) of Population II stars may have allowed them to preserve the original Li produced in the Big Bang. If so, the primordial Li abundance is a factor 10 lower than previously thought, and Li abundance has progressively increased to the present value during the lifetime of the Galaxy.

These and other recent advances have not yet solved the Li problem, but at least have shown clearly that the "classical" picture was oversimplified. Lithium can be depleted by a number of different mechanisms, and parameters so far neglected (such as metallicity and rotation) may actually play the dominant role. Observations of Li in RS CVn binaries and other chromospherically active stars have also provided unexpected results that are not easily interpreted in the framework of the classical theory. In the rest of this paper we will focus specifically on Li observations of chromospherically active stars, a topic which has been the subject of the long-term programme carried out by us at ESO over the past three years.

2. Observing Chromospherically Active Stars

Several years ago we carried out some Li observations of F, G and K stars in the field using the Coudé Echelle Spectrometer (CES) and Reticon detector at ESO. The aim of that programme was to relate the observed Li abundance to other age indicators such as rotation and chromospheric CaII emission. Beside rediscovering the usual pattern that Li abundance rapidly decreases towards lower effective temperatures, and that late F and early G stars present a large range of different Li abundances, we found two interesting results (Pallavicini et al., 1987). First, that a high Li abundance in F8-G5 stars is a necessary, but not sufficient condition for the star to be young; and, second, that there were a few K stars in the sample that showed an unusually high Li abundance.

With regard to the second point, a quick inspection of the literature showed that several K stars reported to have the Li line (including those in our sample) were chromospherically active stars known or suspected to be *RS CVn binaries*. These are close binaries typically formed by a hotter component of spectral type F or G and luminosity class V or IV and a cooler component of spectral type close to K0 IV. They are characterized by an extreme degree of surface activity at optical, UV, radio and X-ray wavelengths. It is generally believed that the high surface activity of these stars is due to their rapid rotation and the subsequent generation of surface magnetic fields by a dynamo process. The evolutionary status of RS CVn binaries has been a matter of debate for some time, until Popper and Ulrich (1977) convincingly showed that RS CVn systems are evolved post-main sequence objects. Li therefore is not expected in these binaries, except in those few cases in which the brightest component is a main-sequence F star.

For these reasons, we thought that a systematic survey of RS CVn stars in the Li region might be worth doing. The primary source for our programme stars is the list of chromospherically active stars of Bidelman and MacConnell (1973) which is based on emission in the CaII H and K lines in low-resolution objective prism spectra. Since this list uses only one indicator of chromospheric activity, it is likely to include a variety of active stars in addition to genuine RS CVn binaries. A second group of sources in our sample comes from the list of active binaries of Strassmeier et al. (1988) which comprises many catalogued RS CVn binaries. Finally, other programme stars were taken from current lists of southern RS CVn candidates. In total the sample comprises more than 60 southern stars of spectral types G and K and luminosity classes V, IV and III. Several inactive stars of various spectral types and luminosity classes were also observed for comparison.

The observations were carried out at La Silla during several observing runs (Nov. '86, Dec. '87, Jan. '89, June '89 and April '90; the run of June '89 through the courtesy of Dr. Luca Pasquini). In all observing seasons we used the Coudé Echelle Spectrometer (CES) fed by the 1.4-m CAT telescope. The

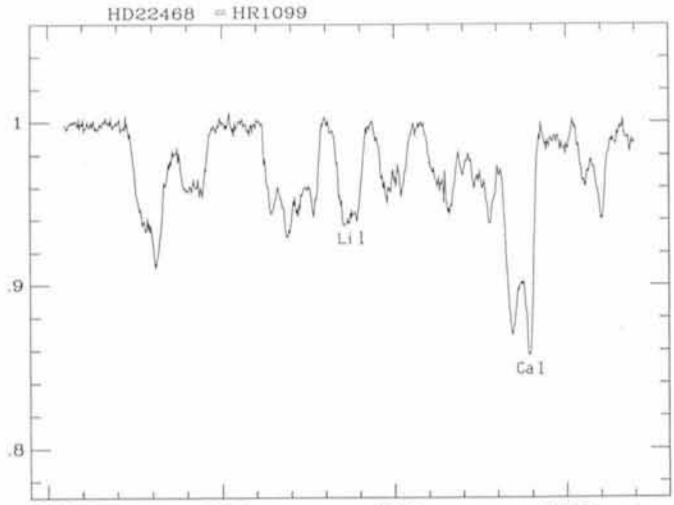


Figure 3: *CES spectrum of the double-lined spectroscopic binary HR 1099, the brightest RS CVn star.*

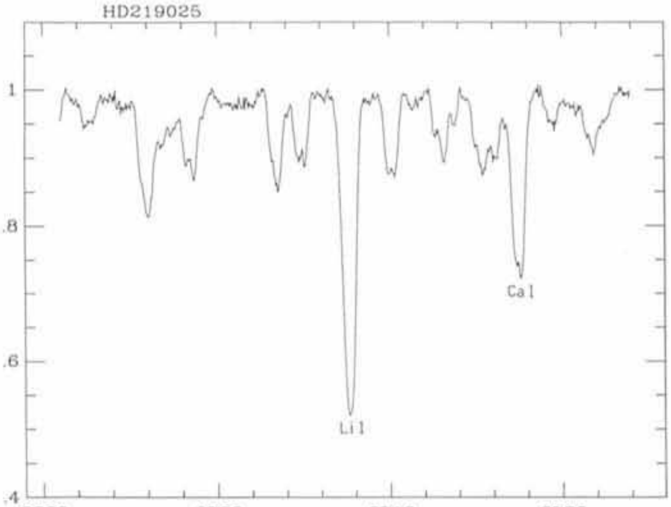


Figure 4: *CES spectrum of HD 219025. Note the extremely strong Li line.*

short camera and a CCD detector were used. The nominal resolving power was R = 50,000 and the S/N ratio was in all cases greater than 100. The spectral range available in the Li region is ≈ 50 Å and was centred at 6708 Å. The LiI unresolved doublet at 6707.81 Å is close to a FeI line at 6704.44 Å. The spectrum of the K0 IV comparison star δ Eri in Figure 1 shows clearly both lines. However, since most stars in our sample are rapid rotators (with V sini greater than ≈ 10 km/s), the Li line is usually blended with the Fe line at 6707.44 Å. A correction must be made for the contribution of the FeI line. The available spectral range allows also observations of the CaI line at 6717.69 Å and a number of other FeI lines that can be used to estimate the metallicity of our stars.

Figure 2 shows the spectrum of the catalogued RS CVn binary HD 81410 = IL Hya (Sp. K1 III) which shows a strong Li I+Fe I blend. The equivalent width of the blend is 113±5 mÅ, of which we estimate that only 37 mÅ can be attributed to the FeI line. In other RS CVn stars the Li blend is not so strong, but still anomalously high for the spectral type. Figure 3 shows the spectrum of the well-known RS CVn binary HR 1099 (HD 22468, Sp. G5 IV+K1V). In spite of the complications introduced by the SB2 nature of this system and by its rapid rotation, it is obvious that the Li blend is present with an equivalent width of 85±8 mÅ, of which only ≈ 25% can be attributed to the FeI line. Finally, in several active stars in our sample, the LiI line is extremely strong, even stronger than the CaI line at 6718 Å. An example is the K2 IIIp star HD 219025 shown in Figure 4 for which an equivalent width of 430±10 mÅ was measured for the LiI+FeI blend, almost a factor 2 larger than the equivalent width of the CaI line.

The results of our survey are summarised in Figure 5 where we plot the derived Li abundances versus effective temperature (filled symbols). We also plot for comparison (open symbols) the results previously obtained by us for a sample of field stars (see Pallavicini et al., 1987). The comparison clearly shows that a large number of cool chromospherically active stars in our sample show *excess Li abundance* with respect to typical stars of the same spectral type. This conclusion is reinforced by the comparison we have made with a random sample of K-type giants observed with the same instrument. Only a couple of stars in the latter sample showed a detectable Li line. Also evident in Figure 5 are the extremely large Li abundances derived from a few stars in the sample.

Roughly, nearly two thirds of our stars appear to have an anomalously high Li abundance, including five stars for which the Li 6708 Å line is stronger than the CaI line at 6718 Å. For four of these stars, the extremely strong (and probably saturated) Li 6708 Å line gives Li abundances comparable to or even larger than the initial cosmic abundance of Li in Population I stars (i.e. ≥ 3.1–3.2). For the vast majority of the other stars in the sample, the derived Li abundances are not so extreme, but they are still large for the spectral type.

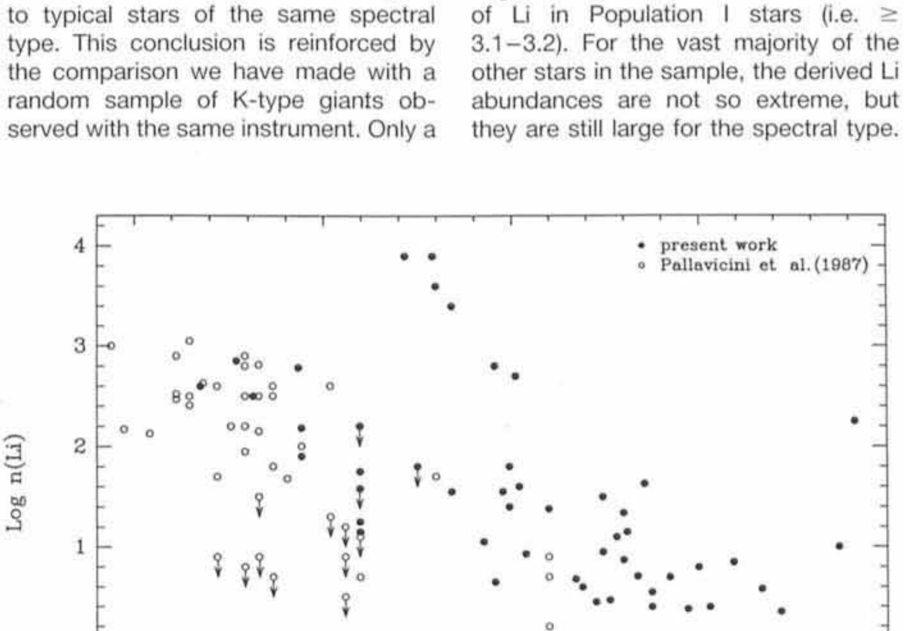


Figure 5: *Li abundance vs. effective temperature for the chromospherically active stars in our sample and for the stars in Pallavicini et al. (1987). Note the excess Li abundance for most stars in our sample.*

In particular, most K stars have Li abundances log n(Li) ranging from ≈ 0 to 2, and only a small number of them show a very weak or absent Li line. This contrasts with what is typically observed for K stars.

3. Search for Rotational Modulation

Before trying to explain why Li is preserved in many K-type active stars, we should test the hypothesis that we are observing a genuine abundance effect. Giampapa (1984) has suggested that surface activity in stars may significantly affect the strength of the Li line. This line is a factor 20–40 stronger in sunspots (owing to the lower ionization of Li in the cool spots), and about a factor 2 weaker in plages, with respect to the undisturbed solar photosphere. If similar enhancement and reduction factors also apply to stars cooler than the Sun, and if these stars are covered by large spots as has been inferred from photometry, the Li line may become enhanced, independently of true abundance effects. This possibility can be tested by observing a rotating star at different phases. Simultaneous optical photometry is necessary because changes of the Li line with phase could only be detected for a highly inhomogeneous distribution of active regions over the stellar surface.

We carried out this test in December 1987 at ESO. We monitored four stars nearly simultaneously in the LiI line and in broad-band UBV(RI)$_c$ filters. The photometric observations were carried out over a two-weak period immediately preceeding the spectroscopic observations. We used the 50-cm ESO telescope equipped with a single-channel photometer and standard UBV(RI)$_c$ filters. The spectroscopic observations were carried out over 6 consecutive nights using the CES fed by the 1.4-m CAT. The instrument setup was the same as the one used by us in all other Li observations. The four stars monitored were HR 1099, YY Men, AB Dor and IL Hya. All are well-known "spotted" stars and were also known from our previous observations to have a strong Li line.

The derived light curves show a clear photometric variation for all stars with amplitudes of ≈ 0.05–0.1 magnitudes in the V band. The ephemerides derived from the photometric variations were used to determine the phases at which the spectroscopic data were obtained. Figure 6 shows the results of the spectroscopic observations for two of the monitored stars. We have plotted, as a function of phase, the measured equivalent widths of the LiI+FeI blend and of the CaI 6718 Å line. No significant variation of the equivalent widths with phase was observed for any for the four stars in spite of the fact that significant photometric variations were observed at the same time.

The upper limits we derive for the variations of the LiI equivalent width (less than 5–10%) are much smaller than what had previously been suggested on the basis of the solar analogy. If we assume that the enhancement of the equivalent width of the LiI line in starspots is about the same as for the Sun, the derived upper limits imply a spot coverage factor of only a few per cent, much smaller than that derived from the photometric variations (≈ 15–25%). It is clear therefore that the enhancement of the Li line in the spots of these stars, if present, is certainly lower than for the Sun.

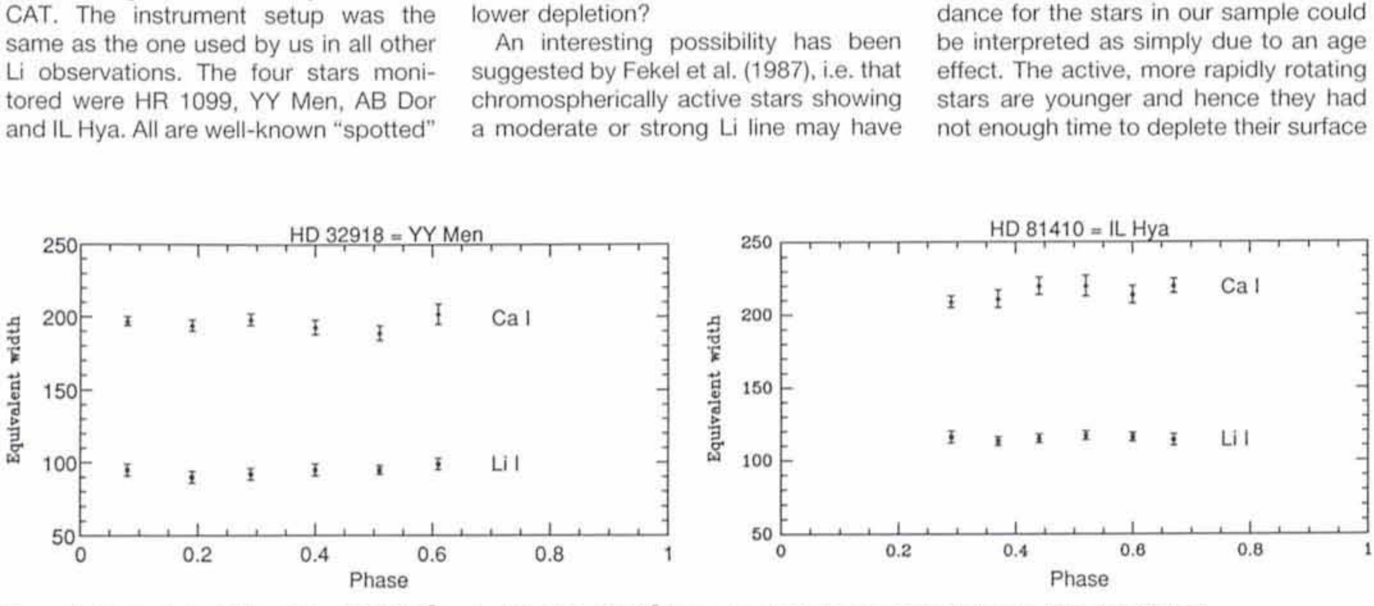
4. Towards an Understanding of the Li Excess

The negative result obtained above shows that the observed Li excess in many K-type giants and subgiants with active chromospheres must be due to a real decrease of Li depletion for these stars. But what are the reasons for this lower depletion?

An interesting possibility has been suggested by Fekel et al. (1987), i.e. that chromospherically active stars showing a moderate or strong Li line may have evolved from late A or early F-type stars with shallow convective zones. These stars would not have time to substantially deplete their Li while on the main-sequence. This interpretation is attractive, but it is not completely satisfying. Only stars sufficiently massive, say with masses larger than ≈ 1.5 $M_\odot$, have subphotospheric convective zones so thin as to prevent a significant Li depletion on the main-sequence. For lower-mass stars, the observations of the Li dip in clusters with ages greater than ≈ 10^8 years show that Li depletion on the contrary may be very efficient. For stars of still lower masses, Li is depleted owing to the increased depth of the convective zones. The masses of RS CVn stars are not well determined (in many cases we have only lower limits or the mass functions); however, it seems that the masses may cover the entire range ≈ 1–2 $M_\odot$. Since a Li excess is observed for the majority of the active stars in our sample, it appears unlikely that all these stars are on the upper side of the allowed mass range and that only the few stars with no detectable Li have masses lower than ≈ 1.5 $M_\odot$.

There is another property of the active stars in our sample that is systematically different from what is typically observed in quiet stars of similar spectral type. This is *rotation*. Virtually all active stars in the sample have in fact a rotational velocity well in excess of what is usually observed for K-type stars. This is not surprising, since our sample has been selected on the basis of surface activity. If the activity is of magnetic origin, and derives from dynamo-generated magnetic fields (as commonly accepted), a correlation should be expected between rotation and surface activity.

At first sight, the relationship observed between rotation and Li abundance for the stars in our sample could be interpreted as simply due to an age effect. The active, more rapidly rotating stars are younger and hence they had not enough time to deplete their surface


HD 32918 = YY Men

HD 81410 = IL Hya

Figure 6: *Equivalent widths of the LiI 6708 Å and of the CaI 6718 Å lines vs. phase for the spotted stars IL Hya and YY Men.*

Li, in agreement with the prescription of the "classical" theory. However, there is evidence that many stars in our sample (particularly the RS CVn binaries) are evolved post-main sequence objects with ages of at least 10^9 years. A few stars in our sample may be very young, but this is not true for most of them. Note also that for close binaries there is no causal relationship between rotation and age. An RS CVn star rotates rapidly, not because there was not enough time during main-sequence evolution to slow it down by stellar winds and magnetic fields, but rather because tidal interaction prevented an efficient braking by locking the star rotation period to the orbital period.

Naïvely, one could expect that more rapid rotation should increase Li depletion by facilitating the circulation of surface Li to deeper layers (see, e.g., Boesgaard, 1990). However, recent calculations by Pinsonneault et al. (1990) suggest instead that there may be an *anti-correlation* between rotation and Li depletion, in the sense that stars that have lost more angular momentum, and hence rotate more slowly, should have suffered more Li depletion than stars of the same spectral type that have only spun down by modest amounts. Pinsonneault et al. base their conclusions on detailed calculations of the rotational evolution of the Sun up to the present epoch. They show that the surface layers of the Sun (at $r \geq 0.6R_\odot$) may have been braked more efficiently than the interior, thus causing differential rotation in the radial direction. Transport of angular momentum leads to rotationally induced mixing which reproduces the Li depletion observed at present in the Sun (we remind that the Li abundance in the Sun is log n(Li) $\approx$ 1.0, i.e. two orders of magnitude lower than the "primordial" value for Population I stars).

According to the model of Pinsonneault et al., we can speculate that the absence of efficient braking in tidally coupled RS CVn binaries may have prevented the onset of a strong radial differential rotation, and hence of an efficient rotationally induced mixing. Li therefore should be more preserved in rapidly rotating stars than in stars of similar spectral type that have suffered a greater loss of angular momentum. The amount of Li depletion does not depend on the rotational velocity *per se*, but rather on how much the rotational velocity has changed during stellar lifetime, i.e. on the amount of angular momentum loss. A star rotating rapidly at the present epoch (either because it is young or because tidal interaction has prevented loss of angular momentum) should have preserved most or a large part of its original Li.

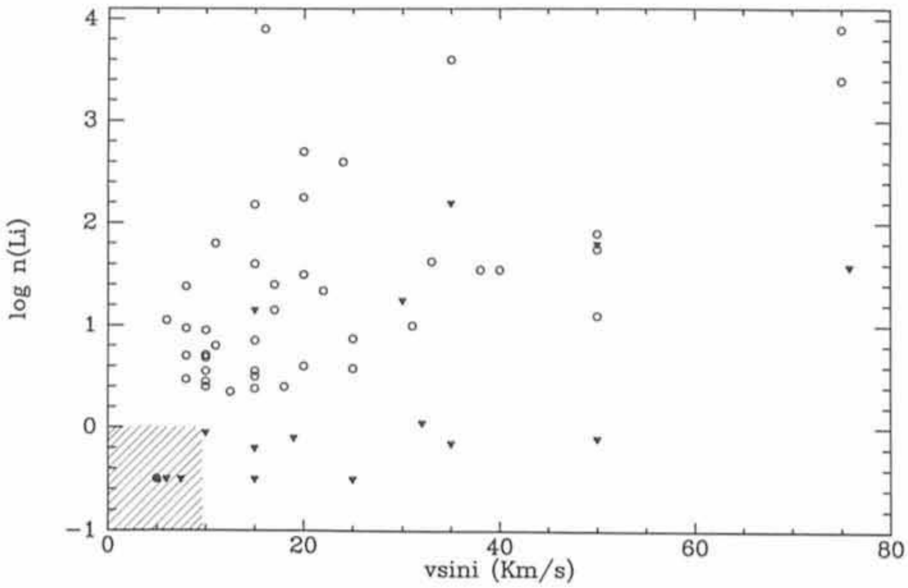


Figure 7: *Li abundance vs. projected rotational velocity for the stars in our sample. Filled triangles indicate upper limits on Li abundance. The dashed area in the lower left corner indicates the region of the diagram typically occupied by inactive K-type stars.*

The conclusions of Pinsonneault et al. depend on the assumption that no significant coupling by magnetic fields exists in the stellar interior. While this is likely to be so for the Sun, it is unclear whether the same also holds for magnetically active stars. Unfortunately, it is difficult to test the model by Pinsonneault et al. by looking directly at a correlation between Li abundance and rotation. Any spread in the initial angular momentum distribution would severely affect the tightness of the correlation. This difficulty is even more severe in our case since our sample of chromospherically active stars is likely to include objects that differ not only in the initial angular momentum, but also in mass, age and metallicity. A plot of Li abundance vs. rotational velocity for our sample is shown in Figure 7. Clearly, the situation is very confusing and no obvious correlation appears to exist. However, the plot reinforces our previous conclusion that *on average* the stars in our sample show both higher Li abundances and higher rotational velocities than a random sample of inactive stars of similar spectral types (dashed area at the lower left corner).

Roughly, we can distinguish three broad regions in the diagram. First, there is a group of very late stars that appear to be "normal" in the sense that they are all depleted of Li and have abundances less than *log* n(Li) $\approx$ 0. In our limited sample, both slowly and rapidly rotating stars appear to be present among them. A second group of objects is that at the top of the diagram. They have a very high Li abundance, comparable to, or higher than, the cosmic "primordial" value of $\approx$ 3.0. They tend to be fast rotators, but in this case too there is a broad range of projected rotational velocities. Finally, in the middle part of the diagram there is a broad region of active stars, which on average have both higher Li abundances and higher rotational velocities than inactive stars of the same spectral types; they show, however, little dependence of Li abundance upon rotation within the group itself (at most, there may be a slight tendency of the more rapidly rotating stars to have also higher Li abundances).

At present, it may be quite unsafe to draw conclusions. However, we can at least attempt some plausible interpretation in the light of the considerations above. The stars at the bottom of Figure 7 may be the less massive ones. Their progenitors on the main sequence had sufficiently deep convective zones to allow efficient burning of Li, independently of rotation. Since they are also older, they had enough time to deplete Li during their main-sequence lifetime and/or may have already entered the post main-sequence Li dilution phase. The stars in the middle group, which have preserved a substantial (but varying) amount of Li may have done so, either because they were rather massive (and then originated from late A or early F stars with very thin convective zones); or, if they were less massive (in the range 1.2 to 1.5 $M_\odot$), because they are rotating rapidly and hence have suffered less differential rotation mixing. A distribution of initial angular momenta may contribute to the scatter in the Li abundance vs. rotation diagram. Finally, the stars with extremely high Li abundance at the top of the diagram are almost certainly very young objects that have recently arrived at the main sequence or are approaching it. The spectra of these stars in the Li region resemble very closely those of the rapidly rotating K stars in the Pleiades as well as those of naked T Tauri stars. Moreover, two of these stars (AB Dor and PZ Tel) have already been shown on kinematic grounds to belong to the Pleiades moving group.

5. Conclusions

Our survey has shown that chromospherically active K stars have a definite Li excess with respect to inactive stars of similar spectral type. This excess cannot simply be an age effect, since it is also present in many RS CVn binaries and other supposedly evolved stars. It cannot be due either to an enhancement of the Li line by large cool spots since observations of a few stars at different phases have shown no rotational modulation of the Li line. We have suggested that a combination of thin convective zones in their main-sequence progenitors, together with little angular momentum loss during the evolution of these tidally-locked rapidly rotating stars, may qualitatively explain the lower Li depletion. It is not easy however to disentangle the various relevant effects in a highly heterogeneous sample as the present one, which may also contain young, rapidly rotating single stars.

More work needs to be done for a proper understanding of the Li problem in chromospherically active stars. First of all, a separation of the total sample in smaller, more homogeneous subsamples is necessary. Secondly, it is desirable to extend the observations to northern stars since most "classical" well-studied RS CVn binaries, with better determined masses and evolutionary states, are located at northern declinations. Third, the metallicity of the various stars in the sample should be accurately determined. Finally, we should be careful in identifying very young stars and possibly pre-main sequence objects in the sample by studying their kinematic properties and surface activity. Research along these lines is currently being carried out by us; the results are expected to provide essential clues for the understanding of Li abundance in chromospherically active stars.

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Lithium in Carbon Stars

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Carbon Stars

Carbon stars (C stars in the following) are characterized by a surface carbon to oxygen ratio (C/O ratio) greater than unity (detected by the presence of strong molecular bands of C_2, CN and CH) and an excess of heavy elements (presence of ZrO molecular bands instead of TiO bands, as seen in M giants, and presence of enhanced atomic lines of Sr, Y, Ba), as well as a huge mass loss.

Those stars are located on the poorly known asymptotic giant branch (AGB) of the H-R diagram. This branch constitutes the locus of intermediate mass ($0.8 \leq M/M_\odot \leq 8$) stars in which hydrogen and helium burn alternately in shells around an electron degenerate carbon-oxygen core (Iben and Renzini, 1983). These stars are also characterized by the occurrence of thermal pulses. After each thermal pulse, the carbon and the s-process isotopes, made in the convective helium-burning zone, can be brought to the surface of the stars by convective dredge-up. Therefore, it is believed that along the AGB, a star evolves from spectral type M (i.e. $C/O < 1$) to S ($C/O \approx 1$) and finally C ($C/O > 1$) when it experiences more and more thermal pulses.

The presence of the unstable s-element technetium in the spectra of some C stars (Peery 1971) is a clear indication that an intense nucleosynthesis is taking place in those stars and that the freshly synthesized material is brought to the surface. The exact mechanism by which this processed material comes to the surface, as well as the conditions present in the pulses, however, are not very well known. Therefore, it is of prime importance to study the Li in AGB stars, as the great sensitivity of this element to the physical conditions makes it a good tracer to constrain those conditions prevailing in the stellar atmospheres.

Lithium

Lithium is a fragile element, easily destroyed by proton captures in the stellar envelopes at temperatures higher than $2.5\ 10^6$ K. In fact, in main-sequence stars, Li only survives in the outer 2 to 3% (in mass) of the stars, its surface abundance depending on the depth of the convective envelope in this phase, itself depending mainly on the effective temperature and metallicity of the star. Observations in main-sequence stars generally show that the abundance of Li correlates strongly with the effective temperature, in the sense of lower abundance for decreasing temperature (from F to G-K dwarfs). But, if phenomena as semiconvection, diffusion or mass loss are also active in this phase, the surface Li abundance will be reduced even more, either by exposing Li to energetic protons, or by removing it from the star. During the ascent of the red giant branch, the convective mixing (first dredge-up) dilutes the surviving Li with Li-free material from the interior. After this process, the expected surface abundance of Li is at most 1/30 of the initial abundance in the stars, that value depending on the initial mass of the star.

In general, the observations of red giants are not in agreement with the theoretical predictions: either the Li abundance is higher than predicted, as is the case for some G-K giants (Brown

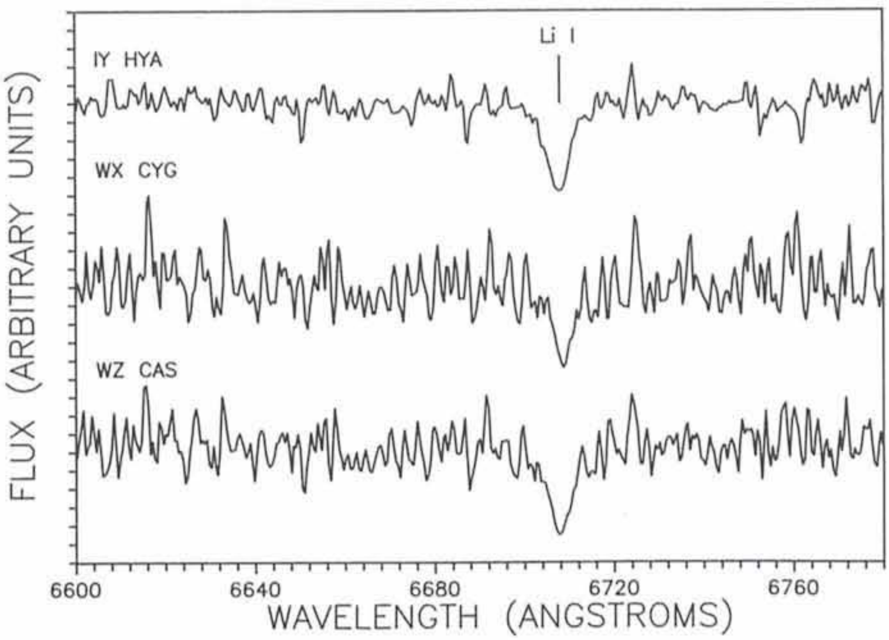

Figure 1: *Spectra of three super Li-rich C stars obtained at the La Palma Observatory. The peculiar nature of IY Hya was discovered in the course of this programme.*

et al. 1989) and for weak G-band stars, or, in the majority of giants, it is lower. In AGB stars, the successive dredge-up episodes will still decrease the Li abundance at the surface of those stars. As an example, Kipper and Wallerstein (1990) found a mean value of log N(Li)≈− 0.5 for a sample of SC stars.

However, the existence of AGB stars with Li abundance higher than 1.5 (Boesgaard, 1970) shows that things are not so simple. More surprisingly are the few AGB – either S or C stars – showing Li abundances about two orders of magnitude higher (Boesgaard, 1970) than the cosmic log N(Li) = 3.1 abundance. This enormous abundance of Li (log N(Li) ≈ 5) is an evidence that those peculiar AGB stars, called super Li-rich stars, might produce this element in their interiors. Different models have been proposed to explain this fact, the majority of them being based on the idea of Cameron and Fowler (1971): under certain circumstances, which remain to be defined and modelled, some of the ^{3}He present in the envelope could be injected into ^{4}He-rich zones. If the temperature of these zones exceed 4 10^7 K, some of this ^{3}He is transformed into ^{7}Be. The ^{7}Be will then capture an electron to give ^{7}Li, but this must occur after ^{7}Be has been transported by convection to regions where the temperature is such that the reaction $^7\mathrm{Li}(p, \alpha)^4\mathrm{He}$ is slow enough for Li not to be completely destroyed. The application of this mechanism to AGB has been proposed by Scalo and Ulrich (1973): they assume that, as a consequence of thermal pulses, the convective envelope penetrates into the He-burning shell. In that case ^{3}He might be transformed in ^{7}Be and this isotope, by convective mixing, transported to cooler and outer regions where the $^7\mathrm{Be}(e^-,\nu)^7\mathrm{Li}$ can occur. After a certain number of pulses, the star becomes enriched in Li.

Another possible scenario (Sackmann et al., 1974) is the hot-bottom burning: some hot nuclear burning at the base of the convective envelope can induce surface enrichment of Li, following the same sequence of reactions as quoted above. Although both models are able to produce Li in the proportions which are observed in super Li-rich stars, these models, however, lack the required self-consistency concerning the treatment of the concomitant nucleosynthesis and convection. Also, mass loss, which is very important in those stars, has not been included in those calculations.

As we see, theory is not yet really able to explain the existence of super Li-rich stars. Improved models are thus required which should satisfy those observational constraints. In the same way, new observations should be done to try to better define those constraints.

Observations

We have started a programme of observations of Li in a large sample of C stars, both at ESO and at the observatories of La Palma and Calar Alto (Spain). Our aims are twofold: First, we want to determine the abundance of Li in each star C/O ratios, mass loss . . . This is why we have preferentially devoted ourselves to study stars from the catalogue of Claussen et al. (1987) which has the property of being a homogeneous flux-limited sample of galactic C-stars and which gives some characteristics of the stars. Secondly, we hope to discover new super Li-rich stars, as well as to determine the real percentage of such stars among C stars and, if possible, what other peculiar characteristics those stars share.

The observations at La Silla were made using the CES on the 1.4-m CAT, with an RCA CCD. The spectral range covered was about λλ 6680–6739 Å and the resolving power was 45,000, giving a resolution of 0.15 Å. This wavelength range gives access to the Li I doublet line at λ 6707.8 Å, as well as to the Ca I line at λ 6717.7 Å. At La Palma, the observations were made with the 2.5-m INT with CCD. The spectral range observed was 280 Å around the Li I, doublet and the resolution was 0.45 Å. At Calar Alto, we used the 3.5-m telescope with the double spectrograph and a CCD. The resolution achieved was about 0.4 Å. For most of the spectra, the S/N ratio was higher than 100.

Until now, about 80 stars were observed at La Silla, 120 at La Palma and 80 at Calar Alto. In Figure 1, we show the spectra taken at La Palma of 3 super Li-rich C stars, one of which was discovered in the course of this programme (IY Hya). The very large line of Li is clearly visible. For comparison, we show in Figure 2 the spectrum of another C star, V Aql, which has a much weaker Li line. Note the higher resolution of this spectrum, which was obtained at La Silla.

Determination of the Lithium Abundance

As clearly shown by Gustafsson (1989), the analysis of cool stars such as C stars is one of the most difficult things to accomplish in spectroscopy. This is mainly due to the fact that model atmospheres of C stars are highly sensitive to composition, that the spectra of those stars are overcrowded by atomic and molecular lines, preventing a good determination of the continuum, and that the parameters of stars (effective temperature, gravities, microturbulence, CNO abundances, . . .) are generally not well known.

This means that if one wants to achieve the best determination of the Li abundance in C stars, synthetic spectra are really necessary. We calculate those synthetic spectra in the LTE approximation, using a grid of models of atmospheres for C stars of Gustafsson et al. (private communication). This grid contains models in T_{eff} from 2500–3000 K in steps of 100 K, log g = 0.0 and solar metallicity ([Fe/H] = 0). For a given effec-

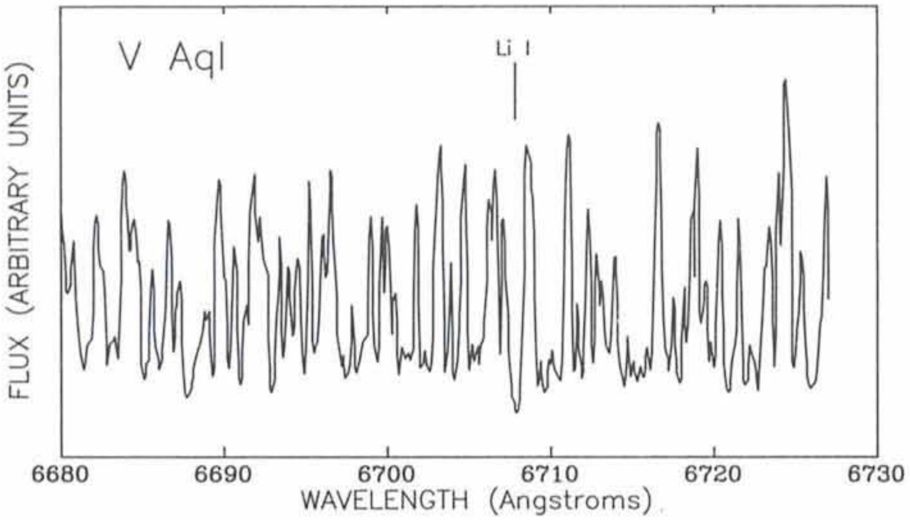

Figure 2: *Spectrum of the C star V Aql taken at La Silla with the CAT. The equivalent width of the lithium line, calculated by integrating the synthetic spectrum, is 300 mÅ. This seems to imply an abundance larger than expected from the standard theory of nucleosynthesis in AGB.*

tive temperature there are also several models with different values of the ratios C/N/O. The spectral region synthesized is between 6685 and 6725 Å. This spectral region contains the doublet of Al I at λλ 6696–6698 Å and the Ca I line at λ 6718 Å. The theoretical fit to these lines was used as an indicator of the metallicity of our stars although it is expected that the metallicity of these intermediate mass stars does not differ too much from the solar one. Neither Al nor Ca are expected to be destroyed in the atmospheres of the AGB stars, thus [Al, Ca/Fe] ≈ 0.0 must be true in our stars. This is verified in galactic stars, at least until [Fe/H] = −0.5.

When possible, we derive the effective temperature from the J-K index. Otherwise, its determination is done from the spectral appearance itself. The uncertainty in the temperature is therefore of the order of 200 K, but this does not bring a very large error in the Li abundance determination. The adopted gravity is log g = 0.0 and the microturbulence is generally taken as 3 km s^{-1}. The major problem in the derivation of the Li abundance is in fact the knowledge of the C, N and O abundances. A few studies have been made in some C stars (see Gustafsson, 1989), but unfortunately the errors are as large as 0.25 dex. This allows a very large range of variation. As the model atmospheres are very sensitive to those abundances, this is the largest uncertainty in our derived Li abundance. Indeed, in the wavelength range we use, a variation of 0.05 dex in the C abundance does not give any noticeable differences in the spectrum, except for the Li line, so that another value of the Li abundance is needed to fit the observed spectrum. As a matter of fact, a change of 0.05 dex in the C abundance induces a variation of 0.3 dex in the Li abundance. We are therefore obliged to admit that our error in the Li abundance must be about 0.5 dex, when all the sources of uncertainty are taken into account. This seems to be the best one can do presently. Indeed, Kipper and Wallerstein (1990), in their study of Li in SC stars, obtained a comparable error.

We show in Figure 3 the observed spectrum of WZ Cas, as well as the synthetic spectrum we find as the best fit. One can see that, even if there is a relatively good agreement, not all of the lines are well fitted. We think that this is mainly due to a lack of accuracy in the atomic and molecular data. The derived Li abundance for this star is log N(Li) = 5.3 ± 0.3. More quantitative results will be published soon in *Astronomy and Astrophysics.*

Chemical Evolution of the Galaxy

In addition to the consequences for nucleosynthesis and stellar evolution, the fact that some AGB stars have such extreme abundances of Li is perhaps more important by their implications on the galactic evolution of the Li abundance. Although there is still a great debate on that subject, it is often claimed that the pregalactic (i.e. from the Big-Bang) abundance of Li was about log N(Li) ≈ 2.1. This fact seems to be confirmed by the observed Li abundance in very metal-poor (unevolved) F-stars of the galactic halo. Since the actually observed maximum Li abundance (in the interstellar medium and in pre-main-sequence stars) is log N(Li) ≈ 3.1, it is evident that a mechanism of Li production, complementary to the Big Bang, is required to explain this increase of the Li abundance in the course of the life of the Galaxy.

Several models of chemical evolution of the Galaxy have shown that, if one takes into account the astration, the well-known galactic mechanism for Li production (i.e. the bombardment of He and CNO nuclei by galactic cosmic rays in the interstellar medium) is not enough to explain such an increase in the abundance of Li from the pre-galactic value (see e.g. Reeves et al. [1990] for a wider discussion on the topic). The proposed mechanisms are of stellar origin: novae, supernovae or red giant stars, but until now only the red giant stars (AGB C stars) are firm candidates. In fact, they are the only objects in which there is a clear observational evidence of stellar Li production.

Furthermore, an inspection of a compilation of Li abundances in unevolved stars suggests how the abundance may have grown with the metallicity: log N(Li) ≈ 2.1 at [Fe/H] ≤ −1, log N(Li) ≈ 2.3 at [Fe/H] ≈ −0.5, to log N(Li) ≈ 3.1 at the present time (near solar metallicity). This behaviour with metallicity suggests a continuous and slow increase of the Li abundance in the galaxy. This fact is more compatible with the AGB evolutionary lifetimes than with those of the pre-SN II or novae. Given the usually long characteristic time for the appearance of the nova phenomenon, a sudden increase of the Li abundance at late epochs in the life of the galaxy would be expected. On the other hand, in the supernova scenario, one would expect the opposite: i.e. a strong increase of the Li abundance at very early epochs. Neither of these facts are observed.

However, even in the AGB stars Li production scenario, there are still many questions to be answered: Will all the AGB stars become super Li-rich stars, or is it rather a random phenomenon? In the former case, what is the range in stellar mass for Li production? What is the amount of Li produced and what

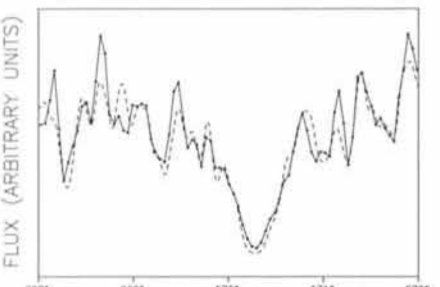

Figure 3: *Best fit (dashed line) to the observed spectrum (solid line) of WZ Cas. The derived Li abundance is log N(Li) = 5.3. The equivalent width computed with the synthetic spectrum is 4 Å.*

percentage of it really survives and is ejected into the interstellar medium? What is the characteristic life-time for AGB stars' Li production scenario? These and others are some of the questions we would like to answer with our observational and theoretical studies of Li in AGB stars.

Acknowledgements

It is a pleasure to thank B. Gustafsson and K. Ericksson for providing us the stellar models of C stars. HB is Boursier I.R.S.I.A. and CA is partially supported by an FPI of the MEC of Spain.

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Saturn's Bright Spot

O. Hainaut, ESO

A very large, white spot has recently appeared on the giant planet Saturn. It is probably a great storm in the planet's atmosphere, which has been initiated by upwelling of clouds from the lower layers into the uppermost regions. The spot began as a small, white feature in Saturn's northern hemisphere and has since developed rapidly so that it now appears to completely encircle the planet's equatorial regions. "Great White Spots" have been seen on Saturn in 1876, 1903, 1933 and 1960 (see below), but the present one seems to be the biggest of them all.

At this moment Saturn is situated in the southern constellation of Sagittarius and is therefore best observed with southern telescopes. It has been monitored at the ESO La Silla Observatory since early October. Most of the observations have been made with the ESO NTT (both EFOSC 2 and EMMI) and later, with the ESO/MPI 2.2-m telescope.

As Saturn is a very bright object, the main problem was to avoid saturation of the CCD. This was solved by using very short exposure times and/or narrow-band filters. Table 1 gives the observational data. Isophotal contours have been plotted, and transferred to the coordinates system of Saturn (using a perspective scale grid as described in [1]). As this planet has a strong differential rotation (the period varies from 10 hrs 10 min to 10 hrs 50 min, depending on the latitude), the longitude definition is not an easy problem. The "System I" [2] was chosen; it is fixed to the equatorial belt, and its period of rotation is 10 hrs 14 min. As the spot is located in that region, this system is rather well suited. The longitudes were taken from the Astronomical Almanac 1990 [3].

For each image, the isophotes of the region of latitude between −30° and +30° are plotted in Figure 1. The limbs of the planet and the position of the rings are also indicated. Saturn presents an important limb darkening, which affects of course also the spot's isophotes. This effect has not been corrected. The visual observations reported in the IAU telegrams (# 5109, 5111 and 5115) are also plotted.

Development of the Spot

The new phenomenon was first reported on September 25, 1990 by astronomers at the Las Cruces Observatory in New Mexico, USA, as a white spot at northern latitude +12°. It was watched by many amateur astronomers in various countries as it slowly grew in size to about 20,000 km on October 2. Further observations determined the spot's rotation period to about 10 hrs 17 min, that is somewhat slower than the surrounding atmosphere.

During the next days the spot became longer and longer and by October 10, its length was approximately half of Saturn's visible diameter. After that it continued to expand and on exposures made at ESO from October 23 onwards it encircles the entire planet as a bright equatorial band. At the same time, several new intensively bright spots have been sighted inside the larger feature; they are now being followed with great interest. There is no indication yet that the phenomenon has started to fade away.

Earlier Spots

New spots on Saturn are not so common: only a few dozens have been observed from the Earth during the past 200 years and only about ten of them were enough contrasted and lasted long enough to give good positional measurements [4]. Most of them were quite small (5000 to 15,000 km), brown,

TABLE 1: *Selected Observations*

Date	Hour (UT)	Telescope	Instrument	Filter	Exp. time
10 01	22:49	*			
10 02	19:36	*			
10 03	05:44	*			
10 04	02:18	*			
10 08	00:00	NTT	EFOSC2	U	0.5s
10 10	02:40	NTT	EFOSC2	U	0.5s
10 16	00:00	NTT	EMMI-B	HeII	1s
10 17	00:04	NTT	EMMI-B	HeII	1s
10 19	02:47	NTT	EMMI-R	SII	1s
10 21	00:00	2.2-m	Adapt.	NU	15s
10 21	23:45	2.2-m	Adapt.	NU	10s
10 23	00:01	2.2-m	Adapt.	NU	10s

Comments: * Visual observation reported in IAU Circulars. – U: Johnson filter. – HeII: Narrow band around 4686 Å. – SII: Narrow band centred around 6732 Å. – NU: Narrow band centred around 3875 Å.

yellow or white, and they lasted for only a few rotations of the planet. Sometimes a spot may last several weeks or even more [5] [6]. The largest ovals are much smaller than those of Jupiter [7]. Most of the oval spots of Saturn are anticyclonic regions, only a few are cyclonic [7].

Four of the earlier spots are referred to as "Great White Spots", but none appears to have approached the enormous size of the present spot. We are therefore witnessing a very rare event.

The first known Great White Spot was detected in December 1876 by American astronomer Asaph Hall in Washington D.C. and the next one was found in June 1903 by E.E. Barnard with the 40-inch refractor at Yerkes Observatory, near Williams Bay, Wisconsin. The third and fourth were both found by eagle-eyed amateurs; in August 1933 by Will Hay in England, and in March 1960 by J.H. Botham in South Africa. All of these spots were seen in the northern hemisphere of Saturn: those in 1876 and 1933 at about the same latitude as the present one, while the two others were further north at +40° (1903) and +58° (1960).

What is a "Great White Spot"?

Detailed observations of the giant planets Jupiter and Saturn have been made since the invention of the astronomical telescope in the early 17th century. The "meteorological" studies of their atmospheres took a great stride forward during the flybys of the Pioneer and Voyager spacecraft, from which accurate measurements were made at close distance.

It has long been known that the "surface" of Jupiter shows many more bands and whirls than that of Saturn; this is now explained by the presence in the Saturnian atmosphere of a high layer of aerosols (small solid particles) and haze (liquid drops) which hide the view of the patterns of streams and turbulence below.

The five Great White Spots have appeared with amazing regularity, about once every thirty years, that is with the same period as the orbital revolution around the Sun. Moreover, these spots have all developed near the moment of Saturnian "mid-summer" in the northern hemisphere, when the insolation (amount of solar energy received) is the greatest possible here. It is therefore obvious that the emergence of large spots in the north must be triggered by some mechanism that is related to heating of the atmosphere.

Most planetary astronomers agree that the Great White Spots are upwellings from the lower atmosphere, where-

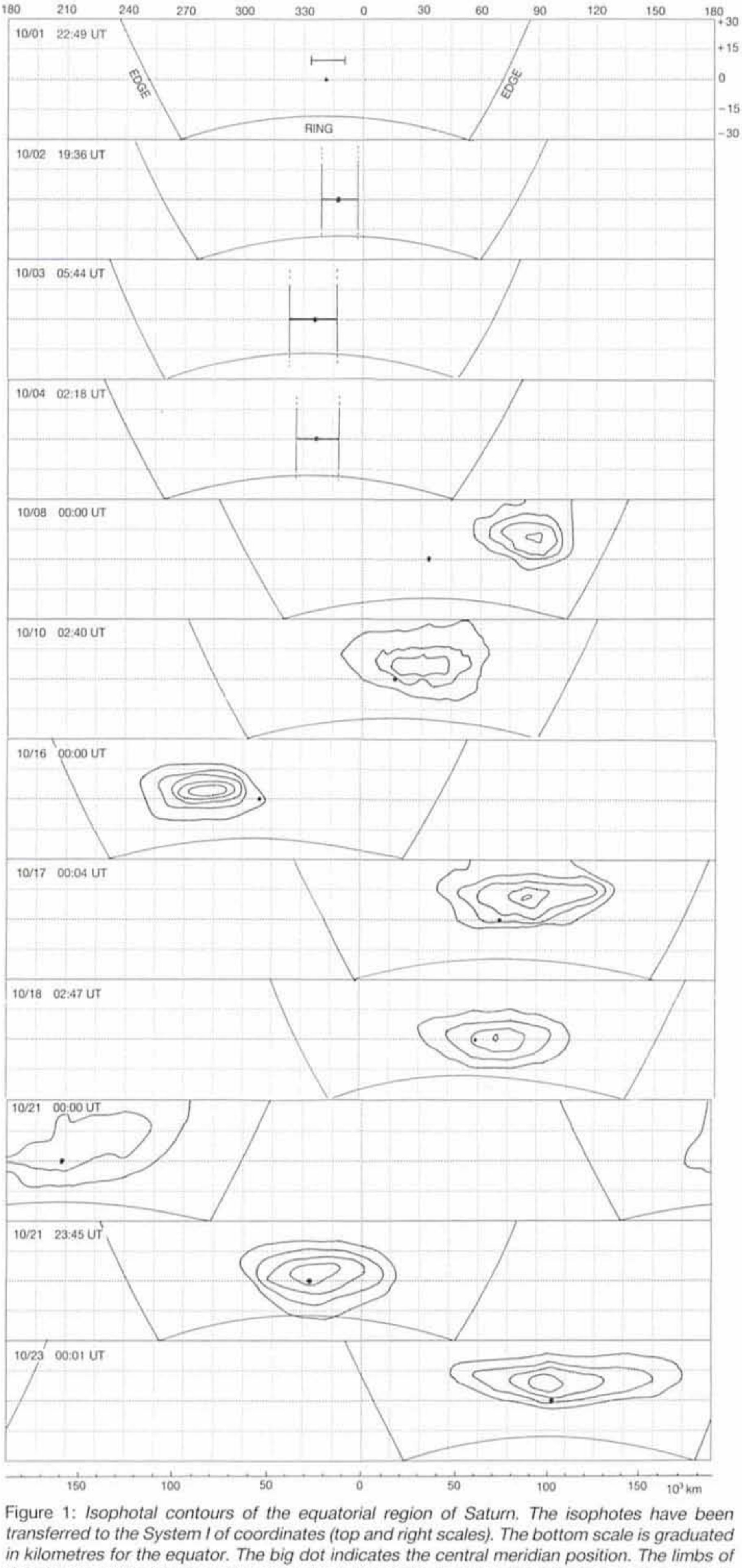

Figure 1: *Isophotal contours of the equatorial region of Saturn. The isophotes have been transferred to the System I of coordinates (top and right scales). The bottom scale is graduated in kilometres for the equator. The big dot indicates the central meridian position. The limbs of the planet and the position of the rings have been indicated. The typical seeing was around 1", or 7500 km close to the sub Earth point.*

by large clouds move upwards and become visible when they penetrate the uppermost, hazy layers. They resemble the towering cumulonimbus clouds often seen in the Earth's atmosphere. However, the lifting mechanism is not yet known; one possibility is that their upward motion is due to the release of heat by water condensation, perhaps in combination with strong updrafts from sublimating ammonia grains.

The spots become longer as the clouds are carried along by strong winds in the upper atmosphere. Eddies and whirl patterns undoubtedly develop because ot the different wind velocities at different latitudes, but due to their smaller size they are very difficult to observe from the Earth. This may imply that the spots, perhaps in particular those which have emerged more recently, are actually gigantic storm centres, just like the Giant Red Spot on Jupiter, that has now been visible for almost 400 years.

Since the Great White Spots on Saturn last much shorter, in the past cases at the most a few months, it will now be very interesting to follow the new one during some time to learn exactly how it disappears. Observations are therefore continuing at ESO as well as at other observatories.

Acknowledgements

I'm very grateful to S. D'Odorico, who took the EMMI images, and to A. Gemmo and A. Iovino, who kindly agreed to give me some of their observing time at the 2.2-m telescope.

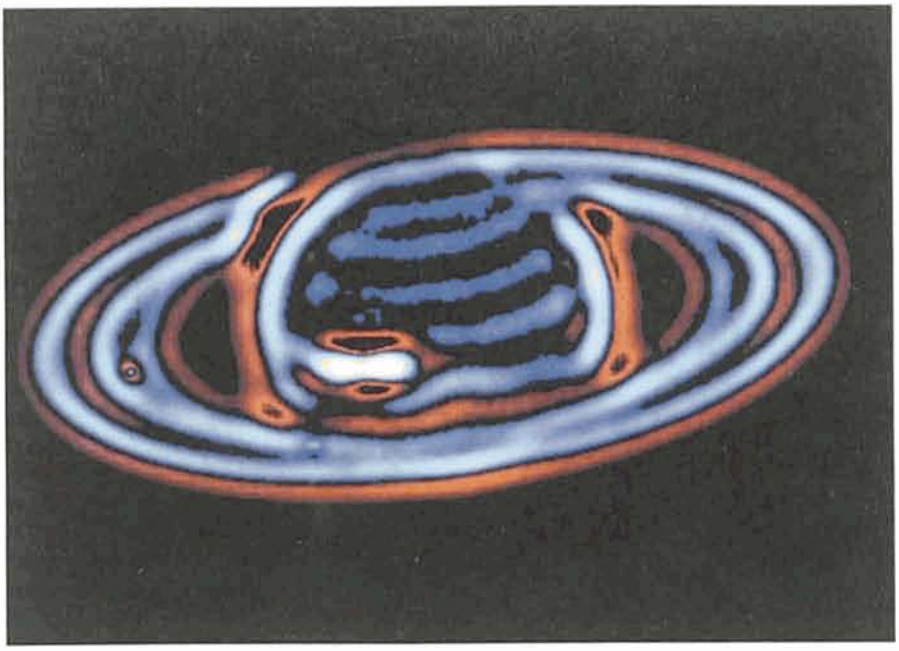

Figure 2: *This picture of Saturn and the Giant White Spot was obtained with the ESO New Technology Telescope on October 16, 1990 at UT 0 hrs 0 min. It is a 1-sec exposure through a 6-nm-wide filter, centred in the blue spectral region at 468 nm. North is approximately up and East is to the left. The seeing conditions were mediocre (~ 1.1 arcsecond), and the false-colour reproduction shown here has been subjected to computer processing by D. Baade at the ESO Headquarters, according to an advanced algorithm, developed by L. Lucy; this has resulted in a sharpening to about 0.4 arcseconds. To "flatten" the image, the original image was subtracted from the "sharpened", so that even small details become well visible. On this date the spot had a double structure, it extended to the equator and had already grown significantly in length. The various atmospheric bands are also well visible.*

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NEWS ON ESO INSTRUMENTATION

EMMI Through the Last Tests Before Entering Regular Use

At the end of September 1990, a new HP A900 computer dedicated to the control of instruments and to data acquisition was installed at the NTT. It is linked to the existing A900 which continues to take care of the telescope and the adaptor operation. Following this installation, the EMMI control software was further debugged and tested. The user interface was installed for the first time: it is based on a new concept and makes use of different menus and forms displayed on the RAMTEK and selected via a mouse. The overall control system performed in a reliable way but a number of improvements to make the system more robust and easier to use were suggested by the first observers and will be implemented early in 1991. Some 14 nights and days were intensively used for technical and astronomical tests and for training of the technical and astronomy staff of La Silla.

In addition to the observing modes described in the September issue of the *Messenger* (No. 61, p. 51) two new ones were successfully tested: the high-resolution echelle in the red arm (resolving power 28,000 with 1 arcsec slit) and the on-line slit punching device. The installation of the echelle requires the dismounting of the standard grating unit, an operation which takes a few hours and has to be planned in advance. The slit punching machine (PUMA3) is mounted on a x-y table in the instrument itself. Thin plates can be inserted in the different positions of the aperture wheel (up to 4 available) and slits of 7.5 × 1.2 arsec can be punched on the plates at positions measured on a direct image taken earlier with the same instrument.

The quality of the data obtained in both modes appears excellent. We will report on the detailed results with this configuration in the forthcoming issue of the *Messenger*.

On November 10, EMMI entered regular use by visiting astronomers.

H. DEKKER and S. D'ODORICO, ESO

Who Needs Nebular Filtres?

Bruce Balick, University of Washington, is interested in soliciting an order for interference filters in imaging and spectroscopy (for order separation) of galactic nebulae. These filters are quite expensive, but significant discounts can be obtained if multiple filters are ordered together. It is suggested that interested parties contact Bruce Balick directly at the following address: Astronomy FM-20, University of Washington, Seattle WA 98195, USA (Bitnet: BALICK@UWAPHAST).

A New Low Limit in the Read-Out Noise of ESO CCDs

In the framework of the EMMI tuning before it started regular operation, a special effort was made last October to optimize the read-out noise of the two 1024^2 pixels, Thomson TH31156 CCDs now in operation at the red and blue arm of the instrument with two ESO-built VME-based controllers. Due to higher tolerances in the line voltage at La Silla the main power suppliers of the CCD controllers had to be modified to suppress pick-up noise. Further adjustment of the CCD clock's timing further improved the rejection of spurious noise.

It was finally possible to reach at the telescope values around 3 e$^-$/pix rms in both the blue- and the red-arm CCDs. This is the lowest instrumental noise ever achieved at ESO and a wide range of astronomical observations (essentially those which are not source or sky photon noise limited) will benefit from the improvement.

S. D'ODORICO and R. REISS, ESO

Results on the Testing of Ford Aerospace and Tektronix CCDs

In the second half of 1990, two new types of CCDs were tested in the detector laboratory in Garching. ESO received 6 2048^2-front-illuminated CCDs from Ford Aerospace (15-micron pixels). The actual testing was carried out in collaboration by ESO staff and Martin Roth of the Munich University Observatory. The best devices of the lot have QE curves typical of thick devices with a peak value of 42% at 700 nm and read-out noise of about 10 e$^-$ without any optimization effort. They have also 3–4 hot columns or major traps. Test of three additional devices delivered by Ford is going on with a view to select one CCD for astronomical tests at the telescope in 1991. In relation to the introduction of the large CCDs at the telescope, an upgraded software on the CCD controllers has also been tested. It makes possible to freely define windows of interests in the CCD image. Undesired pixels are skipped already during CCD read-out and therefore the read and transfer time is reduced. A windowed format, when possible, also makes the use of the IHAP data reduction system much faster.

ESO has also received three back-illuminated 512^2-Tektronix CCDs with 27-micron pixels. These CCDs are of very good cosmetic quality and of high efficiency over the useful spectral range (40% at 400 nm, 60% at 600 nm and 10% at 1000 nm). A read-out noise of 13 e$^-$ has been measured in the first laboratory tests. The La Silla staff is currently preparing the installation of one of these CCDs at the CASPEC spectrograph.

S. DEIRIES, S. D'ODORICO and R. REISS, ESO

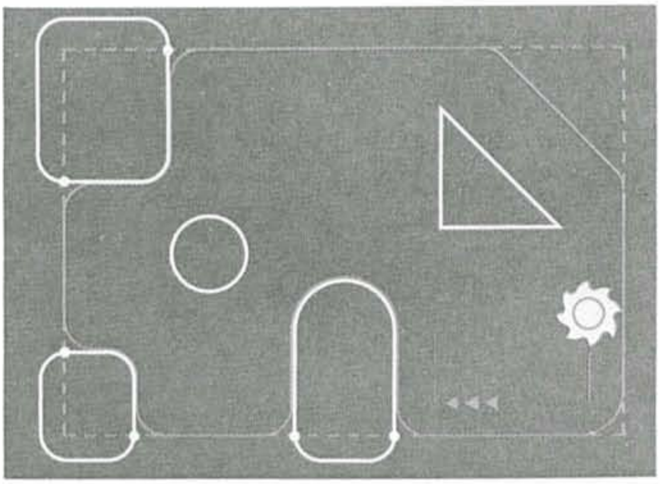
Celestial Mechanics

S.A. BALON, ESO

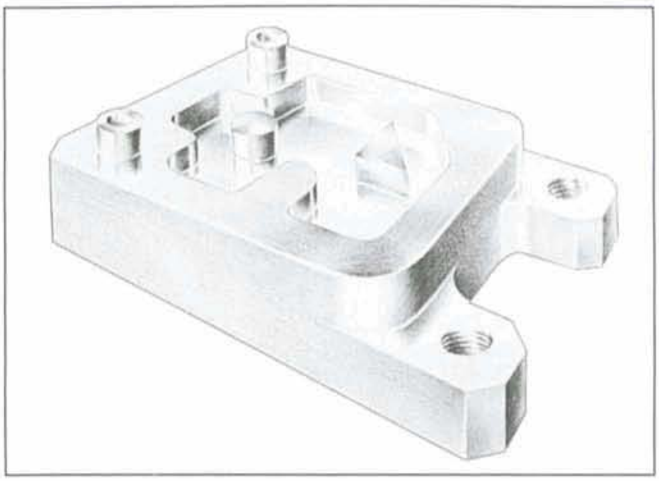
At the beginning of this year I had the pleasure of installing the first Mikron milling computerized machine in the Astroworkshop on La Silla.

We had already made Optopus plates with this machine for a long time in the mechanical workshop at Garching Headquarters (see *The Messenger* No. 31, March 1983, and No. 43, March 1986), and during the long period of testing the machine has demonstrated its good qualities.

After having received our instructions, the personnel at the Astroworkshop on La Silla is now able to take over this work from us. According to G. Avila who



Milling cycles for variable contour pockets.



follows closely the functioning of Optopus, the results continue to be as impressive as before.

At the mechanical workshop in Garching we obviously had to replace the previous machine with a new Mikron in order to ensure compatibility and permit the possibility of an exchange of programmes between Garching and La Silla. As the mechanical workshop in Garching has only one milling machine, we have chosen one with a greater capacity than the previous one, which allows us displacements by 700 mm in X, 500 mm in Y and 500 mm in Z, thus enabling the manufacture of larger parts. The capabilities of this Mikron WF51D "TNC 355" machine are identical to its predecessor with a few new features:

- Programme input during machining
- Programming of chamfers
- Helical interpolation (enabling manufacture of larger diameter, external or internal screw threads)
- The standard cycles which already existed are retained (Heidenhain) but we have cycles unique to Mikron
- Milling of pockets with varied contours allowing us to retain the islands
- Scaling factor 0 to 100 enabling us to enlarge or reduce the forms or figures of geometrically identical holes.
- The control enlarges or reduces shapes or drilling patterns of similar geometry by a scaling factor.
- Shifts from point zero, but also coordinates system rotation, a feature which did not exist on the previous machine. If the milling or drilling patterns are repeated at shifted positions, there is no need for reprogramming, you only specify the offset. If a milling or drilling pattern is rotated on a circular arc, you programme a coordinate system rotation.
- Programme test: programming assurance through test run without machine movement

Jöran Ramberg (1906–1990)

Already in 1933, Jöran Ramberg joined as Research Assistant the newly established Stockholm Observatory in Saltsjöbaden – at the time an institution under the Royal Swedish Academy of Sciences. He remained at the Observatory at different posts – from 1948 as Associate Professor and from 1960 as Professor – until 1963, when he took up duty as Assistant Director of the European Southern Observatory. In 1968, he became the Technical Director of ESO and remained in this position until his retirement in 1971. Through this, Ramberg very actively contributed to the first development of ESO.

Jöran Ramberg's research in astronomy mainly dealt with the structure of the Milky Way system. The method he used is based on the determination of the distances of stars through a combination of spectral analysis and photometry. As both the observing and the data reduction were very time consuming, Ramberg's work had to be limited to deep surveys (as far as the telescopes in Saltsjöbaden could reach) in selected areas. In his thesis, Ramberg controlled and calibrated this method by observing the two nearby star clusters, the *Hyades* and *Praesepe*.

As a side-result, he discovered two white dwarf stars in the Hyades. This was the first time that these extremely compact objects, which represent the end phase of the development of a star, had been found in a star cluster – a discovery important in determining the ages of these stars. The deep surveys also required observations from the Southern Hemisphere; these were made at the Harvard Observatory Branch in Bloemfontein in South Africa. Ramberg's investigations reached a distance of 6000 light-years and are still unsurpassed. They showed that the stars, also those at a relatively high age, are strongly concentrated to the spiral arms that are lined up of gas and dust in the Milky Way. This result is remarkable because it cannot be fully explained by existing theories for the origin of spiral arms in rotating stellar systems.

All of us who have had the pleasure of knowing Jöran Ramberg as friend and colleague, have admired his untiring energy and deep engagement, his meticulousness in both research and instrument construction, and his self-sacrificing work making astronomy and its achievements known to the public. We have always enjoyed his perfect readiness to share his knowledge and his experience. His demise leaves big emptiness behind.

P. O. LINDBLAD

- Programme checking with graphics, simulation of the machining:
  - (a) display of blank
  - (b) views in three planes
  - (c) plan view with depth display
  - (d) 3D view
  - (e) magnify.

The Mikron machines on La Silla and Garching have demonstrated excellent performance and this has enabled us to manufacture not only the Optopus but also to participate in the manufacture of "EMMI", the extraordinary instrument mechanically designed by H. Kotzlowski and described by S. D'Odorico (see *The Messenger* No. 61, September 1990) and with which R. Buettinghaus and myself have been working for almost one and a half years in the Garching Mechanical Workshop.

As the dawn of the VLT approaches, we are well equipped to deal with the instrumentation of tomorrow.

News About Adaptive Optics

After the successful initial test of the adaptive optics prototype system on the 3.6-m telescope (see *The Messenger* No. 60), a second test run was performed from September 26 to October 2, 1990. The aim of this run was to test two improved Shack-Hartmann wavefront sensor configurations, a sensor for the visible wavelength range, equipped with an electron bombarded CCD (EB-CCD), and an infrared wavefront sensor.

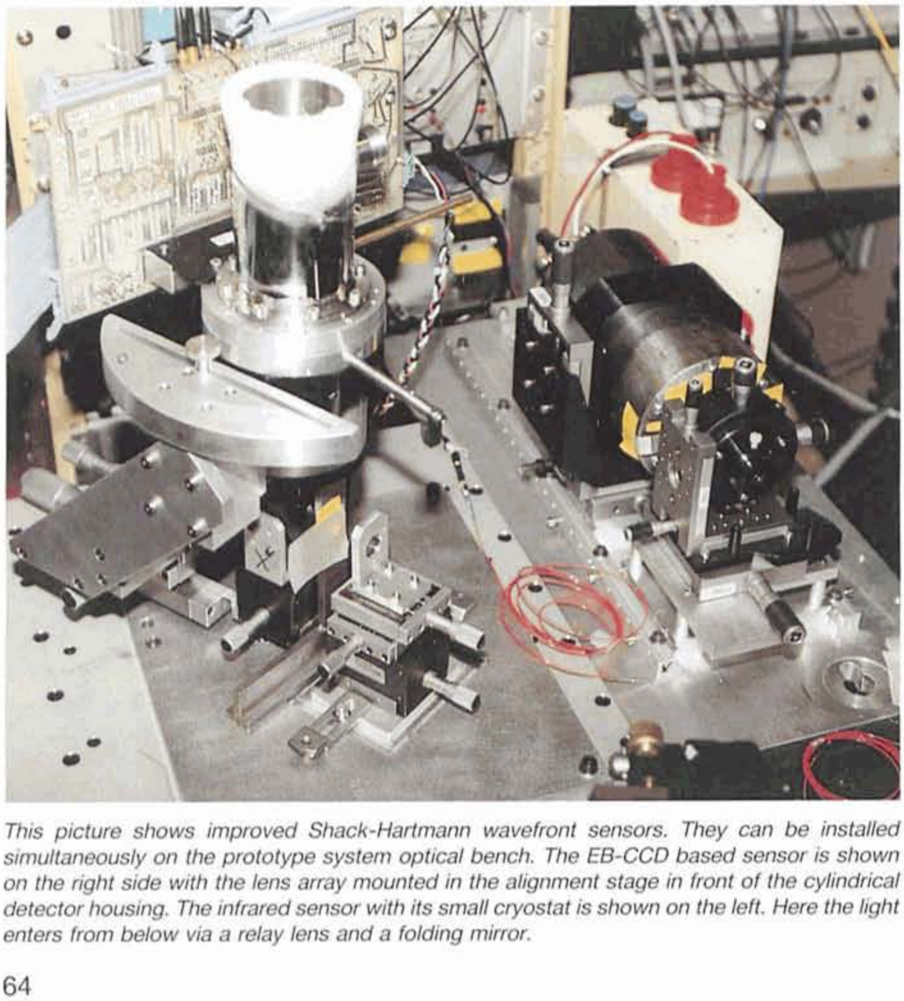
The EB-CCD sensor was developed by the Observatoire de Paris. The EB-CCD, which is still in a prototype phase, was manufactured by LEP (Philips) in France and allowed to push the limiting magnitude for wavefront sensing in the visible to approximately $m_v = 11.5$, a substantial gain compared to the old sensor which was based on an intensified Reticon and only reached $m_v = 8.5$. The new sensor appears to be quantum noise limited.

In a second test an infrared wavefront sensor was applied to the adaptive system. This sensor was built by the Observatoire de Paris and LETI-LIR in Grenoble, where the 64 by 64 InSb detector array has been developed with a readout noise of 450 electrons. Although the system transmission was not yet fully optimized, the servo system, locked on a star of $m_K = 2.5$, offers very good prospects for the future. For this sensor, the limiting magnitude still has to be determined, but it has already proven to be suitable in the closed-loop system.

The above-mentioned test run was aimed at purely technical features and fine-tuning of the prototype system. A science-devoted run with the adaptive optics system followed from October 24 to November 5. For the first time, 6 nights have been exclusively devoted to the scientific exploration of adaptive optics. The set-up and activation of the system has now become a nearly routine operation, and for the team of astronomers from Observatoire de Paris-Meudon it was possible to concentrate fully on the science aspects of their observations.

A second similar science-devoted run is planned for January 1991 before the system will undergo a major upgrade. In early 1992 it will be available again with a deformable mirror with approximately 50 actuators and an increased bandwidth of 25 Hz to possibly 40 Hz (at 0 dB). This will allow diffraction-limited observations at the 3.6-m telescope in the K-Band and possibly the H-band with good seeing. Although it will still be a prototype, we will attempt to make it more "user-friendly". It may then be offered to the ESO community in late 1992 for a limited number of programmes.

F. MERKLE, ESO
F. RIGAUT, Observatoire de Meudon



This picture shows improved Shack-Hartmann wavefront sensors. They can be installed simultaneously on the prototype system optical bench. The EB-CCD based sensor is shown on the right side with the lens array mounted in the alignment stage in front of the cylindrical detector housing. The infrared sensor with its small cryostat is shown on the left. Here the light enters from below via a relay lens and a folding mirror.

MIDAS Memo

ESO Image Processing Group

1. Application Developments – Graphics

The MIDAS graphics package has been subject to a number of questions during the course of this year. Although in principle one can obtain all important information from the MIDAS User Guide (Volume A, Chapter 6), we would like to summarize here briefly the available functionality.

The MIDAS graphics sub-system enables you to visualize (plot) all data structures in MIDAS: frames, tables, descriptors and keywords. To do so, obviously named plot and overplot commands have been implemented. In general these commands have a well defined syntax.

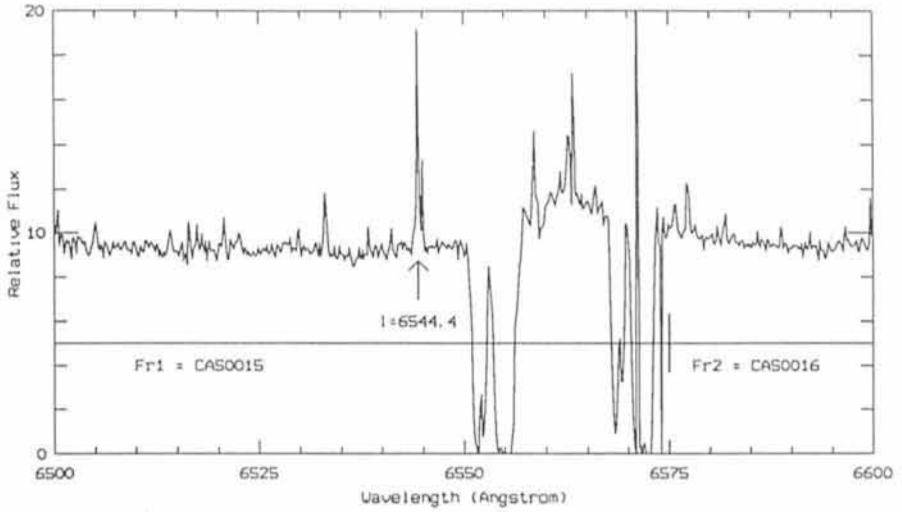
To retrieve e.g. pixel intensities or coordinates from plotted data or to examine spectral features the user can run the general GET/GCURSOR command. The graphics cursor is also used in several other applications like flux determination, computing the centre of spectral lines, line identifications, etc.

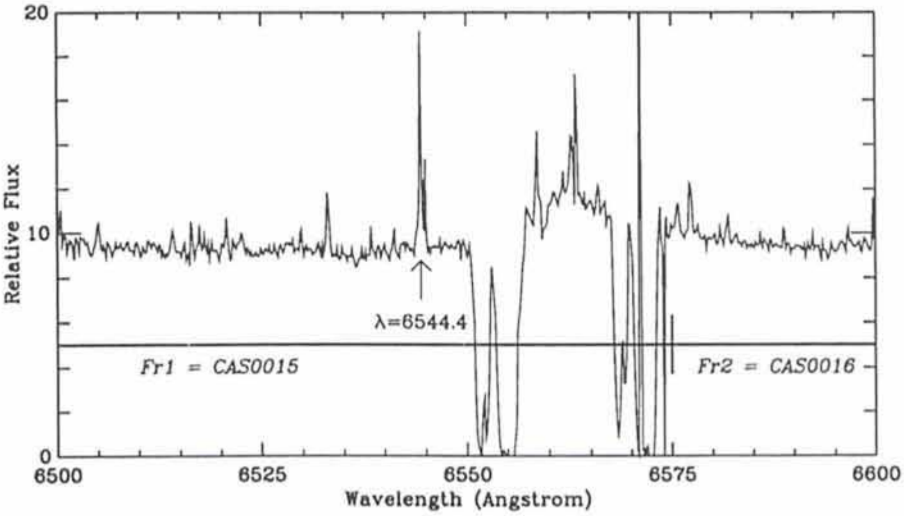
The graphics system uses default settings which in most cases make sense. These plot settings include: axes labelling and format, line width and type, symbol size and type and many others. All these setting parameters are stored in the MIDAS system and can be inspected and changed using the command SHOW/PLOT and SET/PLOT, respectively. The user can also specify how nice the graphics output should look. This layout is determined by the SET/PLOT parameter PMODE. It can vary between rather simple (PMODE = 0 or 1) or more elaborate to produce a high quality (PMODE = 3).

The graphics system is primarily designed for off-line data reduction. However, a number of general purpose commands for drawing axes, lines, symbols and text, combined with the PMODE = 3 setting, make the system very suitable for the production of publication quality plots. On this page, as an example, you see two versions of the same plot produced with PMODE = 1 and PMODE = 3.

Graphics output can be assigned and sent to all display and hardcopy devices. With the command ASSIGN/PLOT the user can determine the output device in advance. The command SEND/PLOT sends the graphics output file (if created) to any of the supported graphics devices. A list of all graphics devices supported can be found in the MIDAS User Guide. Of particular interest is the possibility of producing MIDAS graphics on PostScript printers. Besides the increase in quality the postscript graphics file can also be combined with other postscript documents. This offers the possibility of full integration of the MIDAS graphics output into postscript documents typeset by e.g. TEX or LATEX.

Like all systems, MIDAS is not perfect. Regularly new features and commands are implemented. In order to stay up to date about MIDAS it is useful to read the MIDAS NEWS frequently (also experienced users) and to have a glance at every newly issued MIDAS manual. But this is obvious . . ., we hope.





2. Archiving

Systematic Archiving of NTT data will start from the beginning of Period 46. This means that NTT data will be available directly from Garching, to the observing team only during the proprietary period of one year, and to other astronomers after this period. The delay for availability at Garching will normally not exceed three weeks after observation.

The summary of each observation will be stored in the Archive Catalogue as soon as possible after the observation, normally during the day or at least during the week following the observation. It will be possible to query the Archive Catalogue directly from La Silla, using the Starcat programme installed on a Sun workstation. It is expected that the observer will check the contents of this catalogue during his observation run, and report the anomalies and errors he detected to the *archeso* account at La Silla or at Garching. Note that Starcat can also be used from La Silla to get information about many other astronomical catalogues, including 25 million stars in the Guide Star Catalogue.

3. Personnel

The Image Processing Group deeply regrets to announce that Susan Winter (Lively) has left us for the south of France due to personal reasons. Susan has been handling the MIDAS documentation and distribution ensuring that everything ran smoothly. Her knowledge of TEX and LATEX made it possible for us to maintain nice looking manuals written in good English. She not only took care of the manuals, but also of the technical editing of the Proceedings of the Data Analysis Workshops. We will miss Susan not only for her technical skills but also as a good colleague and we wish her all the best.

4. MIDAS Hot-Line Service

The following MIDAS support services can be used to obtain help quickly when problems arise:

- EARN: MIDAS@DGAESO51
- SPAN: ESO::MIDAS
- FAX.: +49-89-3202362, attn.: MIDAS HOT-LINE
- Tlx.: 528 282 22 eso d, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

Users are also invited to send us any suggestions or comments. Although we do provide a telephone service we ask users to use it only in urgent cases. To make it easier for us to process the requests properly we ask you, when possible, to submit requests in written form through either electronic networks, telefax or telex.

Comet Levy Detected by SEST

A. Winnberg, SEST, ESO

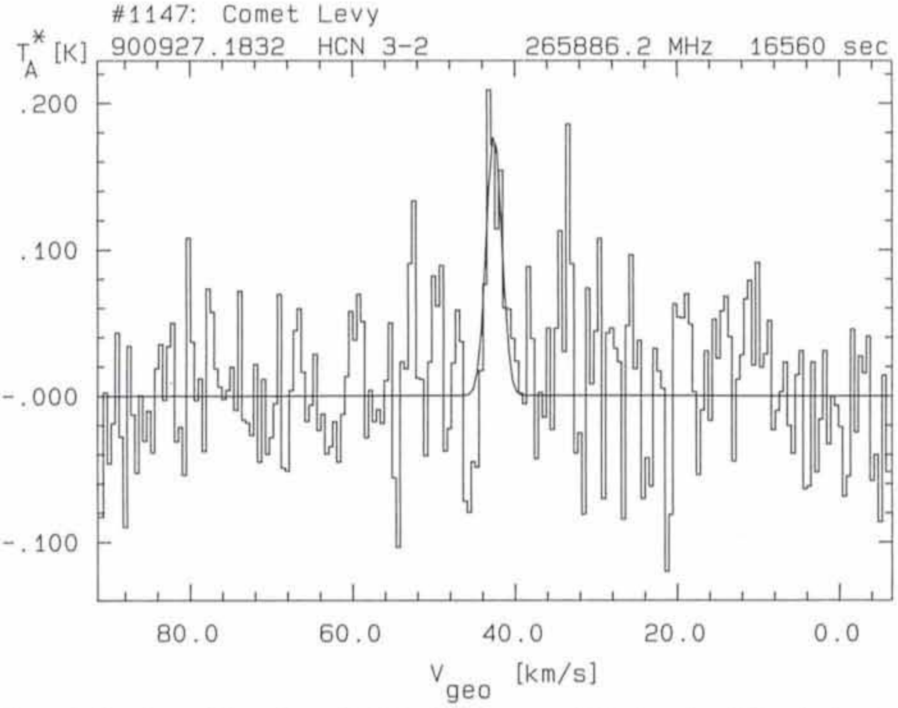


Figure 1: *Spectrum of Comet Levy (1990c) at a frequency of 266 GHz (λ = 1.13 mm) showing the rotational line J = 3–2 of hydrogen cyanide (HCN). The frequency scale has been converted into radial velocity relative to the centre of the earth. The intensity scale is in units of antenna temperature corrected for atmospheric absorption. A gaussian curve has been fitted to the line profile. HCN is believed to be one of the many compounds which are evaporated directly from the surface of the nucleus. Further out in the coma, HCN is photo-dissociated and it is probably the main source of the cyanide radical CN.*

On September 27 the Swedish-ESO Submillimetre Telescope (SEST) tracked Comet Levy (1990c). Its receiver system was tuned to 266 GHz (λ = 1.13 mm) where there is a spectral line of hydrogen cyanide (HCN) created by a transition between the third and second rotational energy levels. The result after an integration time of 4.6 hours is shown in Figure 1.

The spectrum was registered by the acousto-optical spectrometer and its attached on-line computer. The frequency scale has been converted into radial velocity relative to the centre of the earth. At the time of observation the comet was at a distance of 1.1 astronomical units and was receeding from the earth at a speed of 42 km/s heading for its perihelion. The intensity scale is in units of antenna temperature corrected for atmospheric absorption. A gaussian curve has been fitted to the observed line profile. Its amplitude of 0.18 K corresponds to roughly 7×10^{-26} W/m^2/Hz in physical units. Its width is about 2 km/s which reflects a gas expansion velocity of the order of 1 km/s.

Radio spectroscopy of comets is important because it can give us information about the composition of the nucleus. When the solar radiation heats up the surface, the so-called "parent molecules" evaporate and expand from the nucleus. Further out they are eventually dissociated by the solar UV radiation and the resulting atoms and radicals are later ionized. All these secondary species radiate in the near infrared, in the visual, and in the UV regions of the electromagnetic spectrum. The parent molecules, however, radiate only in the millimetre and submillimetre ranges because this gas is extremely cold (approx. 30 K) due to adiabatic expansion. This central "parental cloud" also is quite small (approx. 100 km) which makes its emission difficult to detect.

HCN is probably the main parent molecule of the radical CN, which emits very strong bands in optical cometary

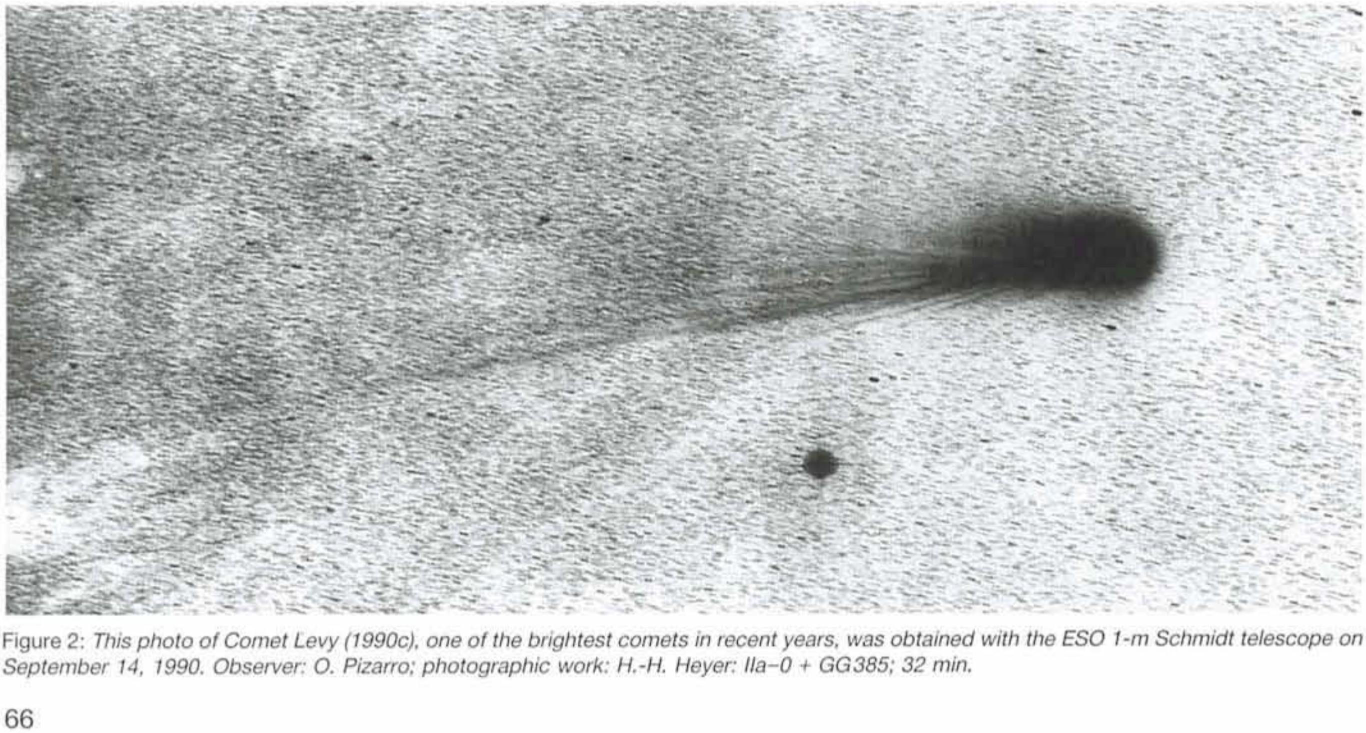


Figure 2: *This photo of Comet Levy (1990c), one of the brightest comets in recent years, was obtained with the ESO 1-m Schmidt telescope on September 14, 1990. Observer: O. Pizarro; photographic work: H.-H. Heyer: IIa-0 + GG385; 32 min.*

spectra. The J = J–0 rotational line of HCN was claimed to be detected for the first time in Comet Kohoutek (1973 XII) by Huebner, Snyder, and Buhl. However, this detection could not be confirmed by any other group and subsequent searches in other comets were unsuccessful. The line was unambiguously detected in Comet P/Halley by three observing groups using three different radio telescopes in 1985–86. (Bockelée-Morvan et al., Schloerb et al.; Winnberg et al.). The J = 3–2 line of HCN (the J = 2–1 line lies at a frequency with strong atmospheric oxygen absorption) was then detected earlier this year in Comet Austin by a French and an American group. The present observation is the first successful detection of a comet by SEST and it has been confirmed by two other telescopes. Let us hope that SEST can continue to contribute to cometary spectroscopy.

Change at the ESO Schmidt Telescope

After a period of nearly 20 years in charge of the ESO Schmidt telescope, and after the successful completion of the taking of plates for the ESO Southern Surveys, *Hans-Emil Schuster* will hand over the reins to *Bo Reipurth*, staff astronomer at La Silla. Dr. Reipurth will take up his new operational responsibilities as of January 1, 1991, so please direct all Schmidt-related questions, enquiries, etc. to him after this date.

Announcement of the 3rd ESO/ST-ECF

Data Analysis Workshop

ESO, Karl-Schwarzschild-Str. 2
Garching, Germany

April 22–24, 1991

The aim of the Workshop is to provide a forum for discussions of astronomical software techniques and algorithms. It is held annually during the spring (April/May) and centres on a different astronomical area each time. Due to available space, participation will be limited to 80 people. At the last Workshop several people could not be accommodated and we therefore recommend that you send in the corresponding participation and accommodation forms well before the deadline.

The topic for the 1991 Data Analysis Workshop will be analysis of direct imaging data. The scientific section of the meeting will consist of three sessions each starting with a main talk followed by presentation of papers of 5–10 minutes duration. The last day is reserved for general user meetings for MIDAS and ST-ECF.

The tentative agenda is:

Analysis of Direct Imaging Data

April 22: 14.00–18.00: Digital Filters
April 23: 9.00–12.30: Image Restoration
14.00–17.00: Decomposition techniques
17.00–18.00: European FITS Committee
April 24: 09.00–12.00: MIDAS user's meeting
12.00–13.00: European FITS Committee
14.00–17.30: ST-ECF user's meeting

Contributions on algorithms and techniques, e.g. removal of cosmic ray events on CCD's, digital transformations, deconvolution, decomposition of images and fitting techniques are especially welcome. We encourage people to present their work in these areas even if it is only ideas. After each introductory talk, we will have a more informal discussion where such contributions can be made. We also plan to have a poster session where people can present short contributions. Proceedings of the scientific sessions will be published.

The scientific organizing committee includes:

P. Grosbøl (Chairman)
L.B. Lucy
D. Baade
P. Benvenuti
S. D'Odorico
R.H. Warmels

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(continued from page 2)

Interestingly, in terms of atmospheric stability La Silla was found to be better than previously thought, with a measured median "seeing" of 0.76 arcsec. Paranal is better with a mean of 0.66 arcseconds, but of even greater importance is the fact that the number of clear nights of exceptional quality (seeing better than 0.5 arcsecond) is about 2.4 times higher on Paranal (16% of all nights) than on La Silla (7%).

The atmospheric conditions on Paranal will allow the VLT to take full advantage of its unique imaging and spectroscopic capabilities so that fainter and more distant objects can be observed than with any other telescope in the world. Moreover, when the VLT is supported by "adaptive optics", it will produce images that are almost as sharp as if it were in space. In the "interferometric" mode, when the light from the four 8.2-m telescopes is combined coherently (in the same phase), the resolving power of the VLT is further increased, so that even finer details can be seen. Under optimal circumstances, it should be possible to achieve a resolution of 0.0005 arcseconds. This would correspond to imaging 1 metre objects on the surface of the Moon.

Because of the extremely low atmospheric water vapour content in the Paranal region, probably the driest area on the surface of the Earth, this site is also highly suited for astronomical observations in the infrared and submillimetre wavelength regions.

The decision to place the VLT Observatory at Paranal implies that some years from now ESO will operate two, geographically separate observatories in Chile. In order to ensure the optimal functioning of both units, it will be necessary to adjust ESO's set-up in Chile.

The efficient running of the La Silla Observatory, on which so many European astronomers are dependent, will of course continue to have high priority, but it is expected that a certain streamlining will have to be made of the operations there.

The next step in the VLT programme will be to decide about the exact configuration of the four 8.2-metre telescopes and their enclosures. Several major contracts will be signed with European industry during the coming year, for instance for the construction of the mechanical structure of the giant telescopes and also the buildings which will be erected on Paranal. *The Editor*

In its session on December 4, 1990, Council elected Professor Franco Pacini (Florence) as new President and Mr. Henrik Grage (Copenhagen) as Vice-President.

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgiu ted by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where fourteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. The 3.5-m New Technology Telescope (NTT) has recently become operational and a giant telescope (VLT=Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.

The ESO MESSENGER is published four times a year: normally in March, June, September and December. ESO also publishes Conference Proceedings, Preprints, Technical Notes and other material connected to its activities. Press Releases inform the media about particular events. For further information, contact the ESO Information Service at the following address:

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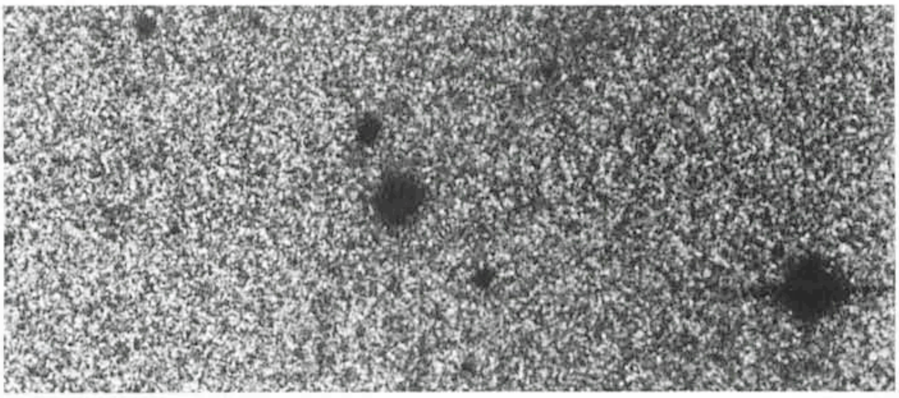

Brightest QSO in the South!

Right at the beginning of the "Bright Quasar" Key Programme, the Hamburg Quasar group discovered the brightest QSO in the southern sky. Already in the first 12 fields covered with the ESO Schmidt objective prism plates for this purpose, Lutz Wisotzki by computer search identified the B = 13.8 mag object at the centre of the photo as a highly probable QSO. Observations at the end of November 1990 with the 1.52-m telescope at La Silla confirmed the discovery. The redshift is z = 0.09. It is also the brightest QSO ever found by optical means.

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