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SEST – the First Year of Operation

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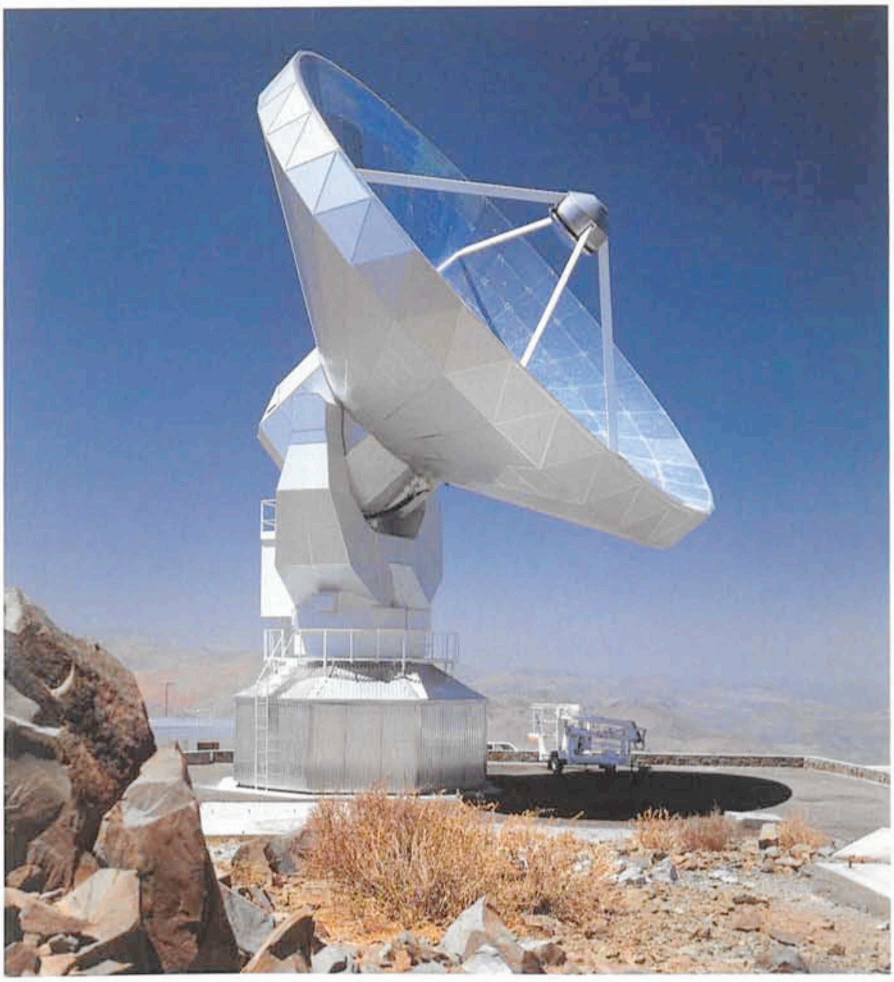
The Swedish-ESO Submillimetre Telescope (SEST) completed one full year of scheduled observations at the end of March this year. Its performance has surprised and delighted many – its trouble-free operation and the clear skies of La Silla combining to effect large volumes of data. Few users of SEST have returned home disappointed. That the telescope has filled an important need is seen clearly in the demand for observing time: its over-subscription, averaged over the year and over ESO and Swedish users, amounted to a factor of about 2.5. This issue of the *Messenger* is devoted in part to summaries of work done with the new telescope. Some of the work described is already published but most is still undergoing analysis; we are grateful to those people who have written the summaries and to those who have provided data prior to publication.



The Swedish-ESO Sub-millimetre Telescope (SEST).

The Telescope and Observing System

Most visitors to La Silla are now familiar with SEST, or at least with its highly reflective surface which often provides a remarkable splash of reflected sunlight from the southern end of the telescope ridge. The telescope has been discussed earlier in these pages (Booth, de Jonge and Shaver, 1987) and a more detailed technical description of the antenna and its observing system has recently appeared in *Astronomy and Astrophysics* (Booth et al., 1989). Here we remind you that SEST is a joint project, funded and operated on a 50/50 basis by the Swedish Natural Science Research Council (NFR) and ESO at a total cost of DM 9.8 M (August 1987). A separate Nordic agreement entitles Finland to 10% of the Swedish time. The 15-m Cassegrain antenna was designed by engineers of the Institut de Radio Astronomie Millimétrique (IRAM) and built under their supervision by French and German industry. It is similar to the telescopes which form the IRAM interferometer on Plateau de Bure and in some ways has become the operational prototype of those antennas. SEST is operated by a dedicated group of seven engineers/astronomers, supplemented by other ESO staff. General (technical) management of the project is in the hands of Onsala Space Observatory, under the direction of Roy Booth with Peter Shaver representing ESO on behalf of the Director General.

The telescope was handed over to the SEST team on March 13, 1987 and it is a tribute to the readiness and enthusiasm of everyone involved that "first light" was obtained just eleven days later with the detection of the 86 GHz SiO maser in Orion. There then followed a one-year commissioning phase during which the telescope and first receivers were thoroughly tested, the surface adjustment refined and a pointing model established. At the end of this period, experienced millimetre astronomers from the European community were invited to make observations with the system and provide suggestions for improvements. Scheduled observations began on April 1, 1988.

The telescope/receiver situation has remained essentially unchanged throughout this first operational phase and the salient parameters of the system are shown in Table 1. Painstaking direct (theodolite) measurements of the reflector surface by Albert Greve, assisted by Lars Johansson, have resulted in an adjustment of its profile to within some 70 micron rms of the best paraboloid. This probably represents the best which can be obtained using the direct technique, accuracy being limited by the errors of measurement of the radial distances to the surface targets sighted by the theodolite. Further improvements in the surface accuracy await holographic measurements which are referred to later.

The pointing accuracy remains of the order 3 arcsec rms on each axis, falling slightly short of the design specification of 2 arcsec. Blind pointing is characterized by systematic offsets of about 10 arcsec radially but these are stable at the arcsec level over time-scales of hours. Although the most likely cause of these offsets is thermal, no clear pattern is evident. Because of the highly reflecting surface, the telescope has been constrained to never point closer than 60° to the sun.

The SEST receivers were built at Onsala Space Observatory, Department of Radio and Space Science, Chalmers University of Technology, Sweden, and the acousto-optic spectrometers (AOS) were built by the millimetre astronomy group of the University of Cologne. The receivers were designed with the possibility of remote observing in mind and therefore incorporate a remote tuning capability, operated via a simple menu-driven interface. It has proved to be extremely efficient and fool-proof, and most visiting astronomers can tune the receivers without calling in the telescope staff.

Some improvements have been made to the receivers during the year. The receiver bandwidth has been increased and now a full 500 MHz is available in both channels. Also the tuning range of the 230 GHz receiver, previously limited by the lack of a local oscillator multiplier at the high frequency end of the band, now extends to 260 GHz, although its noise temperature is high at this frequency. Further improvements in progress are the substitution of the current intermediate frequency amplifiers, which use field effect transistors, to units employing high electron mobility transistors (HEMT), which will reduce the total system noise.

The first year of SEST operations has been remarkably trouble-free and less than 10% of the scheduled observing time has been lost, even including time lost because of bad weather. Scheduled maintenance amounted to 17 hours a week on average, and even with one full month in October/November entirely devoted to maintenance and development, about 75% of the total time was used for observations. Remember, this means some 18 hours a day averaged over the whole year for a radio telescope. The telescope has thus proven to be highly efficient and a large amount of high quality data has been produced. We attribute this in part to the combination of good telescope, receivers and site but most visitors will also agree that the enthusiastic and willing staff at SEST contributed more than a little to this performance.

Problems

Although SEST has been very successful, it has not been without its problems. Ironically, although the system involves much advanced technology, the most serious loss of time has been caused by the failure of light bulbs – specifically those in the positional encoders. The first incident of this kind occurred only a few days before the first scheduled project, when a bulb failed in the incremental elevation encoder. Such failures require the complete replacement of the encoder; in this case replacement was achieved and a new pointing model determined just in time for the observations to start. A more

TABLE 1: *SEST system (status by May 1989).*

Antenna		
Surface accuracy	≃ 0.07 mm (rms)	
Radial pointing accuracy (incl. systematic offsets)	4″ (rms)	
Main beam efficiency	0.71	(115 GHz)
	0.50	(230 GHz)
FHPBW	44″	(115 GHz)
	23″	(230 GHz)
Receivers (dual polarization Schottky mixers)		
Receiver temperatures	240–500 K	(70–120 GHz)
	600–1200 K	(210–260 GHz)
Backends (split mode available)		
High resolution AOS	100 MHz	2048 channels
Low resolution AOS	1 GHz	1728 channels
Possible observing modes		
Total power	up to 60 MHz	
Frequency switching	12′ (wide)	
Beam switching (single, dual)	3′ (narrow)	
Load switching		
Sky switching		

SEST and its control building.

serious incident occurred in July when a similar failure resulted in the replacement encoder being inadvertently bolted down too tightly. This resulted in a 60″ offset in elevation, the sign of which depended on position relative to transit. These offsets were not immediately associated with the encoder change and it took some time to track down the problem. This failure accounts for the major loss of observing time. Further problems have occurred in the compressors which drive the receiver coolers and in the 230 GHz receiver local oscillator multipliers, but these have caused only minor hold-ups.

Observations

Observations with SEST have covered a wide range of subjects with molecular line studies of galaxies dominating, particularly if we include the SEST key project to map the CO distribution in the Magellanic Clouds. As the sensitivity of millimetre telescopes has improved, the volume of the universe available to molecular line observation has increased dramatically and CO has been detected in galaxies with redshifts, z, greater than 0.15. The current record with SEST is $z = 0.09$. The large molecular mass of these high-luminosity infrared galaxies and the possible evolutionary link of these merging systems with quasars is of great interest.

In the nearest system of galaxies important results are also emerging as SEST observations confirm earlier suggestions that the $CO : H_2$ ratio is less than that in the Milky Way by a factor of about 5, probably as a result of the difference in metallicity. An additional result of some interest is the low level of $C^{18}O$ in the LMC.

The other major areas of molecular line research have been well represented in the SEST observational programme. Observations of regions of star formation have resulted in the discovery of many new bipolar flows, some of them associated with spectacular optical indicators of jets and bow shocks. Systematic work on evolved stars is providing better statistics on the chemistry and physics of the stellar envelopes and a data base of molecular properties of evolved stars detected by IRAS should highlight interesting targets for ISO observations.

Finally, a small percentage of time has been devoted to continuum observations. These have concentrated in the main on quasars and AGNs, to extend spectral data and to search for variability. A group from the Max-Planck-Institut für Radioastronomie, however, installed a 1-mm bolometer on SEST in August 1988 and observed interstellar dust and emission from early stars. They also detected emission from SNR 1987 A using this system.

The Staff

At the beginning of 1987, the operation of SEST was carried out by a team comprising two software scientists, two microwave engineers and a telescope scientist as team leader. A digital engineer joined the team in May and later replaced one of the microwave engineers, called back to Sweden to lead the receiver development group. The team was finally brought up to strength by an assistant astronomer and an ESO fellow. The assistant astronomer is funded by Onsala Space Observatory or, occasionally, by the Finnish Academy of Science. All members of the original SEST team were on two/three-year contracts in Chile and by June 1989 they had all been replaced. However, most of them now have positions at Onsala and help to form a knowledgeable SEST liaison group at the observatory. The new team has been built up over a period so that a high level of expertise has been maintained. Table 2 gives a summary of the staff situation at SEST.

The SEST team is basically divided into two shifts, each shift working alternate standard ESO schedules from Tuesday to Tuesday. Holiday and sickness permitting, each shift comprises an astronomer, a receiver engineer and a software specialist. No operators are provided at SEST, the observing system having been designed for easy operation by the astronomer, which has been very successful. Since operations are conducted around the clock, introductions to the system, usually performed by the telescope scientist or ESO astronomer, have to occupy some observing time, but since the system is rather user-friendly, little time is lost.

Future Developments

The SEST team is continuously working to improve the observing system, to simplify and streamline it. A menu-driven interface for the control system is almost complete, the receiver tuning software has been improved and an on-line data reduction system is now in operation. In addition, an alarm system to warn the staff of the more serious malfunctions is in operation and undergoing further development. More internal memory, as well as extra disk space, has been installed on the HP A 900. New software makes it possible to use both wide and narrow band AOS's simultaneously (both in split mode if required), and they may be centred at different frequencies or velocities.

Table 2: *Positions at SEST.*

Telescope Scientist (NFR)	
L. Johansson	Jan 87–June 89
L.-Å. Nyman	July 89–
Astronomer (ESO)	
R. Gredel	Jan 88–
Astronomer (NFR, Finnish Academy)	
M. Lainela	July 87–Dec 87
G. Rydbeck	Jan 88–June 88
B. Höglund	July 88–Dec 88
L.-Å. Nyman	Jan 89–June 89
P. Friberg	July 89–Dec 89
Software Scientist (ESO)	
D.M. Murphy	June 86–June 88
M. Olberg	June 86–April 89
G. Persson	May 88–
R.F. Engineer (NFR)	
M. Hagström	Aug 86–Mars 89
N. Whyborn	Jan 87–May 88
L.-G. Gunnarsson	Jan 89–
Electronic Engineer (NFR)	
G. Delgado	May 87–
Electronic Engineer (ESO)	
M. Anciaux	July 89–
Coopérant (ESO)	
J.-M. Martin	Feb 89–

Recently, more effort has been devoted to reaching the specified reflector surface accuracy. Near-field holography measurements have been tried using a 100 GHz transmitter on the building of the 3.6-m telescope, but the small distance to SEST required that we made an impossibly large map. In addition, holographic observations of the 38 GHz beacon on the Lincoln Labs satellite, LES-8, have been attempted with limited success, but some extra software has to be written before such observations can be conducted properly. We hope that more holography can be carried out in the autumn.

Future receivers for SEST include a 350 GHz SIS receiver, currently under development at Onsala, and we now have funding for a bolometer receiver. We hope that an MPI system can be obtained; discussions to this end are going on with Ernst Kreysa, its designer, and with the MPI directorate. Other projected developments are the replacement of the Schottky diode mixers by superconducting (SIS) mixers and the development of multi-beam receivers. Finally, with the recent successes in millimetre VLBI and the fine maps that will soon appear, we are keen to procure a VLBI recorder and a hydrogen maser for SEST.

Acknowledgements

Many people have contributed to the success of SEST. We are grateful for the continued interest and assistance given by IRAM and thank particularly Albert Greve and Dave Morris who have worked with SEST staff on reflector surface measurements. In this context we also wish to record our gratitude to the Lincoln Labs team under Dr. W. Ward and to Al Richard for this painstaking attention to the satellite control.

The millimetre group of the University of Cologne have maintained a keen interest in the performance of the spectrometers and we thank them also.

The MPI bolometer group not only used their system to obtain some good astronomical results but they wrote a comprehensive report on the telescope performance which has resulted in an improved lateral adjustment mechanism for the sub-reflector. We are grateful for their interest and hard work.

Finally, we wish to express our gratitude to the SEST personnel, to all the staff of ESO both in Chile and Garching who have been called upon to make allowances for this group of 24-hour all-weather radio astronomers and to the staff at Onsala Space Observatory who have provided a professional operating base for the project.

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High-Mass Star Formation

J. MELNICK, ESO

1. Introduction

Massive stars seem to be formed in two different, and indeed quite extreme regimes: a very low-efficiency process (typically less than 1 %) associated with the formation of expanding OB associations, and a much higher efficiency mode (the *starburst* mode) that leads to the formation of bound clusters (Lada, 1985). Clearly, large numbers of massive stars can only form at the density peaks of very massive molecular clouds, while loose OB associations tend to form at the edges of clouds.

Massive star formation is contagious. Both modes of star formation are related to propagatory phenomena. In the case of OB associations, the propagating agents are probably either shock waves associated with the expansion of H II regions (Elmegreen and Lada, 1977), or the collective action of sequential supernova explosions (McCray and Kafatos, 1987).

Very young starbursts are often embedded in very large regions of active star formation called superassociations (Melnick, 1987) and there is ample observational evidence that massive star formation also propagates at the scales of superassociations (hundreds of parsecs). The propagating agents at these scales seem related to stellar winds and supernova explosions (Elmegreen, 1985).

A wealth of information about starburst activity comes from the study of giant extragalactic H II regions. Energetic considerations indicate that the ionizing clusters of these high excitation nebulae must contain hundreds to thousands of very massive stars which must have formed on time scales comparable to the dynamic time scales of the clusters (Melnick, 1987). For this reason, starbursts are also called *violent star-forming regions.* Here I will use both terms indiscriminately.

Since correlations of the form *mass* $\sim \sigma^4$ *and size* $\sim \sigma^2$, *where* σ is the velocity dispersion, are observed both in giant molecular clouds and in giant H II regions (Melnick 1987 and references therein; Solomon et al. 1987), the time scale argument implies that violent star formation must be very efficient. Otherwise the progenitors of starburst clusters would be too large and the free-fall

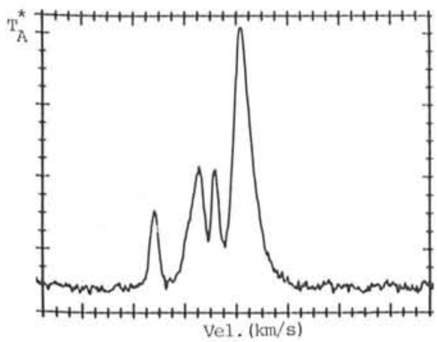

Figure 1: *^{12}CO (1–0) spectrum of the position of RCW 38 E. Maximum antenna temperature is 28° K and the velocity span of the figure is 60 km s^{-1}. (Courtesy of Malcolm Fridlund.)*

collapse times would be longer than the life times of the ionizing stars.

These considerations suggest there must be some physical mechanism to induce giant clouds to undergo free-fall collapse and to form massive stars very efficiently. Elmegreen (1985) suggests that free-fall collapse may be induced by large over-pressures created by expanding stellar wind and supernova bubbles. Silk (1985) postulates that the formation of massive stars inhibits the formation of low-mass stars, but stimulates the formation of more high-mass stars. The feedback of energy from the stars to the interstellar medium, according to Silk, enhances the star-formation rate and efficiency. It is not clear, however, whether this feedback mechanism can work in starbursts where the time scales for massive star formation are very short.

Cloud-cloud collisions have often been invoked as triggering mechanism for massive star formation (e.g. Scoville et al. 1986), but very few detailed calculations have been published so far. Clearly, if this mechanism works, collisions between large clouds could give rise to propagating formation of large clusters of coeval stars.

An attractive speculation is that instead of mechanically, starbursts may be induced chemically. Changes in the chemistry can conceivably alter the cooling function of the molecular gas and therefore reduce the internal pressure. A potentially effective mechanism to generate such changes has been suggested by Roland Gredel from the SEST team. Gredel suggests that very intense cosmic ray fluxes – as would be expected, for example, near multiple supernova explosions – could induce dramatic changes in the chemistry of molecular clouds. It is not easy to predict without detailed calculations, however, if this would lead to an increase or to a decrease of the temperature of the cloud, but clearly supernova-driven chemistry perturbations can be very contagious.

Many of the best cosmic laboratories to investigate the physics of massive star formation are in the southern hemisphere and SEST provides a much needed tool to access these laboratories. Some of the first SEST observations of southern massive star-formation regions are reviewed below.

2. The First Year of SEST

During the first year of operation, SEST was used by several groups to investigate regions of massive star formation both in the Galaxy and in external galaxies. Many groups observed molecular clouds in galaxies of many different types ranging from ellipticals to dwarfs. An account of these observations is beyond the scope of this review, except to note that observations of CO in galaxies show that starbursts are generally located at the edges of massive molecular cloud complexes. This reflects the contagious nature of massive star formation, and indicates that starburst activity is probably not triggered by cloud-cloud collisions.

Detailed studies of Galactic regions of massive star formation were done by A. Pagani and M. Heydari-Malayeri, by M. Fridlund, and by Lars Johansson and myself during the first year of SEST. I should mention that the succinct overview of the observations presented below is based on a preliminary analysis of the data.

Pagani and Heydari-Malayeri observed molecular clouds associated with expanding H II regions. These observations should lead to a better understanding of the formation of OB associations. Through the study of molecules of different isotopes, they should be able to place observational constraints on the physics of sequential star formation.

Fridlund mapped a sample of molecular clouds showing signs of massive star formation. He found that one of these clouds, RCW 38, an H II region in Vela, is one of the most luminous CO and HCO^+ sources in the Galaxy. The H II region is ionized by a cluster of OB stars located on the edge of the molecular cloud, a recurring signature. An interesting feature of the molecular cloud is the complex structure of the line profile (reproduced in Fig. 1) which is interpreted by Fridlund as evidence of gas flows in the

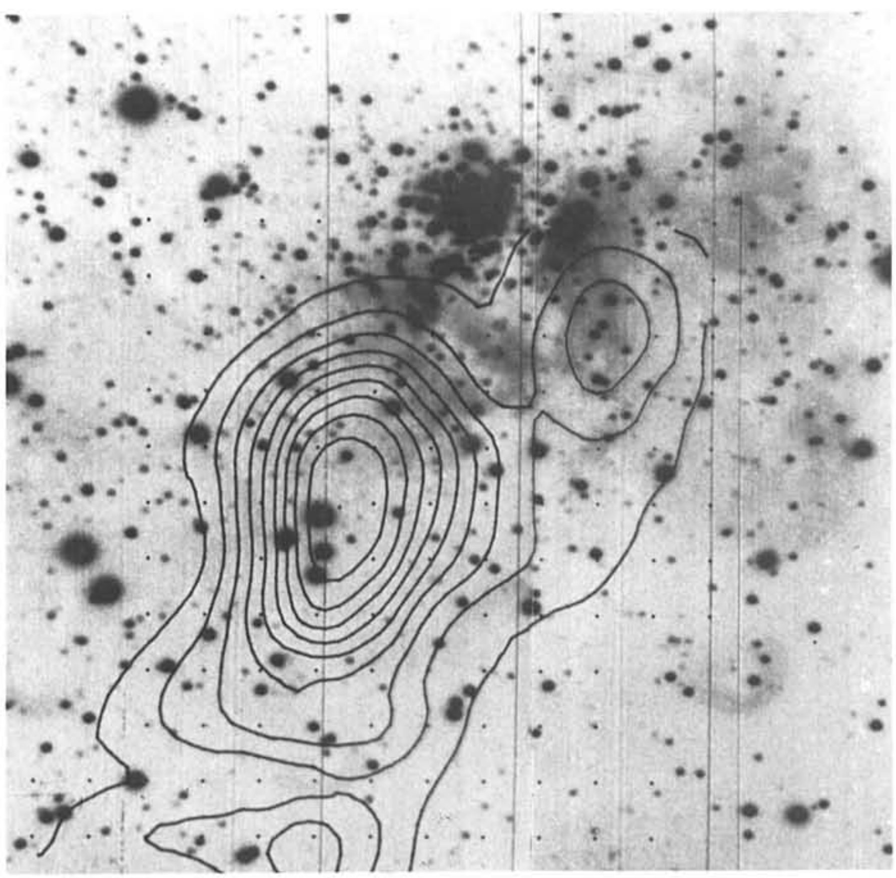

Figure 2: *^{12}CO (1–0) map of NGC 3603 superimposed on a mosaic of 2 CCD images of the complex in blue light. The grid spacing of the map is 20" and the beam size 44". The image covers an area of 6' × 6'. North is on top, East to the left.*

Figure 3: ^{12}CO *profiles in NGC 3603. The antenna temperatures range from −2 to 18° K and the radial velocity range covers 100 km s*$^{-1}$. *The grid spacing and orientation are as in Figure 2.*

region. Fridlund concluded that the molecular cloud is a new site of massive star formation in this active region.

My own research was aimed at understanding the mechanisms of formation of very massive starburst clusters. I selected the giant H II region NGC 3603, one of the most massive in the Galaxy, and the 30 Doradus superassociation in the LMC, but this region is at present being investigated by the SEST Magellanic Cloud consortium.

In collaboration with Lars Johansson and Andrea Moneti, I started a programme of SEST, IR, and optical observations of the NGC 3603 complex. Figure 2 shows a mosaic of 2 CCD images of the region in blue light on which our ^{12}CO (1−0) map is superimposed. As is the case for RCW38, for 30 Doradus, and for extragalactic violent star formation regions, the young cluster is located at the edge of the molecular cloud. The size and velocity dispersion of the cloud are consistent with that of other galactic molecular clouds and fit well the *(size − σ)* relation. $^{13}CO(1-0)$, $C^{18}O(1-0)$, and $^{12}CO(2-1)$ observations suggest the NGC 3603 molecular cloud is similar to LMC molecular clouds associated with violent star formation regions.

The line profiles in the direction of NGC 3603, illustrated in Figure 3, are very complex, and are particularly complex in the region where (in projection) the giant H II region meets the molecular cloud. NGC3603, however, lies very close to the galactic plane in the direction of Carina, so it is not clear whether the complex velocity structure is intrinsic to the source or is due to contamination by background sources.

Massive star formation is presently taking place in the molecular cloud. Figure 4 shows a true colour JHK infrared mosaic of the region obtained by Andrea Moneti and Hans Zinnecker. These images show the presence of a small cluster of massive stars located halfway between the starburst and the core of the molecular cloud. One of the goals of our work is to determine whether and how the formation of this cluster has been triggered by NGC 3603.

Figure 4: *True colour JHK mosaic of infrared images of NGC 3603 obtained by A. Moneti and H. Zinnecker with the IR camera at the 1.5-m telescope of CTIO. (Courtesy of Andrea Moneti.)*

3. The Future

Much of the progress of astronomy in the past two decades has been driven by improvements in observational technology and, in particular, by the opening of new windows to the Universe made possible by advances in radio and infrared instrumentation, and by the advent of space observatories. The timely arrival of SEST opens a new window to the southern skies. Together with the other powerful instruments available on La Silla and other observatories, SEST will certainly provide a definitive impulse to the understanding of massive star formation.

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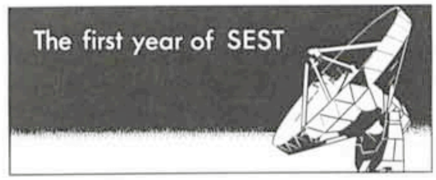

Low-Mass Star-Forming Regions

B. REIPURTH, ESO

While high-mass star formation is a dramatic process visible throughout large parts of our Galaxy, the formation of low-mass solar-type stars involves much more modest phenomena. But because low-mass stars are so much more common than high-mass stars, it is possible to find molecular clouds with abundant young low-mass stars at distances as small as 100 to 200 pc.

Of the five closest stellar nurseries, four are located in the southern Milky Way, namely the Chamaeleon, Lupus, Ophiuchus and Corona Australis cloud complexes. Of these, the Ophiuchus and Corona Australis cloud complexes are just within reach of mid-latitude northern radio telescopes. At La Silla, however, they pass through the zenith.

It is therefore not surprising that the arrival of the SEST at La Silla has been anxiously awaited by the low-mass star-formation community, and that through the first year of operation, SEST has been used for intense studies of southern low-mass star-forming regions. A few of these studies are reported in the following.

At declinations between −70° and −80°, the Chamaeleon clouds are virgin territory for millimetre observations at the resolution provided by the SEST. They are also at a rather high galactic latitude (b = −16°), so most of the confusion with background clouds in the galactic plane is avoided. And, finally, at a distance of only 140 pc, they are among the very closest of star-forming clouds. Kalevi Mattila and associates at Helsinki Observatory have embarked on a large-scale survey of the northern half of the Chamaeleon I cloud. Here, five young low-mass stars are clustered around HD 97300, a B9V star surrounded by a bright reflection nebula.

Mattila and co-workers mapped the cloud structure by observing $C^{18}O$ in frequency-switching mode, and found a dense molecular core centred on the young stars. The area was also mapped in the ^{13}CO line, but it appears to be optically thick over most of the field observed.

Maps in ^{12}CO have revealed a large molecular outflow, with well-defined blue and red wings outlining a bipolar flow and centred on the region of young stars (see Fig. 1). The total angular extent of the flow is about 14 arcminutes, corresponding to a projected length of almost 0.6 pc. Closer examination of the data shows that the outflow is not associated with HD 97300, but rather with one of the less luminous pre-main sequence stars. It appears that the star-formation efficiency of the cloud core is around 25 %.

In recent years much attention has been paid to the high-latitude clouds, relatively diffuse molecular clouds at high galactic latitudes and often very nearby. Jan Brand, Jan Wouterloot and Loris Magnani have studied L 1569, a high-latitude (b = −36°) cloud on the celestial equator between Eridanus and Taurus. They first used the ESO 3.6-m telescope with a grism to search for faint H-alpha emission stars projected on the cloud. Five such stars were found. Subsequently, SEST was employed to map part of the cloud in ^{12}CO and ^{13}CO in a study of cloud structure and possible interaction between the stars and their ambient medium. The cloud appears clumpy, with core sizes of approximately 0.05 pc. An interesting feature is that low-intensity wings of the line profiles are present, also in parts of the cloud away from the H-alpha emission stars. Recently, such puzzling wings have been found in several other high-latitude clouds without internal energy sources; their origins are not yet properly understood.

Molecular clouds with Herbig-Haro objects were among the first regions to be observed with the SEST. Michael Olberg and Roy Booth of Onsala Space Observatory and myself have studied a number of such regions in various tran-

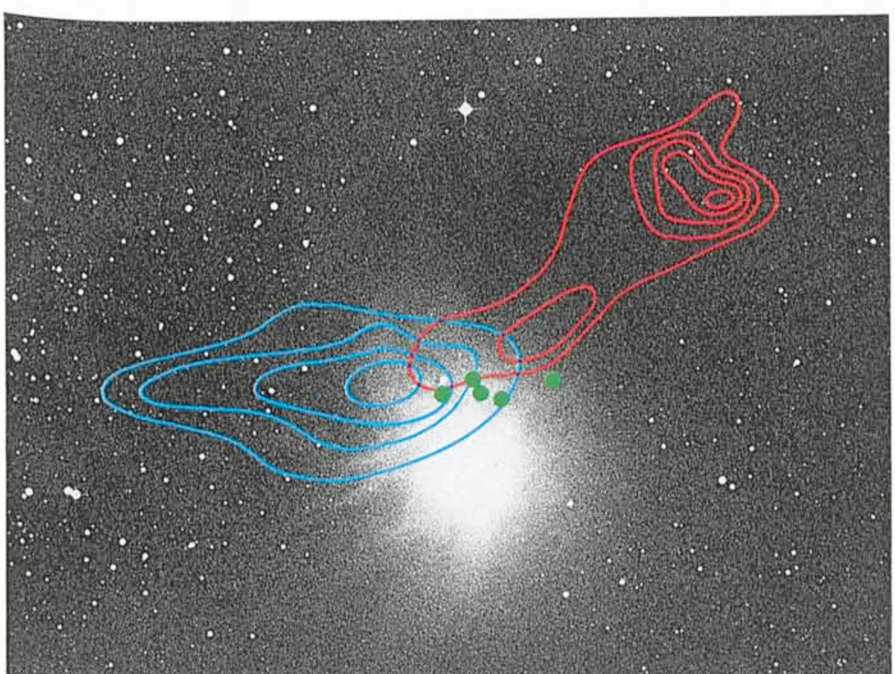

Figure 1: *A composite figure showing the blue and red lobes of a major molecular outflow in the northern part of the Chamaeleon I cloud. Young stars are indicated by dots. The bright nebulous star is HD 97300, a B9V star unrelated to the flow. The underlying photograph is reproduced from a blue ESO Schmidt plate. North is up and East is left. Courtesy K. Mattila and C. Madsen.*

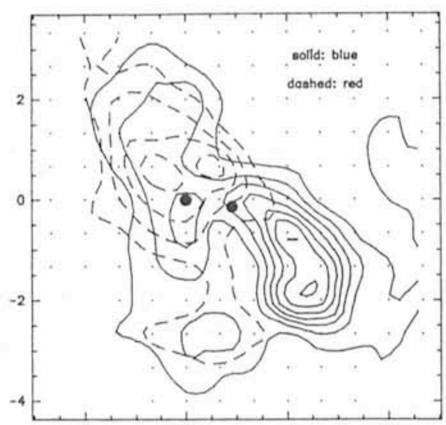

Figure 2: *A contour diagram of the two molecular outflows associated with the Herbig-Haro objects HH 56 and 57. The positions of the two driving energy sources are indicated. Solid lines are the blue lobes, dashed lines are the red lobes. The HH 56 flow is to the right, the HH 57 flow to the left. North is up and East is left.*

sitions. One of the most interesting regions is located in a small cloud in Norma, containing the Herbig-Haro objects HH 56 and 57 (see centrefold of the *Messenger* No. 52). Each of these objects is powered by a separate energy source; the one associated with HH 57 belongs to the rare class of FU Ori stars, which are thought to be T Tauri stars in very active accretion phases.

We have detected two large molecular outflows, one from each of the energy sources (Fig. 2). The two flows are slightly inclined with respect to each other, so that the blue lobes approaching us are well separated, while the red, receding lobes are mixed or at least projected on each other. The velocities of the outflows are modest, less than 5 km/sec. The masses of the swept-up ambient material is of the order of 5 solar masses.

I have worked at La Silla during the last several years, and it has been noticeable that a new user community of radio astronomers has appeared on the mountain. It has been interesting to witness how these new users have gradually integrated into the daily life of the observatory. Because La Silla is now an optical, infrared and radio observatory, it acts as an interface between what has long been almost separate European communities of radio astronomers on the one hand and optical/infrared astronomers on the other. Many collaborations spanning the optical-infrared-millimetre regimes have been started in the restaurant at La Silla. Especially in low-mass star-formation studies such multi-wavelength programmes are of the greatest importance.

Cometary Globules

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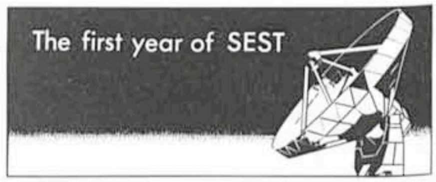

Cometary globules (CG's; see Fig. 1), first observed in 1976, are interstellar clouds with comet-like morphology, consisting of compact, dusty, and opaque heads and long, faintly luminous tails. Unlike most dark clouds, CG's are isolated neutral globules surrounded by a hot ionized medium.

Most CG's are located in the Gum nebula, a large region of ionized gas with approximate distance and size of 450 and 300 pc, respectively. Its prominent sources of energy are γ^2 Vel (WC 8+O9 I), ζ Pup (O4), and the Vela supernova remnant. Figure 2 (Zealey et al. 1983) demonstrates that the CG's are located on an annulus between 6° and 11° from "centre 1", i.e. at the boundary of the ionized bubble, with the tails pointing away from the central region.

Two scenarios were suggested to explain the spatial distribution and the comet-like appearance: Brand (1981) argues that CG's were initially nearly spherical clouds which were shocked by the blast wave from a supernova explosion. Reipurth (1983) suggests that the CG's are shaped by UV radiation impinging on a neutral cloud in a clumpy interstellar medium. Discrimination between these and other possible models is only possible, if we know the mass, density, temperature, and velocity distribution of the globules. These parameters can be determined by measurements of molecular spectral lines which are most easily accessible at mm-wavelengths.

Because of their southern location (Declinations $< -40°$), detailed maps could not be obtained until recently. The SEST telescope, however, has completely changed the situation. A number of sources have now been mapped in CO and its rarer isotopes and data from other molecules sensitive to higher densities have also been obtained. While it is too early for a systematic review,

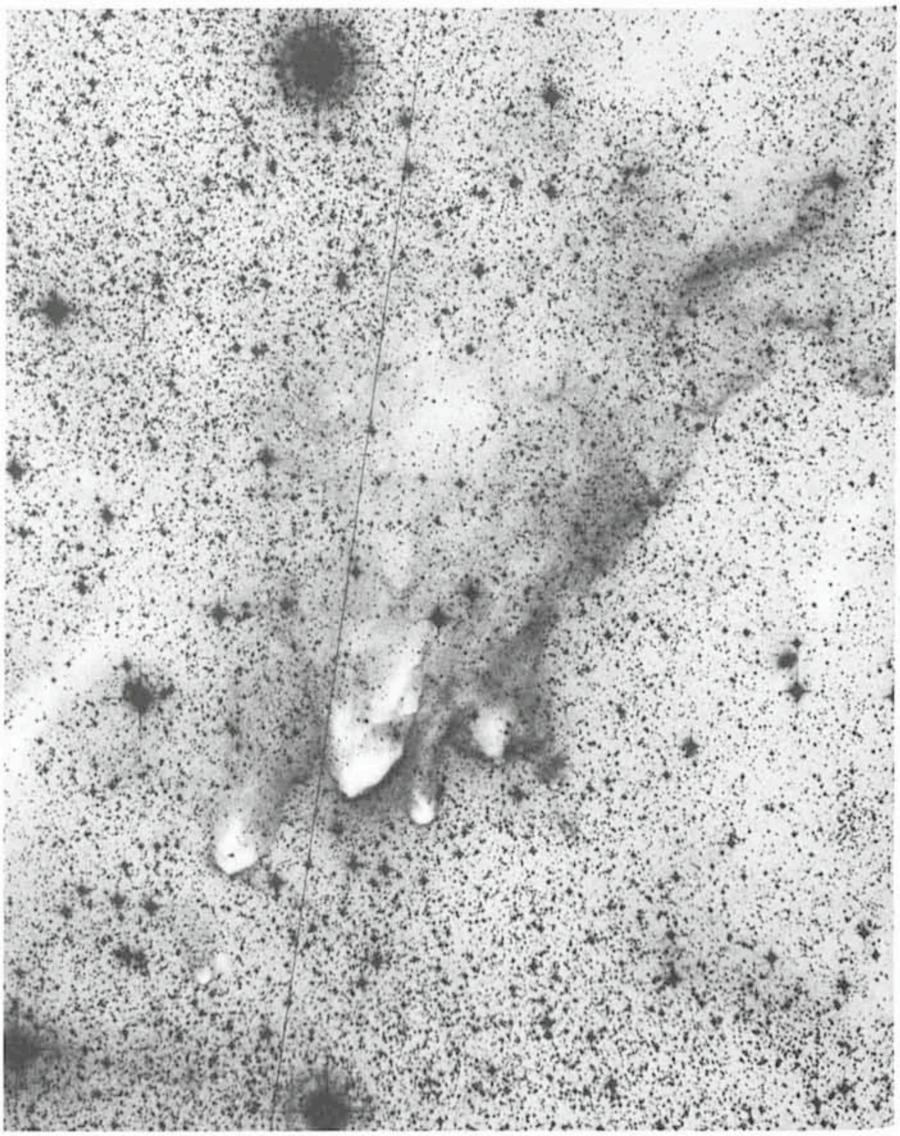

Figure 1: *An optical photograph of CG 30/31/38 (Reipurth 1983, Laustsen et al. 1987).*

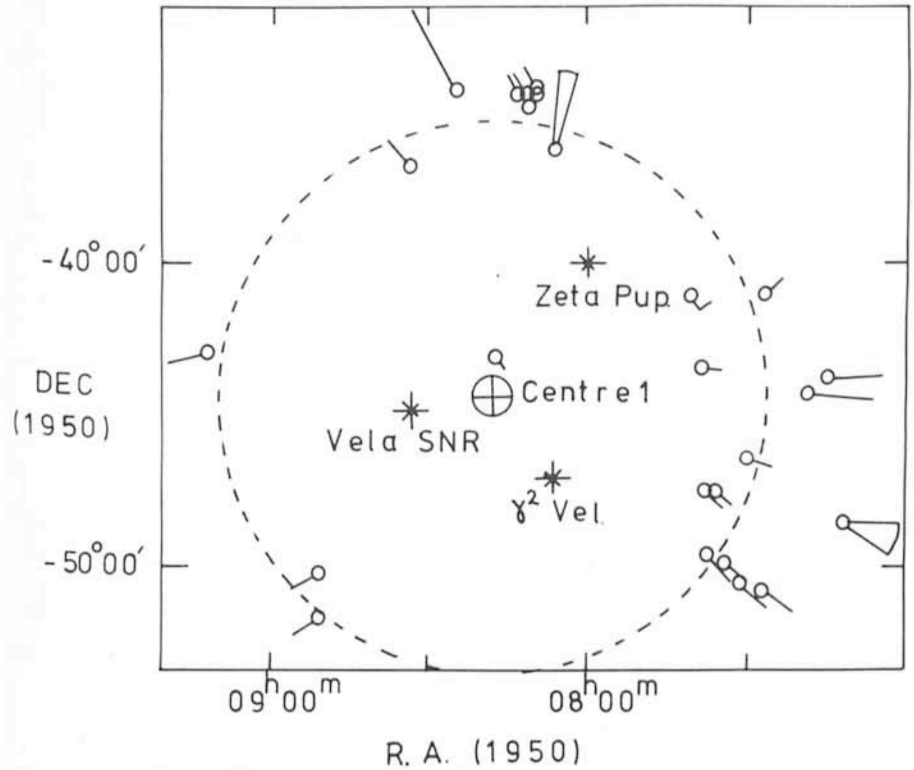

Figure 2: *The distribution of CG's in the Gum nebula, showing centre 1, the position from which most of the tails point away, and a 9 degree circle around that point (Zealey et al. 1983).*

there are already some interesting results:

So far mapped are CG 1, 15, and 21 (Harju et al. 1989), CG 4 and 6 (Cernicharo and Radford 1989), the ESO 210-6A globule, and CG 30/31/38 (Booth, Olberg, and Reipurth 1989; see Fig. 1). The data demonstrate that most of the mass of the globules is indeed in the form of molecular gas. Spectral lines allow the determination of radial velocities to an accuracy of 0.1 km s^{-1} (see the spectra in Fig. 3). They also allow estimates of excitation conditions and mass distribution.

The ESO 210-617 and CG 30/31/38 globules are of particular interest because of their association with the Herbig Haro objects, HH 46/47 and HH 120. There is a molecular outflow oriented along the direction of the optical jet which is formed by the HH 46/47 system, demonstrating the activity of one (or more) young stars formed in the globule.

CG 4 shows a high degree of clumping and a rather unsystematic velocity pattern, indicating complex structure not revealed by the optical image (e.g. Reipurth). The detection of CS in CG 4 demonstrates that number densities in excess of 10^4 cm^{-3} can be reached in such sources. Similar densities are also obtained from the "nose" of CG 1, where a second CO velocity component might indicate a shock, presumably associated with the "recently" formed star, Bernes 135.

Unlike CG 4, CG 1 (Fig. 4) shows the rather uniform picture also seen at optical wavelengths. The mass of the globule is of order 10–100 $M_\odot$, most of it located in the tail. The gas is cool, with kinetic temperatures only slightly above 10 K. CG 15 appears to be a scaled down version of CG 1, however without the second velocity component near the head and without any sign of recent star formation. CG 21, the only measured cometary globule not belonging to the Gum nebula, shows quite a complex velocity pattern with up to three or more velocity components in a single spectrum and a highly clumped tail. It hence appears that the structure of the molecular gas, responsible for the bulk of the mass, is quite heterogeneous.

A careful analysis of the molecular spectra will significantly increase our knowledge on cometary globules and will motivate further theoretical studies to elucidate their nature and history.

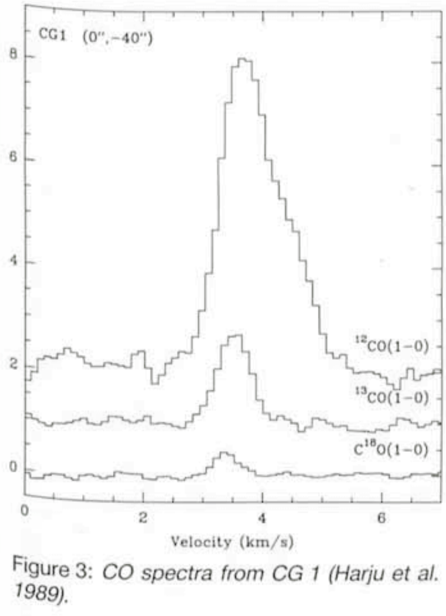

Figure 3: *CO spectra from CG 1 (Harju et al. 1989).*

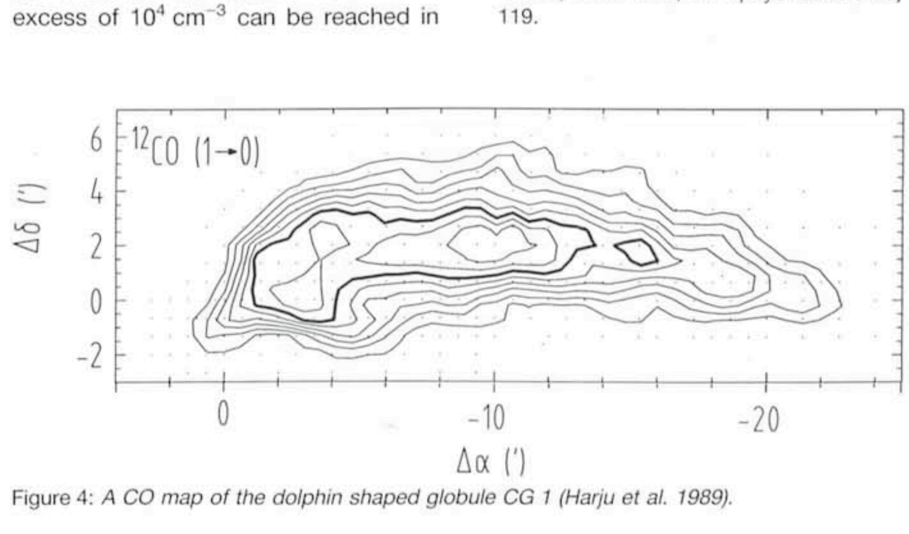

Figure 4: *A CO map of the dolphin shaped globule CG 1 (Harju et al. 1989).*

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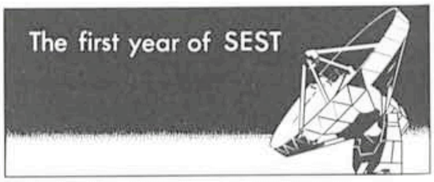

Interstellar Chemistry

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The research regarding interstellar chemistry with SEST can be divided into three categories: (i) searches for new molecules, (ii) studies of known molecules in order to shed light on their formation, and (iii) spectral scans – systematic observations of large frequency bands in a few interesting sources. Spectral scans give a good overview, not only of the chemical content, but also of physical traits. Typical excitation temperatures for different species give a handle on the kinetic temperature. The variation of excitation temperature with energy level and/or molecular state reveals regions of different temperature and density inside the beam (point-spread function) of the telescope. Of course, unidentified lines and unexpected molecules are also found.

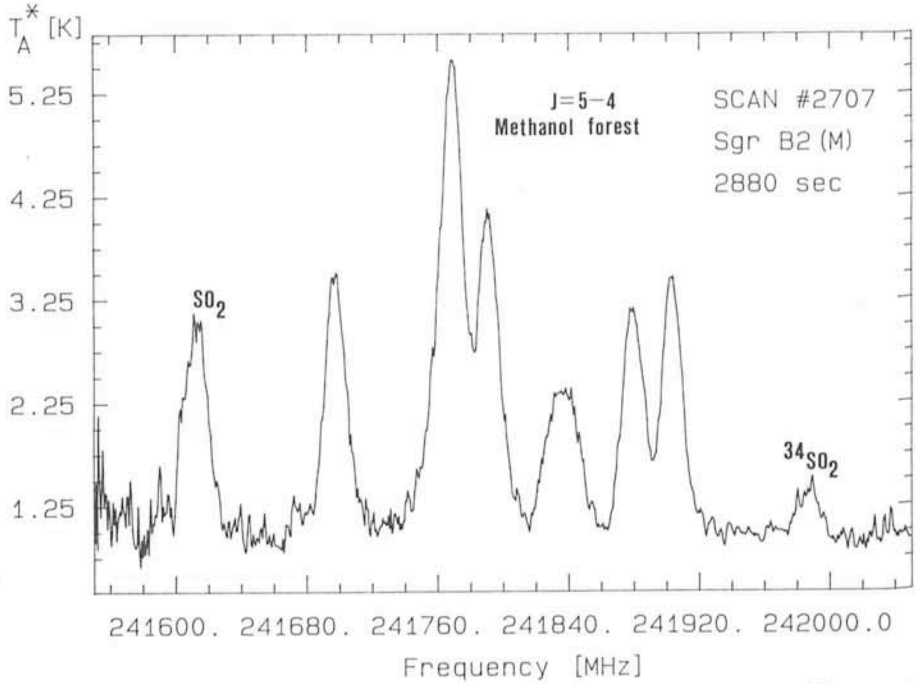
Two searches for new molecules have to my knowledge been done. Both searches only set upper limits on the abundance, i.e. neither molecule was detected. Gerin et al. (1989) searched for HCOCN in Orion and Sgr B2. They determined that HCOCN is less abundant than other large organic molecules such as cyanoacetylene (HC_3N) and methyl formate ($HCOOCH_3$). Irvine et al. tried to confirm the existence of propadienone (H_2C_3O) in Sgr B2 by observing several adjacent rotational transitions. One transition, observed at Nobeyama, had previously been tentatively assigned to propadienone. The previously observed line was confirmed but one of the adjacent rotational transitions was missing and two others were doubtful due to blending with other lines. Hence, in contrast to its isomer, propynal (HC_2CHO), propadienone has not been detected in the interstellar medium.

However, observations at 80 GHz ($\lambda \approx 3.7$ mm) led to a possible detection of another molecule, deuterated water (HDO), in Sgr B2. Observations of deuterated molecules towards the Galactic centre are very rare. Determining the abundance of deuterated molecules close to the Galactic centre can help to determine the Galactic deuterium gradient and resolve the question of non-cosmological deuterium formation. Since at least 15 other lines appeared in the same 500 MHz wide spectrum the risk for an accidental coincidence is very big. However, the tentative identification is supported by 1.3 mm observations (see later).

To try to understand why protonated carbon dioxide ($HOCO^+$) is only observed towards clouds close to the Galactic centre (Sgr A and Sgr B2 clouds), Minh et al. have mapped Sgr A in the $4_{04}-3_{03}$ rotational transition ($\lambda \approx$ 3 mm). It turns out that $HOCO^+$ is distributed like more commonly encountered molecules. Hence the reason for the unique abundance of $HOCO^+$ in the Galactic centre clouds affects the bulk of these clouds. The investigators argue that the most probable reason is that the Galactic centre clouds encounter more frequent shock waves in which the parent molecule carbon dioxide (CO_2) can be formed from CO and OH. The carbon dioxide is then protonated by reactions with H_3^+, N_2H^+, . . . Since other protonated molecules are not unusually abundant in these clouds, the high $HOCO^+$ abundance is traced to CO_2 and not to the protonating species H_3^+, N_2H^+, . . .

Spectral scans at the 1.3-mm range of Sgr B2 and LMC are also in progress. The observations of LMC by Johansson et al. provide a good test of the assumptions in chemical model calculations because of the lower metallicity in LMC. The observed $C^{18}O/^{12}CO$ line intensity ratio is close to 1/500 (much lower than the value observed in the Galaxy but equal to the terrestrial $^{18}O/^{12}C$ isotope ratio) while the observed $^{12}CO/^{13}CO$ line ratio is close to the "Galactic" value of five. The interpretation is not easy since the ratios are affected not only by the curve of growth and carbon isotope ratios but also by cloud structure and self shielding against UV dissociation. Hence, the apparent non Galactic $C^{18}O/^{12}CO$ line intensity ratio may be due to the lower metallicity in the LMC and not to differences in isotope ratios.

The scan in Sgr B2 (Bergman et al.) has so far covered the range between 238.85 to 243.85 GHz (5 GHz). Three positions are observed in the Sgr B2 cloud – two active regions with signs of on-going massive star formation (compact H II regions, OH and H_2O masers) and one position in the ambient cloud. While the spectra are very rich towards the active regions with about 15–30 lines per GHz, the line density is only 4 lines per GHz towards the ambient cloud position. The spectra towards the active regions are dominated by lines from methanol, methyl cyanide (vibrationally excited), and ethyl cyanide. It is also apparent that the northern of the two active regions (Sgr B2 (N)) contains the hottest material since the spectra contain lines from transitions between states of much higher energy than towards the other active region. The estimated temperature of the hot gas is 100–130 K and 60–80 K for the northern and southern region, respectively.



Sample spectrum from the 1.3-mm scan against Sgr B2 (M) containing lines of SO_2, $^{34}SO_2$, and many J = 5–4 methanol transitions. One HNCO line is blended with the central cluster of methanol lines.

The southern active region Sgr B2 (M) exhibits pronounced emission from SO_2. About 20% of the lines have not been identified and the identifications of at least another 10% are very questionable. It has to be stressed that the work to identify the lines is far from completed yet. One of the lines preliminarily identified is another HDO line, which supports the identification at 80 GHz. Still the line density is high enough to make a two-transition identification doubtful. We hope to be able to confirm the HDO identification in our next observing run (June 1989).

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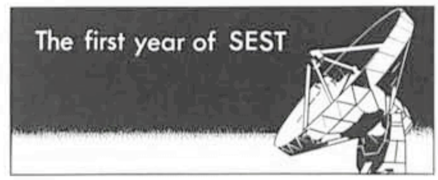

Evolved Stars

L.-Å. Nyman, SEST, La Silla

Introduction

Studies of evolved stars using sub-mm and mm-wave telescopes such as the SEST are mainly concerned with the very last stages of the life of a star, when it throws away its outer envelope and is surrounded by a shell of dust and gas. The dust obscures the star optically and most studies of stars at this stage of their evolution have been made in the radio and infrared regions of the spectrum. The circumstellar gas consists mainly of molecular hydrogen, H_2, but also of other less abundant molecules (e.g. CO, SiO, OH, H_2O, HCN, etc.), which are important since they radiate in the radio region, something that is not these case for molecular hydrogen. These molecules can be used to study the properties of the circumstellar envelope (CSE), e.g. to determine mass-loss rates, which are important for the evolution of the star, and to study the chemistry of the envelope.

These studies are important because the envelope contains processed material from the interior of the star that is now returned to the interstellar medium. The material will eventually be incorporated into new stars, making our Galaxy evolve chemically. The mass loss is important for the evolution of a star, since its end point is determined by how massive it is. A star with a mass $> 1.4\ M_\odot$ should end as a supernova, but because of the extensive mass loss in the final stages of its life, even a star of $10\ M_\odot$ will lose enough mass to put it below this limit, and it will end as a planetary nebula and later as a white dwarf. Many of the observations with the SEST telescope have been made of stars at different stages in the final point of their lives and a brief summary of stellar evolution will be given below.

Stellar Evolution

Stars with masses $< 10\ M_\odot$ spend most of their lives on the main sequence, quietly burning hydrogen to helium in the core. When the hydrogen is exhausted in the core, the star moves up the Red Giant Branch (RGB) burning helium in a shell around the core, which is contracting and becoming hotter and hotter. Finally it is hot enough for helium to start burning, and the star moves to the horizontal branch burning helium to carbon and oxygen. Eventually the helium is exhausted in the core and the star starts to move up the Asymptotic Giant Branch (AGB). At this stage it consists of a degenerate carbon-oxygen core surrounded by a thin helium burning shell.

It will now reach a phase in its life where many things will happen on a relatively short time scale. When all the helium in the core has been converted to carbon and oxygen, hydrogen and helium will start to burn alternately in a thin shell around the core. Every time a critical mass of helium has been processed from the hydrogen burning it ignites with a flash, a thermal pulse (TP). Between the helium flashes a deep convection layer brings up processed material to the surface of the star and it may even change its composition from being oxygen-rich to carbon-rich. The star will also become unstable and start to oscillate. The pulsations will form shock waves in the photosphere, supplying energy to lift the gas to regions that are cool enough for dust formation. The radiation pressure on the dust will accelerate it away from the star dragging the gas along with it, forming an expanding CSE.

In the final stages of the AGB the mass loss increases rapidly and a superwind occurs. Almost all the matter in the hydrogen envelope is stripped from the star. The remnant core contracts rapidly at constant luminosity and the ejected material drifts outward. When the surface temperature is hot enough to produce UV photons, the ejected gas is ionized and a planetary nebula (PN) is formed. Eventually the gas disperses and the star will become a white dwarf.

Since the star is surrounded by a thick dust shell during the last phases of its life, it is difficult to study it optically. The

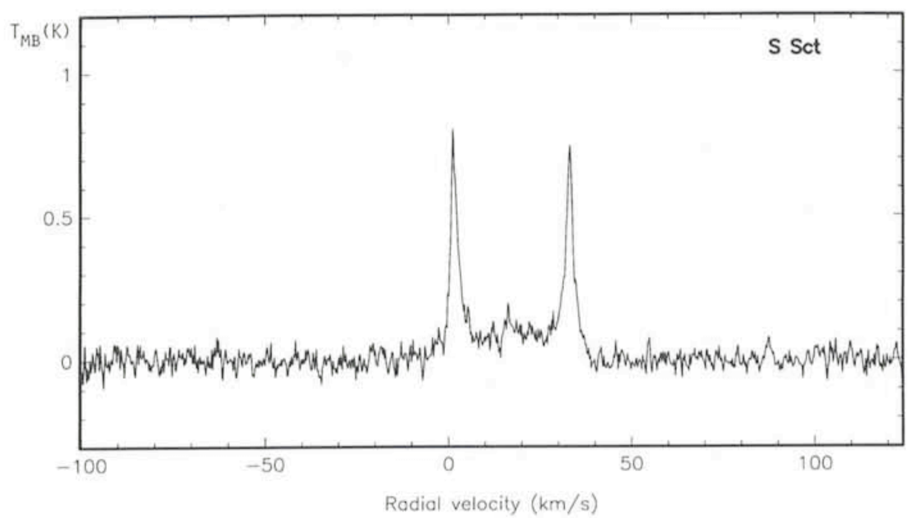

Figure 1: *A ^{12}CO (J = 1-0) spectrum of the bright carbon star S Sct. The double-peaked line profile and the map data suggest that the circumstellar envelope is detached from the star, i.e., its mass loss has decreased considerably during the last few thousand years. This may be an effect of a thermal pulse during the AGB evolution.*

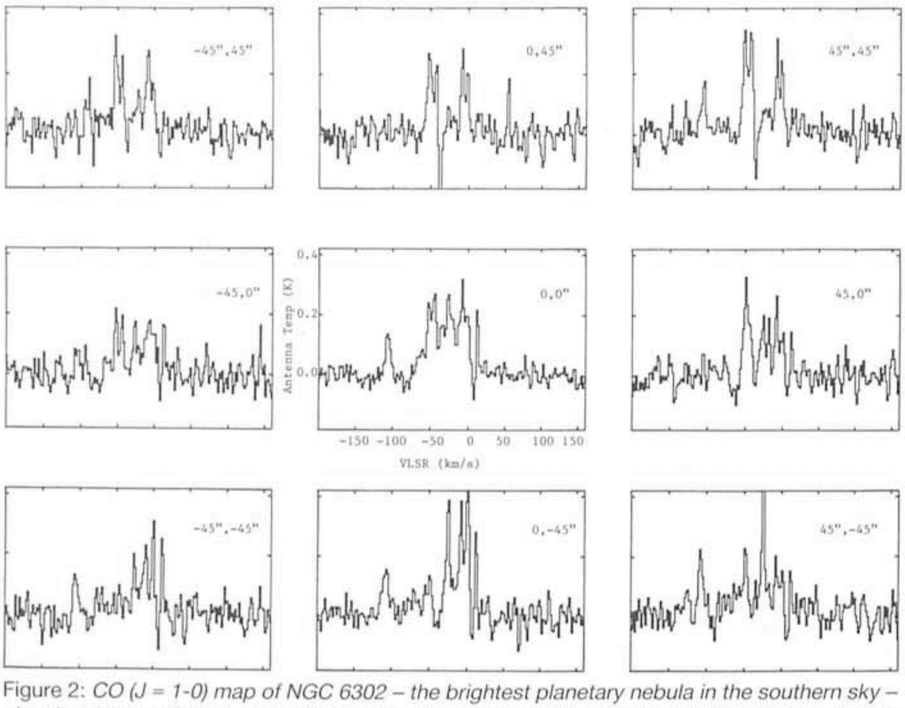

Figure 2: *CO (J = 1-0) map of NGC 6302 – the brightest planetary nebula in the southern sky – showing several distinct, spatially-variable, kinematic components (Sahai, R., Wooten, A., and Clegg, R.E.S.).*

dust radiates in the infrared, however, mainly between 2 and 100 μm, and infrared observations (especially those of the IRAS satellite) have given us insight into the properties of CSEs and stellar evolution. Van der Veen and Habing (1988) have studied the IRAS two-colour diagram (F_{60}/F_{25} versus F_{25}/F_{12}) in the region where CSEs are situated and interpreted the distribution of IRAS point sources together with other properties such as variability, etc., as an evolutionary sequence of increasing mass-loss rate, i.e. the IRAS two-colour diagram can be used to study the evolution of a star on the AGB and beyond.

In their scenario a star becomes variable somewhere on the AGB, maybe during the thermal pulses, and starts to lose mass. The mass-loss rate is fairly low in the beginning, $\sim 10^{-7}$ $M_\odot$ yr^{-1}. This is the region where Mira variables are situated. The mass-loss rate then gradually increases to a few times 10^{-5} $M_\odot$ yr^{-1} and the star will be surrounded by a thick CSE, moving along the evolutionary track in the two-colour diagram. The star is now obscured and in this region we find the OH/IR objects. The mass-loss rate may not be continuous; during a thermal pulse the stellar oscillations may stop for some time, inhibiting the mass loss, and then start again. After some time the variability decreases, the mass loss stops and the star will become a planetary nebula. The planetary nebulae and their progenitors, the protoplanetary nebulae (PPN), are situated in certain parts of the two-colour diagram, thus making it possible to find candidates for further observations at this interesting stage in the life of a star.

Sometime during the evolution of some stars, enough processed material from the interior may have been brought up to the surface to change the composition of the star from oxygen-to carbon-rich. A few carbon stars with oxygen-rich CSEs have been observed, supporting this idea.

Circumstellar Molecules

The gas in the CSEs has mainly been studied through observations of molecular transitions in the radio region (some molecules have also been detected in their infrared transitions). So far, 36 molecules have been detected in CSEs (Olofsson, 1989). The strongest emission lines are produced by the SiO, H_2O, and OH molecules, situated in oxygen-rich envelopes. The population in some of their transitions may under certain conditions become inverted and the molecules will act as amplifiers, i.e. they will amplify the background emission at the frequency of the transition; they are so called *masers*.

The SiO masers are situated close to the surface of the star while the H_2O and OH masers are located further out, thus these molecules probe different parts of the envelope. Especially the OH masers have been useful to determine mass-loss rates and also the distances to stars.

Another useful molecule for studies of CSEs is CO. It is found both in oxygen- and carbon-rich envelopes, it is the most abundant molecule next to H_2, and can be used to determine mass-loss rates and other properties of the envelope. A large fraction of the observing time on the SEST telescope has been spent on observations of CO in different samples of stars at various stages in their evolution. Compared to the oxygen-rich envelopes the carbon-rich envelopes contain a variety of molecules, among them carbon chain molecules (HC_3N, HC_7N, C_4H, etc.) and ring-like molecules (C_3H_2, SiC_2).

SEST Observations

The SEST telescope has been used for several surveys of circumstellar CO emission in different kinds of samples, mainly to extend the observations to include southern objects. A survey of IRAS point sources in the IRAS two-colour diagram includes many kinds of evolved stars in different stages of their evolution, and many new detections have been made. Observations of a sample of bright carbon stars with well-known photospheric characteristics have made it possible to study the relation between photospheric properties, and those of the CSE. Of special interest is the detection of detached circumstellar shells, implying that the mass loss sometimes stops. A sample of S-stars was observed in order to study their relation to oxygen- and carbon-rich stars, and several new planetary nebulae have been detected.

Two surveys of SiO masers have been made, one of a sample of IRAS point sources, another of bright infrared objects. The detection rate was high in both surveys. Several individual southern objects have been studied in detail, among them the two supergiants VY CMa and VX Sgr, and the bright carbon star IRAS 15194-5115. In the latter, many molecules have been detected and its properties seem to be similar to IRC+10216, a well-known carbon star in the northern sky.

The individual programmes will now be described in more detail. Many of the projects are not finished and have been allocated more observing time during 1989, so the results are preliminary.

Observations of samples from the IRAS point source catalog. The project with the largest amount of allocated observing time is a joint ESO and Swedish project with 11 participants (Booth, Nyman, Carlström, Winnberg, Sahai, Habing, Heske, v.d. Veen, Omont, Forveille, and Rieu). It is a survey of circumstellar CO (J = 1-0) emission in a sample of totally 787 sources from the IRAS point source catalog, with the colour-colour characteristics described in the paper by van der Veen and Habing. The sources are all stronger than 20 Jy at 25 μm. The sample consists of all kinds of evolved stars, oxygen and carbon rich, Mira variables, OH/IR objects, PPN, and PN. Of these sources, 459 are situated in the southern sky, and the others will be observed with the Onsala 20 m telescope.

The idea is to build up a data base of circumstellar CO emission from stars at different stages of their evolution, to study mass-loss rates, chemistry, and other properties of the envelopes. Near infrared photometry of the sample is planned, and the stars will also be observed in the CO (J = 2-1) transition. So far, 215 objects have been observed with the SEST telescope, 88 objects have been detected, of which 54 are new detections. Objects with very cold CSEs, e.g. OH/IR objects and PPNs, are very weak in CO and sensitive observations are needed to detect them. Therefore, a special project to observe this type of objects was initiated together with the large survey. Several objects have been detected, among them a supergiant with an extremely wide line profile, almost 300 kms^{-1}.

Many evolved stars show strong SiO maser emission at 86 GHz. Haikala has made a search for SiO (v = 1, J = 2-1) masers from objects in the IRAS point source catalog with colour-colour characteristics similar to sources with already detected SiO maser emission.

The objects are mainly situated in the region of the colour-colour diagram of oxygen-rich sources with moderately thick CSEs (van der Veen and Habing, 1988). He observed 114 sources and found 53 new SiO masers. Since the SiO masers are variable in intensity, many of the non-detected sources would probably be detected, if they were observed at a later time.

Bright infrared sources. Le Bertre and Nyman have observed the SiO (v = 1, J = 2-1) maser emission from a sample of bright infrared sources, and made nearly simultaneous near-infrared observations. The sample consisted of 5 Mira variables, 2 supergiants, and 10 OH/IR objects. All sources, except 3 of the OH/IR objects, were detected in SiO. Previous attempts to detect this SiO transition in OH/IR objects have largely been unsuccessful (Nyman et al., 1986), maybe because of the large distance to many of these objects compared to Mira variables. In this sample of bright infrared sources (bright because they are nearby or intrinsically bright) there seems to be no difference in SiO intensity versus infrared intensity for the different types of sources.

Bright carbon stars. Olofsson, Eriksson, and Gustafsson have made CO observations of a sample of bright carbon stars (situated both on the northern and southern sky) with well determined photospheric characteristics, e.g. effective temperature T_{eff}, CNO abundances and $^{12}CO/^{13}CO$ ratio, giving a good opportunity to compare photospheric properties with those of the CSE. The first results have been presented in Olofsson et al. (1987) and Olofsson et al. (1988). In total, 32 stars were observed and 26 were detected of which 15 are new detections. A good correlation was found between the far infrared properties and mass-loss rates and also between the variability of the stars and their mass-loss rates.

One interesting result in this project is the discovery of three sources, S Sct (Fig. 1 by Olofsson), U Ant, and TT Cyg, with a peculiar double peaked CO line shape. A simple model of the CO emission from these objects shows that there is a distinct inner radius inside which little mass exists. The conclusion is that the mass loss has stopped, maybe because the star is experiencing a thermal pulse. The CO (J = 2-1) spectrum of U Ant also consists of a narrow parabolic profile which may indicate that the mass loss has recently recommenced in this source.

Olofsson, Eriksson, Gustafsson, and Carlström have observed HCN and $H^{13}CN$ toward the sources in the same sample to compare the HCN/CO abundance ratio in the photosphere with the same ratio in the CSE. This is interesting because in carbon stars HCN is thought to be of photospheric origin, while in oxygen-rich stars a photoinduced circumstellar chemistry is required to produce HCN. They detected 20 stars in HCN, and $H^{13}CN$ was seen only in the two ^{13}C rich stars in the sample. Due to the uncertainties in abundance determination, the preliminary result is that the HCN/CO abundance ratio is similar in the photosphere and the circumstellar envelope, in agreement with the chemical models.

S-stars, planetary nebulae, and supergiants. Sahai has made a survey of CO (J = 1-0) emission from S-stars to determine their mass-loss properties and compare them with oxygen-rich and carbon stars to test the hypothesis that the S-stars represent an evolutionary stage between the O- and the C-stars.

So far 15 objects have been observed and 4 new sources were detected, almost doubling the number of S-stars detected in CO. The proto type S-star π^1 Gru was mapped, it has an unusual asymmetric line pofile and an extended outflow.

Sahai, Wootten, and Clegg have made a search for CO (J = 1-0) emission from a large list of southern PN, detected 6 new sources and mapped 3 of them. NGC 6302 (Fig. 2) has a very interesting structure with at least 3 separate kinematic components. Sahai has observed two supergiants, VY CMa and VX Sgr, in CO. They both have very large outflow velocities. The CO profile of VY CMa is rectangular and almost point like in the CO map, implying that it is optically thin, which is surprising since the mass-loss rate determined from OH observations is very high. HCO^+ was also detected. The CO profile of VX Sgr is heavily contaminated by interstellar

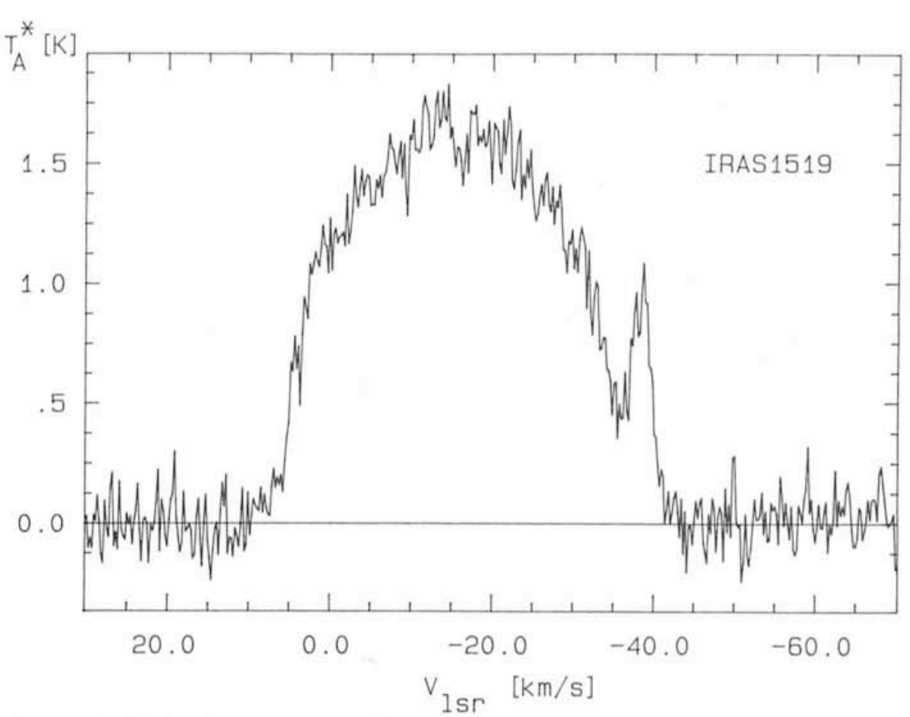

Figure 3: *A CO (J = 2-1) spectrum of IRAS 15194-5115.*

CO lines because it is situated in the Galactic plane. Further observations of all these projects are planned during 1989.

Molecular observations of a bright carbon star. The third brightest carbon star in the sky at 12 μm, IRAS 15194-5115, is located in the southern sky. It has properties similar to IRC + 10216 (the brightest carbon star and situated in the northern sky), which has a very well studied spectrum with many detected molecules. IRAS 15194-5115 is situated at a larger distance, however. Booth, Johansson, Nyman, Olofsson, and Wolstencroft have observed the IRAS source in many molecular transitions to compare it with IRC + 10216. CO, ^{13}CO, CS, HCN, HNC, HC_3N, C_2H, C_3H, C_4H, C_3N, SiS, and SiC_2 have been detected. The lines are about 10 times weaker than those in IRC + 10216 confirming the larger distance to the IRAS source, but the relative intensities of the molecular lines with respect to the CO (J = 1-0) line intensity are the same within a factor of two between the two sources. Figure 3 shows a CO (J = 2-1) spectrum of IRAS 15194-5115. Preliminary CO maps give a source size of 24″ (deconvolved with the beam) in the CO (J = 2-1) transition and 33″ in the CO (J = 1-0) transition.

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Molecular Clouds and Galactic Structure

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One of the features of the SEST is its sub-arcminute resolution, allowing one to observe molecular clouds at high spatial resolution, as described in a number of the other reviews in this issue. However, the SEST can also be used to investigate the large-scale distribution of the molecular cloud ensemble. Such a study, focused on the outer Galaxy, is the topic of this contribution.

Molecular clouds consist almost exclusively of H_2, which is, however, difficult to detect. CO is the next most abundant molecule in interstellar space, and it has easy-to-observe transitions in the mm-wavelength range. Because CO is primarily excited through collisions with H_2, it is possible to infer the distribution of the latter from that of CO.

The Outer Galaxy

The outer Galaxy, defined as those reaches of our system with galactocentric distances R larger than $R_\odot$ (= 8.5 kpc; the distance of the Sun to the galactic centre), has gained renewed interest as a region of study. From observations of HI emission it has become clear that at $R > R_\odot$ there are large-scale systematic deviations from a flat distribution (called 'warping') as well as a significant increase in the thickness of the gaseous disk (called 'flaring'). Such a morphology is in marked contrast to that of the inner Galaxy, where the atomic gas is confined to a disk of thickness ~250 pc (~120 pc for its molecular counterpart). The same phenomenon is seen in a number of other spiral galaxies, which in turn has stimulated astronomers to have a closer look at their own backyard. Almost all information on the distribution and motion of material at large R has come from observations of HI, mostly because all other "tracers" are confined to the inner Galaxy. It is important, however, to extend our knowledge of the outer Galaxy beyond what can be found from the 21-cm emission. We would like to know, for instance, the distribution and kinematics of the molecular material, an essential ingredient for the study of the influence of a changing galactic environment on star formation.

Much observational work, especially in CO, has already been devoted to the study of individual molecular clouds at $R > R_\odot$. But the larger scale picture suffers from incompleteness. Molecular clouds in the outer Galaxy are much more sparsely distributed than in the inner parts, and the intensity of the emission is generally low. Large-scale surveys, done on a regular grid, are out of necessity carried out with either severe undersampling or low sensitivity, and are in general confined to $|b| < 5°$. These constraints imply that many clouds, especially at larger distances, will be missed due to beam dilution, or due to the galactic warp.

IRAS sources

A representative view of the population of molecular clouds in the outer parts of the Galaxy can only be obtained if one knows where to look, such that the chance of detecting a CO emission line is high. In this way even a large telescope like the SEST can be used to derive the large-scale distribution of molecular gas. Jan Wouterloot (now at the University of Köln) and I searched for CO in the direction of a large sample of IRAS sources in the outer Galaxy, in a project started in September 1987 (when we used the SEST in test time, and we were both at the MPIfR in Bonn). These sources were selected from the IRAS point source catalog, on the basis of their colours, as having a high chance of being associated with regions of star formation. As all star formation takes place in molecular clouds, these IRAS sources act as flags for the location of the clouds in which they are embedded. A number of these IRAS sources are located close to optically visible HII regions, but many are not. The latter could be (ultra) compact HII regions, or be associated with a pre-main-sequence object.

In order to account for the galactic warp, the sources were selected in a latitude range between +10° and −10°. Initially the longitude range of the sample was chosen to be between 165° and 280°, and was later extended down to l = 85°, using the IRAM 30-m telescope.

Spatial Distribution

CO was detected towards 1077 (83%) of the 1302 sources selected in this way. We found CO emission towards these sources at velocities of (absolute values) up to 110 kms^{-1}. This is quite a difference with uniform-grid surveys, or surveys of optical HII regions, where very little emission, if any, is found at velocities in excess of 50 kms^{-1}. Using a rotation curve (i.e. the relation that gives the velocity of rotation around the galactic centre as a function of R, assuming all objects are in circular rotation), a kinematic distance could be derived for each CO emission component. In terms of distance, we found CO emission up to 15 kpc from the Sun, and out to R ≈ 20 kpc. In many cases more

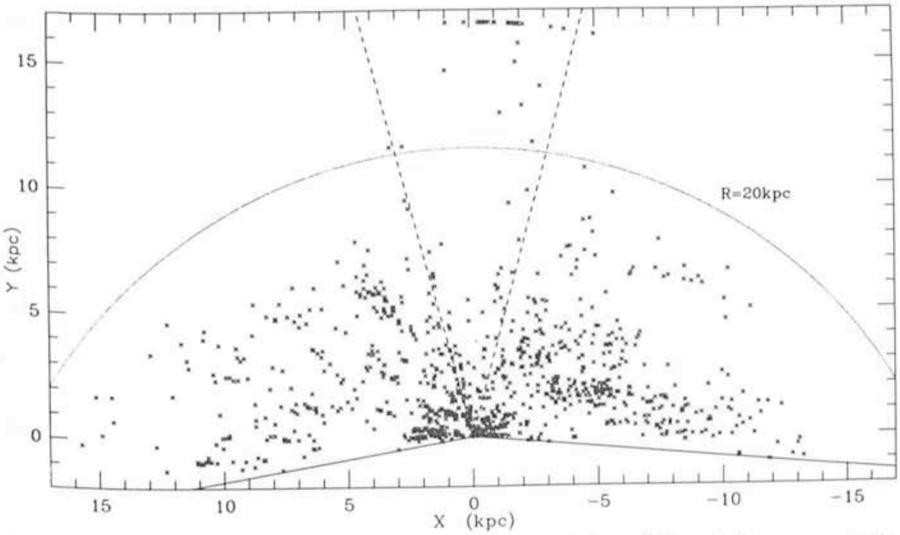

Figure 1: *Distribution projected onto the galactic plane of those CO emission components associated with the selected IRAS sources. The Sun is at (0,0); the galactic centre at (0,−8.5). The full-drawn lines show the longitude limits of the sample. The dashed lines mark the region within 15° of the anticentre where kinematic distances are very uncertain; objects in this region are excluded from the final sample used in the data analysis.*

than one emission component was found towards a particular IRAS source. Identifying the one that is associated with the IR source usually did not pose a problem, as one of the components was always stronger and broader than the others. Most of the not-associated emission comes from local ($d < 1$ kpc) clouds.

Figure 1 shows the distribution on the galactic plane of the CO emission associated with the IRAS sources. The dashed lines mark a region near $l = 180°$, where kinematic distances are very uncertain. Note that very few clouds are at $R > 20$ kpc. Because the sample was chosen such that the IR sources had colours of star-forming regions, we conclude that no star formation takes place at distances larger than that (otherwise we would have detected it).

We also see that distant objects are found more or less evenly distributed in longitude. There are more molecular clouds with embedded IR sources in the second quadrant than in the third. In the second quadrant a concentration of clouds occurs around R = 12 kpc, which we associate with the Perseus arm. No large-scale spiral arm feature can be distinguished which extends over both galactic quadrants.

The distribution of the CO emission perpendicular to the plane shows that the molecular material partakes in the galactic warp, with clouds reaching heights of 800–1000 pc at the largest distances. Similarly, the molecular gas disk shows an increase in thickness with increasing R, eventually approaching that of the HI.

Sources that would have a flux S (25 μm) >0.25 Jy if they were at d = 15 kpc, would be visible over the whole range of distances where CO emission was found. Excluding those around $l = 180°$ (see Fig. 1), this sample contains 416 IRAS/CO sources (i.e. molecular clouds), which were used to derive the distribution of H_2.

Assuming that the number of far-IR sources per unit of H_2 mass is constant (as indicated by a preliminary study), we can derive the surface density of H_2 ($\sigma(H_2)$) as a function of R, by calculating the number of IR sources per square pc, and scaling the value at $R_\odot$ with the value of $\sigma(H_2)$ at that location. We find that $\sigma(H_2)$ decreases from a value of 1.80 $M_\odot pc^{-2}$ at the Sun, to 0.64 $M_\odot pc^{-2}$ at R = 14 kpc, to 0.015 $M_\odot pc^{-2}$ at R = 20 kpc. This decrease is much slower than what was derived from earlier, general-sampling CO surveys. From our data, we derive a total mass of 5.8 10^8 $M_\odot$ residing in H_2 clouds at $R > R_\odot$.

This project shows how the SEST can be used to increase our knowledge of an important aspect of our Galaxy, the large-scale distribution of molecular clouds. The dataset contains of course much more information, which space unfortunately does not permit me to write about; a detailed account of this work has been submitted to *Astronomy and Astrophysics*.

It's a pleasure to thank ESO and the staff at the SEST for providing and maintaining this very user-friendly telescope, and Jan Wouterloot for making improvements on the manuscript.

The Galactic Centre

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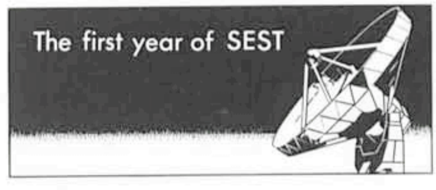


One of the most interesting and mysterious regions of our Milky Way galaxy is the Galactic Centre (GC). Lying at a distance of 8.5 kpc in the direction of Sagittarius, it is best observed from the southern hemisphere. However, great masses of intervening dust in the plane of the Galaxy produce 30 magnitudes of absorption and the GC is not observable in the optical region. Most of the knowledge that we possess about the GC has been obtained at infrared and radio wavelengths, using northern hemisphere telescopes. These observations are often hampered by the low elevation of the object, resulting in atmospheric problems and short observing sessions. With its declination of about −30°, the GC becomes almost a zenith object at transit over La Silla and is therefore well suited for studies with SEST.

The inner ten parsecs of the Galaxy contain a giant molecular complex which surrounds the strong continuum radio sources at the nucleus, known collectively as Sgr A. This region somewhat resembles the nuclei of more active galaxies (even to the extent of possibly containing a 3 10^6-$M_\odot$ black hole) and its proximity to us is of course a great advantage, making possible observations with high spatial resolution. The inner one hundred parsecs of the Galaxy contain more exotic objects, such as continuum threads, filaments and arcs, as well as the most significant star-formation region in the Milky Way, namely Sgr B2.

Four GC projects have been in progress during the first year of SEST and more are in the offing in the near future:

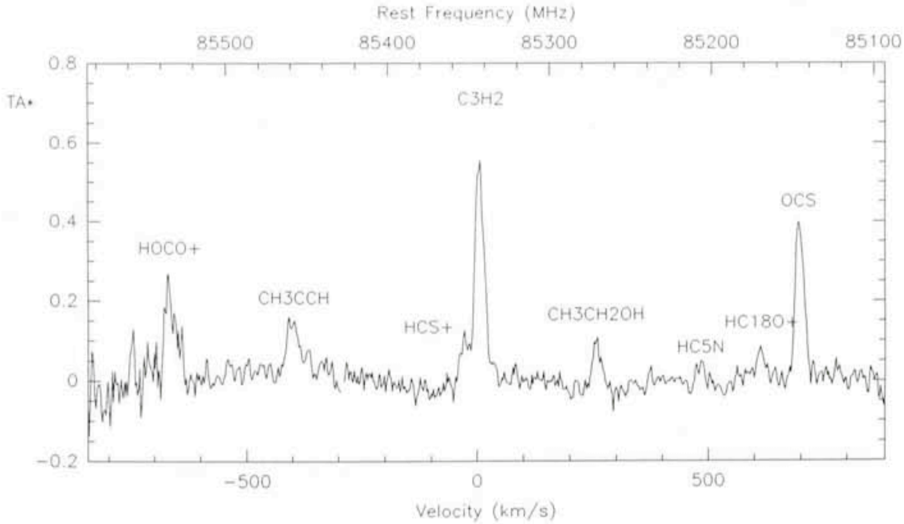


Figure 1: *Part of the spectrum of the Sgr A +20 km s^{-1} molecular cloud covering the frequency range 85.1–85.6 GHz.*

1. Physical Conditions in the Sgr A +20 km s^{-1} Molecular Cloud

A research group from Observatoire de Meudon, consisting of N. Bel, M. Gerin, F. Combes and Y.P. Viala, have observed parts of the massive Sgr A +20 km s^{-1} molecular cloud in a large number of molecular lines in the 85–115 GHz frequency range. Figure 1 is an example of one such spectrum where emission lines from several molecules and molecular ions can be identified, the most intense lines being due to C_3H_2 and OCS. The centre of the cloud was mapped in ^{13}CO, $C^{18}O$, HNCO and CH_3CN with 40″-spacing. Figure 2 presents maps of integrated line intensities ($\int T_A{}^* dv$) in the velocity range 5–25 km s^{-1}. At other frequencies four points were observed roughly along the major axis of the cloud. The main purposes of the project are to obtain a better insight into the physical conditions and clumpiness of the cloud and to determine the heating source (gravitational collapse, cosmic ray, magnetic heating, gravitational turbulence).

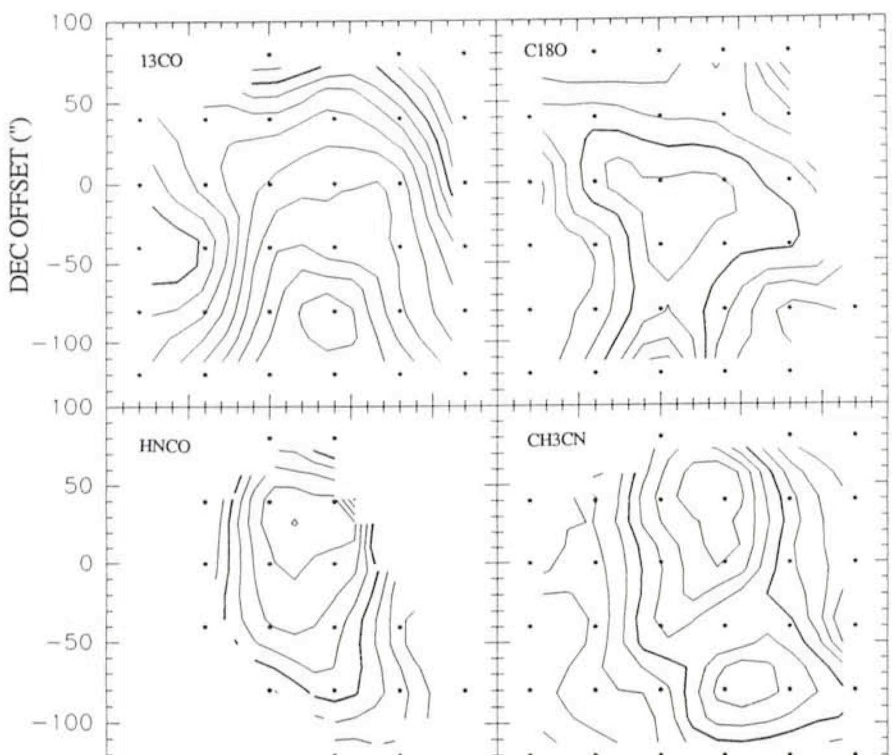


Figure 2: *Maps of the integrated line intensities in the Sgr A +20 km s^{-1} cloud of a) ^{13}CO (J = 1-0), b) $C^{18}O$ (J = 1-0), c) HNCO (5_{05}-4_{04}), d) CH_3CN (J = 6-5), in the velocity range of 5–25 km s^{-1}. RA and DEC offsets are from α (1950) = $17^h42^m29^s.4$, δ (1950) = $-29°03'31''$. Contour levels, in K km s^{-1}, are as follows: a) 45 to 100, step 5, bold at 60; b) 5 to 15, step 1, bold at 10; c) 20 to 60, step 5, bold at 40; d) 4 to 60, step 4, bold at 20.*

2. Prominent Galactic Centre Molecular Clouds

F. Yusuf-Zadeh, M. Lindqvist, J. Bally and L.Å. Nyman have begun a programme of mapping a number of prominent GC molecular clouds (Sgr B, Sgr C, Sgr D, Sgr E) in the 98-GHz J = 2-1 CS and 230-GHz J = 2-1 CO lines. So far, a 10′ × 13′ region around Sgr B1 has been mapped in the CS line with 45″ spacing. The kinematical and spatial distributions of molecular material will be compared with recent 30″-resolution VLA observations of the radio continuum and radio recombination lines. Objectives include determining the reasons for the low rate of massive star formation in the inner few hundred parsecs of the Galaxy (with the exception Sgr B2) and studying the effects of large-scale mGauss magnetic fields.

3. A Multitransition CH_3CN Study of the Sgr B22 Molecular Cloud Core

Another group from Onsala Space Observatory, consisting of P. Bergman, P. Friberg and Å. Hjalmarson, is studying the chemical and physical properties of the giant star formation region Sgr B2, which lies about 100 pc from the GC. Sgr B2 has been found to consist of two major cores – Sgr B2 (Main) and Sgr B2 (North) – separated by about two parsecs. The two cores show remarkable differences in their chemical compositions and excitation parameters. Using two multitransitional mapping tools, supplied by the symmetric top molecule CH_3CN at frequencies of 110 (J = 6-5) and 220 GHz (J = 12-11), the group expects to derive the temperature structure and heating mechanism in these cloud cores as well as the density structure and CH_3CN abundance variations. Figures 3 and 4 show the J = 6-5 $CH_3{}^{12}CN$ and $CH_3{}^{13}CN$ profiles observed towards Sgr B2 (N) and (M), respectively. From the relative intensities of the different K-components and isotopic lines, it can be deduced that Sgr B2 (N) has considerably higher optical depth and kinetic temperature than Sgr B2 (M).

4. Lunar Occultations of Sgr B2 in the J = 1-0 ^{13}CO Line

During 1986–1989 a series of lunar occultations of the GC is taking place, a

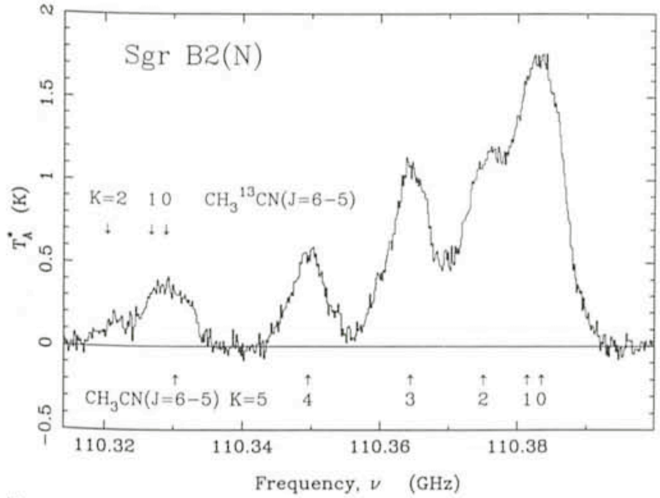


Figure 3: *The line profile of the 110-GHz CH_3CN (J = 6-5, K = 0-5) transitions towards Sgr B2 (N).*

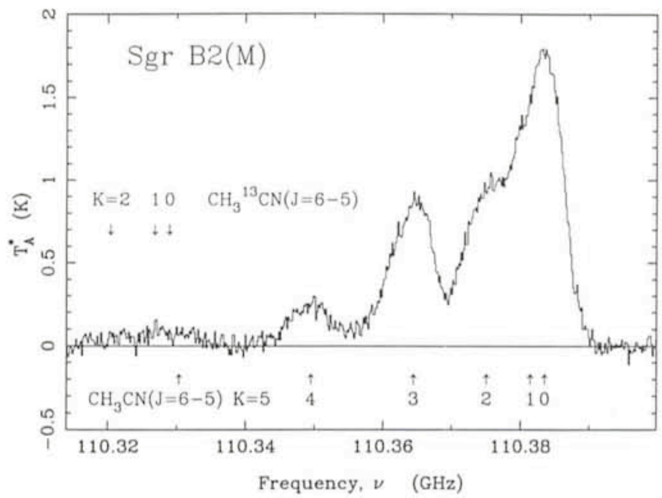


Figure 4: *The line profile of the 110-GHz CH_3CN (J = 6-5, K = 0-5) transitions towards Sgr B2 (M).*

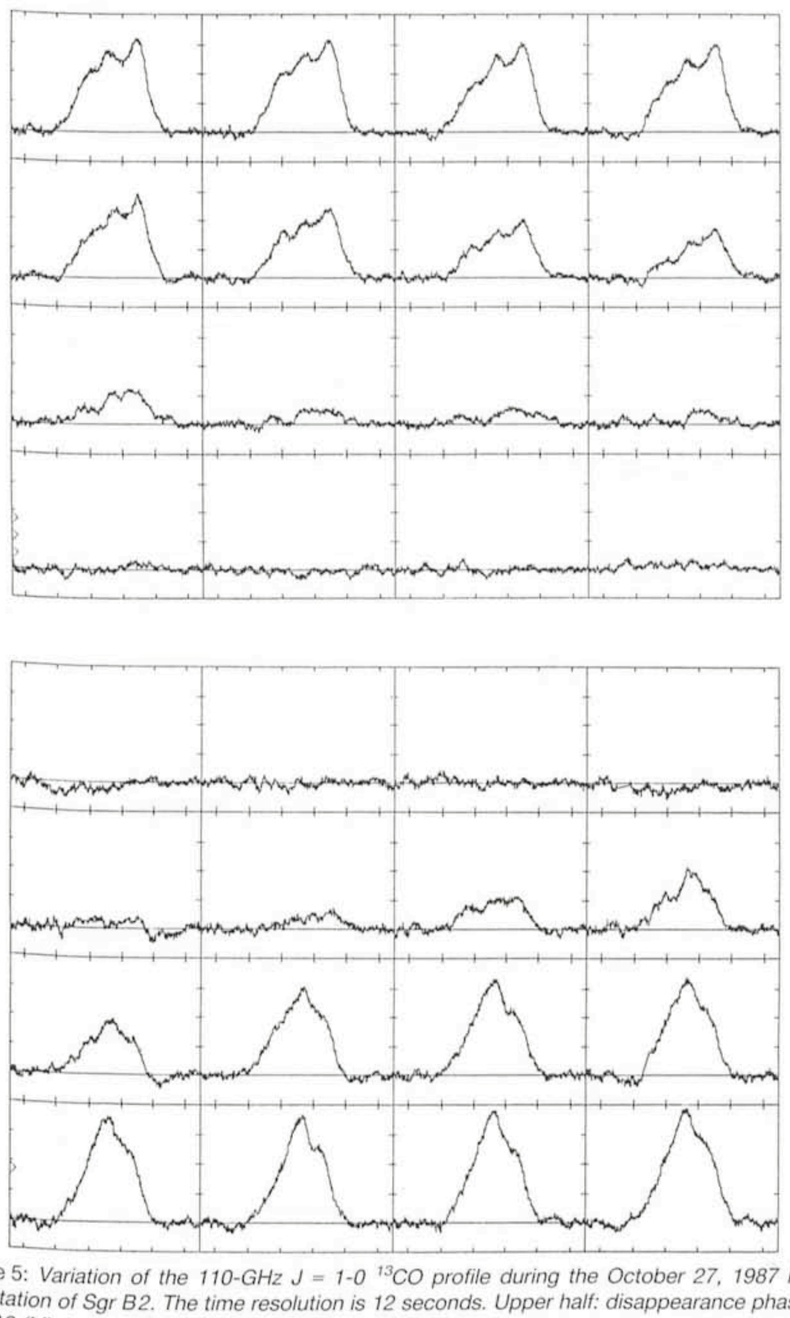


Figure 5: *Variation of the 110-GHz J = 1-0 ^{13}CO profile during the October 27, 1987 lunar occultation of Sgr B2. The time resolution is 12 seconds. Upper half: disappearance phase of Sgr B2 (M); lower half: reappearance phase of Sgr B2 (N).*

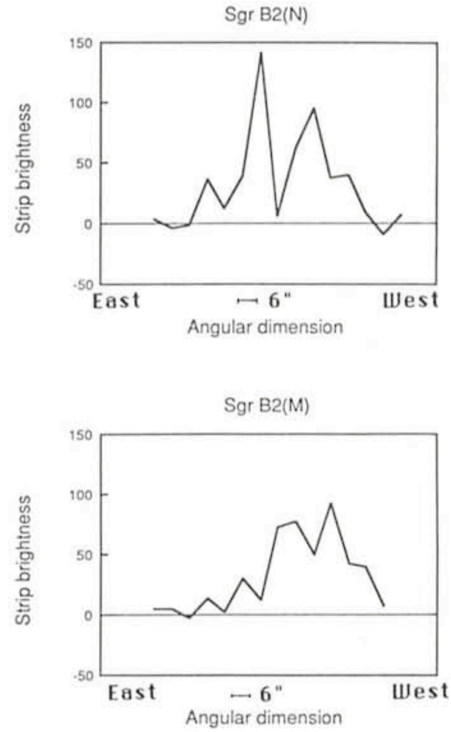
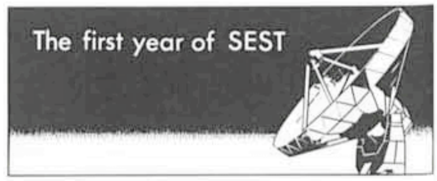


Figure 6: *The restored strip brightness distributions of the integrated line intensity of J = 1-0 ^{13}CO across Sgr B2 (M) at a position angle of 92°, and across Sgr B2 (N) at a position angle of 250°. The effective angular resolution is 6″.*

rare phenomenon. SEST is ideally located for observations of the occultations of Sgr B2 and four occultations have been observed in the 110-GHz J = 1-0^{13}CO line by Aa. Sandqvist, L.E.B. Johansson and P. Lindblad. These data can yield the strip brightness distributions along eight different directions across the sources, four for each of Sgr B2 (N) and (M). Figure 5 shows the variation of the ^{13}CO profile during the disappearance phase of Sgr B2 (M) and the reappearance phase of Sgr B2 (N) on October 27, 1987. The time elapsed between each dumped profile is 12 seconds, which results in an angular resolution of about 6″. This should be compared with the 46″ beamwidth of SEST at 110 GHz. The corresponding restored strip brightness distributions are seen in Figure 6, showing both sources to be double. The combination of all the strips should yield 5″-resolution maps of the two-dimensional brightness distributions of ^{13}CO isotope in Sgr B2 (N) and (M).

SN 1987 A and other Bolometer Observations at 1.3 mm



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Introduction

During August/September 1988 the bolometer group of the MPI für Radioastronomie, Bonn, visited SEST to perform continuum observations at 1.3 mm. It was the first observing time of our group at this telescope and the first sensitive test for SEST at that wavelength. The submm qualities of La Silla were another uncertainty in the mission so that it seemed more than questionable whether any astronomical data would come out of our run.

We started on August 24 to install our bolometer in the receiver cabin of the telescope. This action turned out to be quite an adventure because the access to the cabin door – 9 m above the ground – is only possible from outside via a ladder or a hydraulic platform (cherry picker). During the observing run we had to use the "cherry picker" each day in order to take the cryostat with the bolometer from the telescope, bring it back to the ground and refill with Helium. The ladder was also used very often because receiver alignments and all kind of trouble-shooting in the cabin had to be interrupted at least four times a day to experience La Silla's famous cuisine.

Sub-Millimetre Observing Conditions

The sub-mm-transparency of the atmosphere is – as in the infrared spectral region – confined to a few windows. Most of the radiation is absorbed by the water vapour content of the atmosphere so that dry sites of high altitude are ideal for observations of that kind. The first measurements of the atmospheric transmission on La Silla at 1.3 mm with SEST were quite surprising because we faced conditions as good as those on the 4200 m volcano Mauna Kea in Hawaii, the world's most famous submm site. However, the joy lasted for only a few hours and then we had – despite blue skies – 9 days of only moderately good sub-mm observing weather. Together with the SEST team we used this time to test various properties of the telescope like pointing, tracking and the accuracy of the 15 m diameter surface. The short observing wavelength of 1.3 mm and the superior sensitivity of our bolometer system enabled us to detect telescope errors much more efficiently than with existing receivers at SEST. We located encoder problems which caused tracking errors and found a misalignment of the subreflector that distorted the beam shape.

Unfortunately, SEST was not yet equipped to record our continuum data by the telescope computing system and no on-line reduction of the signals was possible. Likewise, our own PC data acquisition was too busy with taking data so that the strip chart records were the only way of monitoring the observations. Just as we had finished the technical tests and had most of our problems under control, heavy clouds came in and stopped further astronomical activities during the next 4 days. This was the opportunity to summarize our experience with SEST and to discuss further observations that could be reasonably done with the present state of the system. The telescope performance had turned out to be still inferior to what it was supposed to be; any efficient observing procedure was extremely difficult because of the lack of corresponding on-line reductions. Daytime observations were severely limited by an increased turbulence of the atmosphere which resulted in an overall sensitivity-loss of the system. In addition, the reflecting aluminium surface of the telescope had once burnt the subreflector, so we had to avoid the sun by an angle of 60 degrees and, as a consequence, could not reach many interesting objects. In view of all these limitations, the bad weather and the knowledge that only a few days of telescope time were left, a feeling of disappointment set in whenever the dining room was closed.

Observations – At Last!

Finally, it cleared up, the relative humidity dropped below 15 % and the average temperature fell to 3°C, much below the previous values. During the last three days we experienced excellent sub-mm conditions and started with astronomical observations. To observe faint sources with a radio or a sub-mm telescope it is essential to determine the pointing of the telescope by means of nearby strong sources with well-known positions. For that purpose we observed a sample of quasars well distributed across the southern hemisphere and selected those which were strong enough at 1.3 mm, to establish a system of pointing calibrators.

It must be noted of course that all these measurements were new for the southern hemisphere and tell quite a lot about the physical properties of the quasars: Their 1.3 mm radiation is due to fast moving electrons (synchrotron radiation). From the intensity of the emission (in combination with other radio data) one can learn about the energy of the electrons, the strength of the magnetic fields and even about the size of the emitting regions.

The sub-mm emission of most other objects, however, is – as in the near and far infrared spectral region – thermal in origin and comes from interstellar dust that is heated by nearby stars. In particular, star-forming regions are strong emitters of sub-mm radiation because young stars there are deeply embedded in dust clouds. The light at optical and infrared wavelengths is completely absorbed by dust and is re-radiated at longer, i.e. at far-infrared and sub-mm wavelengths. Thus, sub-mm emission is very often the only sign for star formation occurring in dense clouds.

Even more interesting is the search for "protostars", i.e. cool and dense objects of gas and dust which are still in a phase of gravitational contraction. Here it seems that sub-mm observations are the most promising way to detect these cool (≈ 20 K) precursors of stars. We mapped several well-known southern star-forming regions to determine the amount of gas and dust associated with them and to look for condensations which might develop into stars in the future.

Other prominent emitters of sub-mm radiation are external galaxies. Their stellar population heats the galactic dust to temperatures of 20 to 40 K. From the amount of dust one may calculate how much gas is contained in a particular galaxy. This quantity is very important because it finally determines how many stars can be created and how bright the galaxy appears in the sky. We observed a number of galaxies only accessible from the southern hemisphere in order to study the global star formation in these objects.

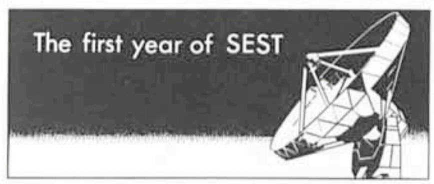
SN 1987A Detected!

As mentioned above, observing conditions improved during the nights and they were best a few hours after midnight. That was the time when all colleagues had gone to bed and the Large Magellanic Cloud came into the field of view. Knowing all the limitations given by the imperfect performance of the telescope, on the one hand, but trusting in the excellent sensitivity of our bolometer, on the other hand, I "wasted" a few hours before sunrise and pointed the SEST towards SN 1987A, the most spectacular event in the southern hemisphere. There was no idea at that time what signal could be expected from this object at 1.3 mm but everybody agreed that it must be extremely faint. In addition, at that time there had been no detections at wavelengths longer than 20 μm so that it was quite a challenge to try the supernova.

During the integration I was carefully watching the strip chart recorder. Sometimes, I had the impression that the pen moved in the right direction when the telescope switched from the source to the blank sky, but this could as well have been a product of my imagination. Nevertheless, after the third night of staring at the strip chart I was sure that there was a faint signal from SN 1987A. Meanwhile our software specialists had reached a stage where they could reduce – to a limited extent – the bolometer signals from SEST. Of course, the first data I suggested looking at were those of the supernova. After a few hours, there was something to celebrate: we had detected very weak 1.3-mm emission from SN 1987A of 29 mJy! To exclude a possible contamination by emission from the LMC, we observed two additional nearby positions, however, without any significant signal. This was the final proof that the observed flux was indeed coming from the supernova.

The origin of this radiation is not quite clear because both emission from hot dust as well as free-free emission from the ionized outer part of the former star may contribute. Combining our data with observations at other wavelengths we come to the conclusion that most of the 1.3-mm flux density is due to free-free emission; dust has formed in the former star's envelope and must be distributed in an extremely clumpy manner. Of course, it will be of interest to study the development of SN 1987A at sub-mm wavelengths in the future and to verify this interpretation. Unlike in other spectral regions – SEST will be the only choice for that purpose in the southern hemisphere.

CO Observations of the Magellanic Clouds

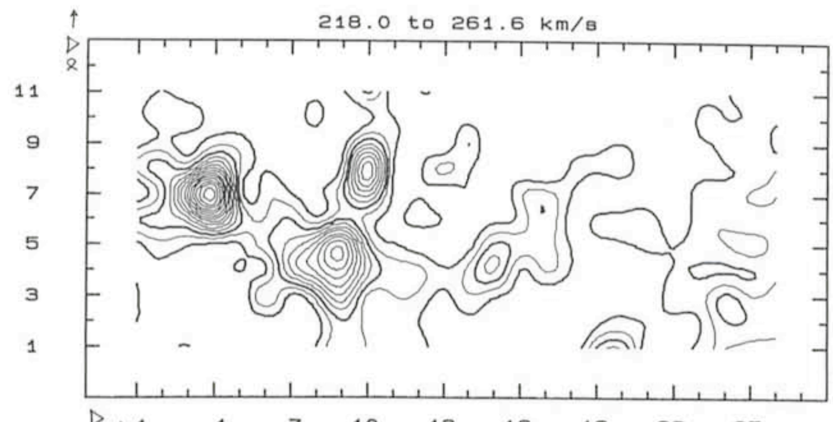


F. P. ISRAEL, Sterrewacht Leiden, the Netherlands

The commissioning of the SEST on La Silla has opened up a new era in the study of the interstellar medium in the Magellanic Clouds. With this telescope, for the first time extensive, detailed studies of the (CO) molecular component of the clouds has become possible. Previously, a rather limited number of sightlines had been sampled with resolutions of 1 to 2 arcmin (see review by Israel, 1984), and a CO map covering the whole LMC, but with a coarse resolution of 8 arcmin (125 pc) was obtained from Cerro Tololo (Cohen et al., 1988).

The SEST, with its 40 arcsec beam at the J = 1-0 ^{12}CO transition and its large aperture, yielding a high sensitivity, thus is a major step forward. It was immediately realized by ESO and by Sweden that a major target for the SEST would be the Magellanic Clouds, objects unique to the Southern Hemisphere, but that a systematic study would require a large block of observing time owing to the large angular dimensions of the Clouds (LMC: 720 SEST beams across; SMC: 180 beams across). This led to the designation of an ESO-Swedish SEST Key Programme 'CO study of the Magellanic Clouds', and the formation of a consortium headed by L.E.B. Johansson (Onsala) and F.P. Israel (Leiden) to conduct this programme.

The programme aims at a systematic study of the CO content of the Magellanic Clouds. Several aspects are of importance. Foremost is a determination of the CO to H_2 ratio, as H_2 is the major molecular component of the interstellar medium, thought to be present in galaxies in amounts comparable to those of H I. This ratio is almost certainly lower than Galactic in low-metallicity, UV-rich galaxies such as the Magellanic Clouds due to stronger photodissociation in such environments. Clue to this important ratio can be obtained from a comparison of (area, position) integrated CO intensities with



Map of the N 160/N 159 region in the LMC in the J = 1-0 ^{12}CO transition integrated over the velocity range 218 to 261 km/s. The two CO clouds slightly left of the centre of the map are associated with N 159. The bright CO cloud at the left is located in a visually inconspicuous region between N 159, N 172 and N 173. The much weaker CO cloud just right of the centre is associated with N 160 (from Booth et al., 1989).

for example virial theorem masses.

Preliminary SEST CO results confirm the estimates by Cohen et al. (1988) that for the same amount of H_2, CO in the LMC is about five times weaker than in the Galaxy. In the SMC the limited data indicate CO to be of order ten times weaker. Curiously, the data in the 30 Doradus region show a trend for the CO to H_2 ratio in the LMC to be closer to Galactic for the largest and most massive clouds (Booth et al., 1989). Clearly, these results are only preliminary and need careful further investigation. The results are of importance, not only for our understanding of the Clouds, but also for interpretation of CO measurements of more distant (dwarf) galaxies.

Another area of interest, also with respect to photo dissociation models and the physical condition of the molecular interstellar medium, is that of the isotopic ratios $^{12}CO/^{13}CO$ and $^{13}CO/C^{18}O$. Under Galactic conditions and opacities, the first is of order 5–8. In the LMC, we have measured several CO emission peaks with $^{12}CO/^{13}CO$ ranging from 7 to 16, with a mean of 9. In the SMC, the (preliminary) mean appears to be around 12. The important result is not that these ratios are significantly higher than in Galactic objects, but rather that they are not even higher. In the one peak (N 159) where all three CO isotopes have been detected we find $^{12}CO : ^{13}CO : C^{18}O = 500 : 70 : 1$ (Booth et al., 1989), which is unusually weak for $C^{18}O$. Again, more measurements and careful modelling are needed before final conclusions are drawn; such measurements are in progress.

Both the limited maps obtained during commissioning (Booth et al., 1988) and a several degrees long, fully sampled scan at constant right ascension through 30 Doradus, N 158, N 160 and N 159 show the presence of a significant, rather clumpy molecular complex, extending well southwards of optical objects such as N 159. The same complex, clumpy molecular cloud structure has been found to be associated with the large H II region complex N 11 in the northwest of the LMC, which has been fully mapped. Detailed studies of such regions are of importance, because combination of the molecular data with IRAS infrared maps, and abundant optical information yields insight into the large-scale process of star formation that gave rise to the existence of such H II region complexes.

In the SMC, it was found that IRAS sources were about the only reliable detection criterion for molecular emission. In this galaxy, CO is generally weak and predominantly seen in the southwest end of the bar, although clouds are present throughout the SMC. Several small clouds (about 30 pc in size) have been mapped in the SMC, notably those associated with the H II regions N 12, N 27 and N 88. Mapping of the southwest bar, and of individual clouds throughout the SMC is in progress, but the going is slow because of the weak CO signals, and consequently long integration times (of the order of 30 minutes per point) needed.

The above is merely a first glimpse of the molecular population of our nearest extragalactic neighbours in space. Much work remains to be done before the important questions on physical conditions and processes can be answered with confidence. This first glimpse, however, is an exciting preview of things to come.

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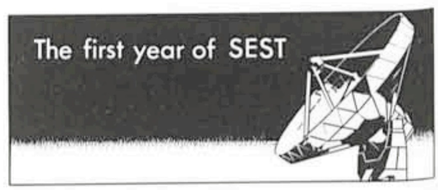
CO Isotopic Emission and the Far-Infrared Continuum of Centaurus A



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Introduction

Centaurus A (NGC 5128) is a peculiar elliptical galaxy with a prominent dust lane. At a distance of about 3 Mpc (*The Messenger* No. **44,** p. 1) it is the closest radio galaxy, and to date it has been observed in almost every accessible wavelength band. Here we report on recent measurements with the SEST telescope which have contributed to our understanding of the molecular interstellar medium in this spectacular object.

First we briefly describe the status of the observations at other wavelengths. The cm-radio emission of Centaurus A is characterized by a compact milliarcsecond core (Kellermann 1974, Shaffer and Schilizzi 1975) and, on larger angular scales, a jet extending over several arcminutes (Burns et al., 1983) with giant radio lobes on either side of the dust lane. The warped dust lane (Bland et al., 1987) and a system of faint, narrow shells around the elliptical galaxy (Malin et al. 1983) suggest that Centaurus A is a relaxed remnant of a merger of a disk and an elliptical galaxy. Centaurus A is also a strong source in the X-ray (Feigelson et al., 1981) and γ-ray domain (von Ballmoos et al., 1987). Observations prior to 1983 are summarized in the review article by Ebneter and Balick (1983).

Investigation of the interstellar medium in Centaurus A has begun only recently. A map of the 21-cm H I emission, which traces the bulk of the atomic gas, has been obtained by van Gorkom (1987). The molecular interstellar medium can be traced by line emission of CO, the second most abundant molecule in the universe. The ^{12}CO J = 2-1 emission in the dust lane has been partially mapped by Phillips et al. (1987) at the CSO in Hawaii. Furthermore at the nucleus the 158 μm [C II] fine structure line has been measured (Crawford et al., 1985). This is one of the brightest far-infrared cooling lines and is indicative of photoionization regions which originate when strong UV light illuminates the surfaces of adjacent molecular clouds.

Observations with SEST

Since Centaurus A is a southern source, the SEST telescope is ideally placed to investigate its millimetre and submillimetre radiation and, to date, two independent observing programmes have been carried out in order to study the molecular interstellar medium. This phase of the interstellar medium is of particular interest since it is intimately related to the star-formation process in galaxies. Eckart et al. (1989) obtained a complete map of the ^{12}CO J = 1-0 line emission (Fig. 1) and measured the ^{12}CO J = 2-1, ^{13}CO J = 1-0, and the $C^{18}O$ J = 1-0 lines at selected positions. Israel et al. (1989) have studied the absorption

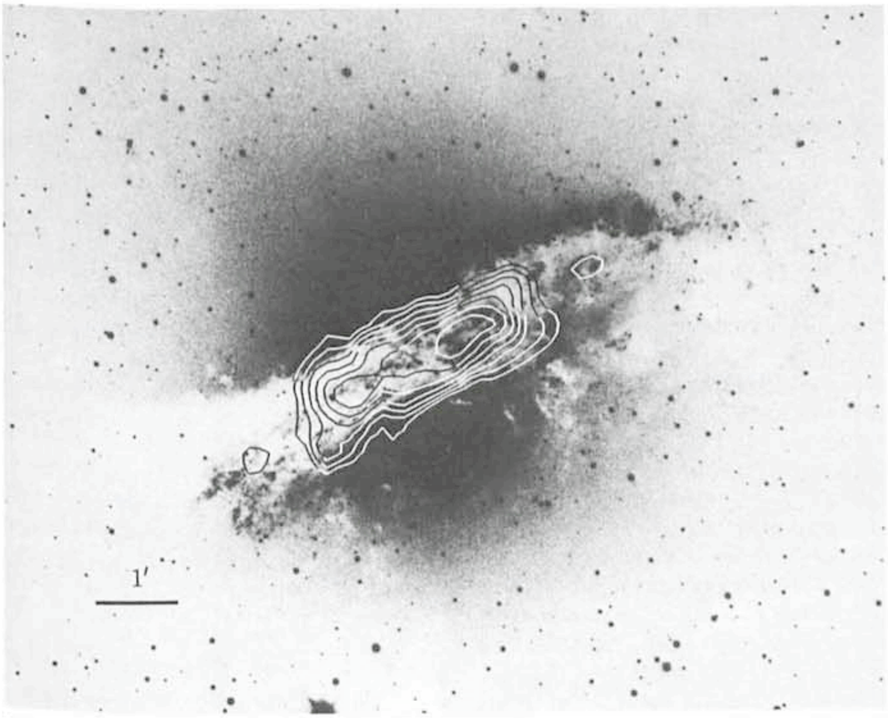

Figure 1: *Contour map of the integrated ^{12}CO J = 1-0 emission of Centaurus A superimposed on an optical image. The emission is well concentrated along the dust lane. Contour intervals are 17.5, 22.5, 27.5, . . . K km s^{-1}. The peak intensity is 54 K km s^{-1}.*

features in the CO lines against the nuclear continuum source.

The main results of these observations are that the bulk molecular material is closely associated with the dust lane and contained in a disk of about 180″ diameter with a total molecular mass of about 2 10^8 $M_\odot$. The total molecular mass of the disk and bulge is of the order of 3 10^8 $M_\odot$. The molecular gas in the nucleus is warm with a kinetic temperature of the order of 15 K and a number density of 10^3 to 3 10^4 cm^{-3}. Absorption features in the ^{12}CO and ^{13}CO lines against the nuclear continuum indicate that the properties of giant molecular clouds are comparable to those in our Galaxy.

Comparison with Other Data

The molecular data have been combined with 100 μm and 50 μm far-infrared emission of Centaurus A in order to study the variations in the gas and dust distributions (Eckart et al., 1989). These far-infrared data were taken with the CPC instrument on board IRAS and show that the dust temperature in the dust lane is about 42 K. The ratio between the far-infrared luminosity and the total molecular mass is 18 $L_\odot/M_\odot$ which is close to the mean value obtained for isolated galaxies. For giant molecular cloud complexes in our Galaxy, this ratio is of the order of 1 to 10 $L_\odot/M_\odot$. A comparison of the ^{12}CO J = 1-0 and the far-infrared data indicates that a considerable amount (about 50%) of the far-infrared emission at 100 μm is not intimately associated with massive star formation. This emission is larger in extent than the molecular disk and is probably due to diffuse gas clouds in Centaurus A, similar in nature to the "cirrus" emission in our Galaxy.

The absorption features detected in the CO emission lines are coincident with known H I, C_3H_2, and H_2CO absorption lines, although the molecular content of gas in red and blue shifted clouds (with respect to the centre velocity of v_{LSR} = 550 km s^{-1}) seem to be different. A combination of new molecular data obtained with the SEST, H_2 emission from an unresolved nuclear source measured with the 3.6-m telescope at La Silla (Israel et al., 1989), and literature data suggest that the nucleus of Cen A is surrounded by a disk of 2 10^7 $M_\odot$. Such a disk, with an outer edge radius of 160 pc and with a density distribution of $n \propto r^{-2}$, is consistent with all existing observations of the nuclear region of Centaurus A.

Future observing programmes that are currently in progress or have already been scheduled will investigate the distribution of the molecular material with the highest possible spatial resolution, the molecular line emission in high density tracers – such as HCN, CS, and HCO^+, as well as the absorption features in those species. A combination and detailed analysis of these data will cast more light on the nature of the interstellar medium and star formation in Centaurus A and elliptical radio galaxies in general.

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Molecules in External Galaxies

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The 15-m SEST telescope is the unique facility to study with high resolution the molecular component of galaxies in the southern sky. One could object that galaxies in the northern sky already give a large enough sample to investigate, but there are outstanding objects that can only be studied from the southern hemisphere; apart from the obvious Magellanic Clouds, it is well known that most beautiful barred galaxies, for example, are at low declinations (NGC 1300, NGC 1365, NGC 1097 ...). For this first year of operation, extragalactic astronomers have explored all types of galaxies, at all distances, from the nearest spirals (the equivalent of Andromeda in the North), to the outskirts of the detectable molecular sky, at redshifts of $z \approx 0.1$.

1. Nearby Spirals

Nearby galaxies, like the Magellanic Clouds (see the article by F. Israel in this issue of the *Messenger*), give the opportunity to study Giant Molecular Clouds (GMC) one by one, almost un-diluted in the 45″ beam of the SEST at CO (1-0) frequency, and even less with the 23″ CO (2-1) beam. One can then learn whether the physical nature of their clouds is similar or not to the Milky Way's; this is useful in particular to confirm the universality of the $N(H_2)/I(CO)$ conversion ratio, widely used by millimetric radioastronomers (I(CO) is the integrated CO emission).

The NGC 300 galaxy, an Sc spiral in the Sculptor group, is a good object for such a study (45″ = 360 pc). Albert Bosma, from Marseille Observatory (France), has observed 19 positions in this galaxy, corresponding to H II regions. Signals are very weak, lower than 1 Kkm/s in integrated CO emission. The derived H_2 masses in each complex are between 1 and $5 \cdot 10^5 M_\odot$, i.e. even less massive than the GMCs in our own Galaxy. Yet the surface explored in each beam is larger than a GMC's surface. This kind of weak and very narrow profiles has already been seen in northern nearby galaxies, like in M33 and M81. It is important to better study these objects, since their weak abundance of molecules is still a complete mystery.

In the nearby and almost edge-on barred galaxy NGC 4945, J. B. Whiteoak (CSIRO, Australia), M. Dahlem (MPIfR, Bonn, FRG), J. Harnett (CSIRO) and R. Wielebinski (MPIfR) have obtained 270 CO (1-0) spectra. They have identified five velocity components in the central region. Only three of them are in the nucleus, as shown by OH absorption spectra taken at 6 GHz with the Australian radio telescope. The two outside components seem to come from a rotating ring-like structure: they correspond to two peaks at 460 and 640 km/s (on each side of the systemic velocity), separating the rigid rotation curve inside 100″ of radius, from the differential rotation beyond. Such a ring at the radius of maximum rotation velocity is expected in barred galaxies, as discussed now.

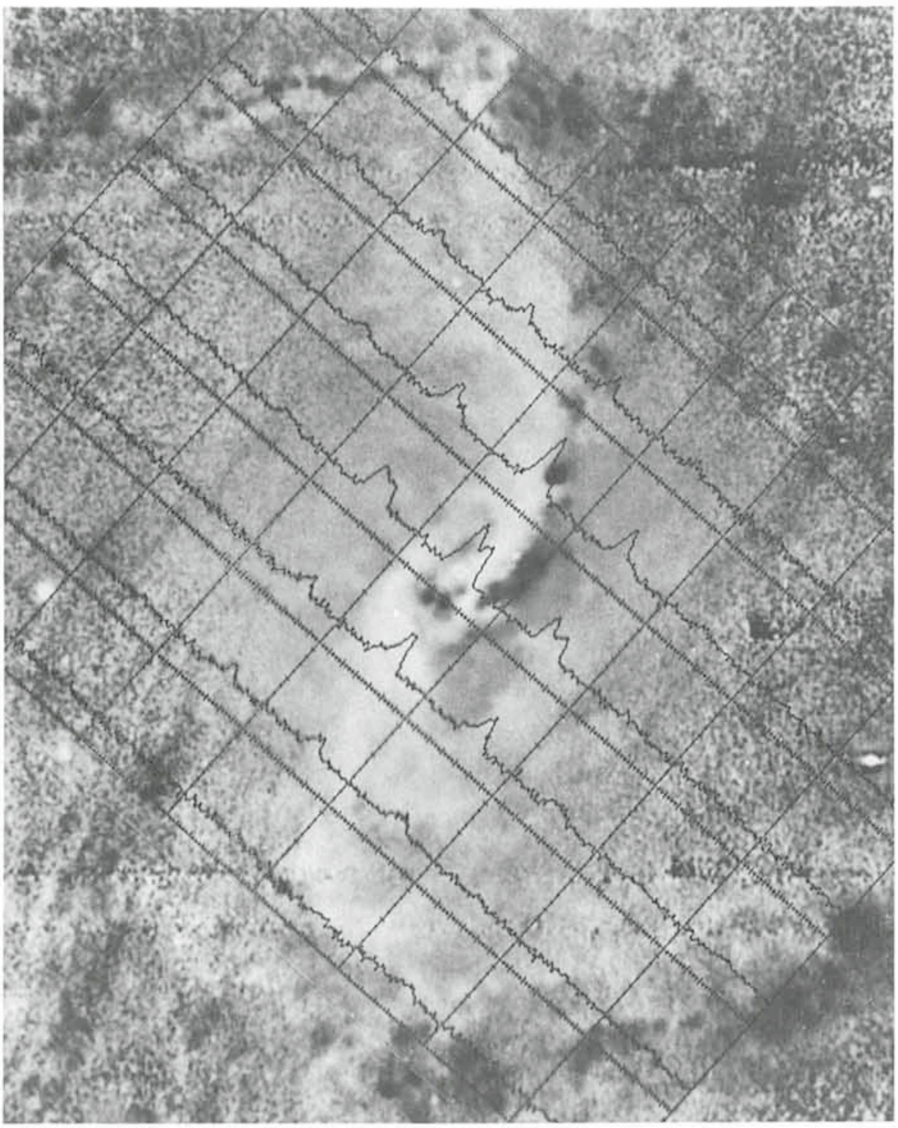

Figure 1: *Gunn z colour image of NGC 1365 showing the dust (light areas) as well as regions with hot stars and H II regions (dark areas). The overlay shows the J = 1-0 CO profiles observed with SEST on a 20″ grid. The velocity scale goes from 950 to 2250 km/s, the antenna temperature scale from −0.12 to 0.36 K.*

2. Barred Galaxies

Barred galaxies possess most of the time strong spiral density waves, and the gas component is essential for the persistence of these waves. The gas behaviour in a barred potential has been the subject of many theoretical studies and hydrodynamic simulations. It is expected that cloud collisions will deflect the cloud orbits with respect to those of stars, that are ellipses aligned with the bar. These gradual deflections produce the spiral wave. The gravitational torque exerted by the bar on the spiral will drive gaseous radial transport from the end of the bar towards the centre. When there exists an inner Lindblad resonance, the gas will accumulate in rings. As the inner resonance always occurs near the maximum of the rotation curve, the ring is predicted to be located there, in good agreement with the nuclear rings that are often observed in hot spot galaxies. The rings contain conspicuous H II regions, tracers of intense star formation.

The molecular clouds are therefore expected by theory to be highly centrally concentrated in barred galaxies, and to follow the spiral structure in the disk. N. Loiseau (INPE, Brazil), J. Harnett (CSIRO, Australia), E. Bajaja (Argentina) and H.-P. Reuter (MPIfR, Bonn, FRG) have started observational projects on barred galaxies, to test these models, and in particular whether the gas reveals peculiar velocities that could be interpreted as inflow towards the centre. It is expected that starburst or even nuclear activity could be triggered by the effect of the bar. Results obtained towards the barred spiral NGC 613 have already been reported by Bajaja and Hummel in the *Messenger* No. **55** (March 1989).

A beautiful southern barred spiral is the Seyfert galaxy NGC 1365. Sandqvist et al. (1989) are in the process of map-

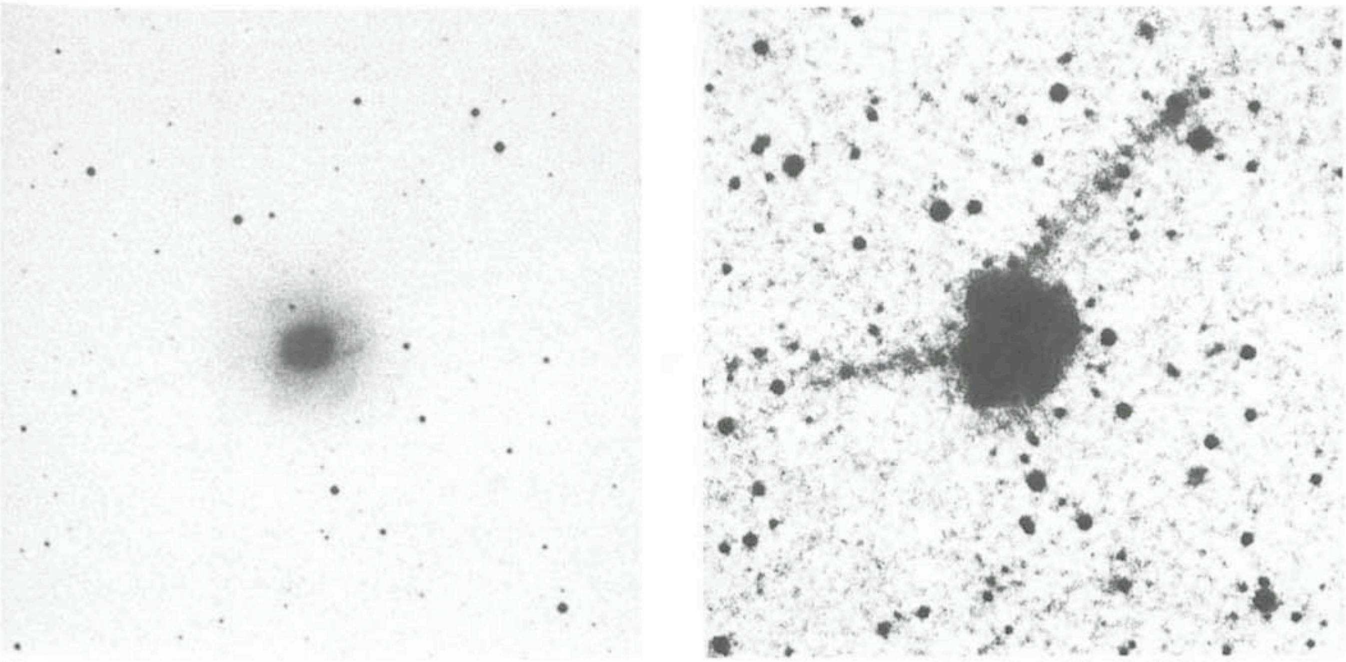

Figure 2: *Optical photograph of NGC 7252, reproduced from IIIa-F + RG 630 plate, obtained for the ESO red half of the ESO/SERC Survey of the Southern Sky. (a) inner structure; (b) showing outer arms. Photographic work by H. Zodet.*

ping it in the two CO lines (1-0) and (2-1). On the photograph in Figure 1 is superimposed a map of CO (1-0) spectra obtained so far. An interesting result is that spectra in the centre present two velocity components, revealing a deficiency of CO emission at the systemic velocity. This behaviour suggests the presence of a ring of molecular clouds inside the bar, supporting the results of hydrodynamical models in barred systems (Schwarz 1984, Combes and Gerin 1985).

In collaboration with M. Gerin (Paris), N. Nakai (Nobeyama) and J.M. van der Hulst (Groningen) we have mapped the barred galaxy NGC 1097, which is the prototype of the nuclear ring barred spiral. From previous observations with the 45-m of Nobeyama (Japan), and the 30-m of IRAM, we determined that molecular clouds are tracing the nuclear ring (Gerin et al., 1988). With the SEST 15-m we mapped the whole extended disk, and discovered that most of the mass has accumulated towards the centre: about 50% of the mass is found in the central beam, i.e. within a radius of 1.7 kpc, and we know that it is evenly diluted in the central beam, according to the higher resolution observations. Bars are indeed able to drive the gas inwards, as predicted by theoretical models.

We have also undertaken a survey of galaxies with Hα rings, to check the prediction that most molecular clouds may be accumulating in these features (Combes, Gérin and Buta, 1989). CO rings cannot be seen directly but they are revealed by typical two-horn-profiles (such as seen in NGC 1365).

NGC 1808 is a spectacular barred galaxy, where dust filaments seem to emerge from the plane. It was mapped in CO by M. Dahlem, U. Mebold, U. Klein (MPIfR, Bonn, FRG) and R. Booth (Onsala, Sweden). The central area shows ring-like rotation. The velocity peaks correspond to the maximum of the rotation curve. The optical filaments have a molecular gas counterpart: CO outflows are normally observed to the major axis. Is the central starburst the cause of this gas ejection, as is proposed in M82?

3. Interacting Ring Galaxies

Another kind of ring morphology is obtained with nearly head-on collisions between galaxies. The prototype of these objects is the Cartwheel. The tidal phenomenon has been simulated with great success by Lynds and Toomre (1976) and Theys and Spiegel (1976). The main observational difference with previous rings is that stars participate in the ring structure, and not only the gas. Also the radii of these rings are much larger than those of the gaseous nuclear rings. Is the gas compressed in the density wave that corresponds to the ring? Sometimes the ring can be decomposed in knots: do they correspond to star formation? We have discovered CO emission in two of these ring galaxies, IC 4448 and AM 064-741 (F. Casoli, F. Combes, C. Dupraz from the Paris group). The 45″ resolution does not enable us to distinguish between nuclear or ring emission, but in AM 064-741 the kinematics suggest that the CO emission comes from the nucleus. Further observations (in particular in CO (2-1)) are needed.

4. IRAS Galaxies and Mergers

Far-infrared observations by IRAS have revealed that galaxy mergers can trigger huge starbursts: most of the ultraluminous IRAS galaxies, that radiate 90% or more of their total luminosity in the infrared, are interacting galaxies and mergers.

One problem in these actively star-forming objects is to determine the gas excitation. Indeed, it is likely that the gas is heated by the starburst, and becomes less optically thick in the CO lines. This would yield an overestimation of the total molecular mass, if standard $N(H_2)/I(CO)$ conversion ratios were used. Such a phenomenon occurs in the central part of Messier 82, where the CO (2-1)/CO (1-0) integrated emission ratio R between the two rotation lines of CO, reaches 4 in some regions, indicating a large fraction of hot optically thin gas.

NGC 3256 has been observed by C. Dupraz, F. Casoli and M. Gerin in the two CO lines with the SEST 15-m telescope. The ratio R is about 1, but the surprise was in the weakness of the ^{13}CO (1-0) emission with respect to the ^{12}CO (1-0) one. The integrated emission ratio between the two isotopic molecules is about 30, while it is around 10 in most ordinary galaxies. This high ratio indicates that the gas is optically thinner than usual. The very peculiar line ratios in this object may be due to it being a

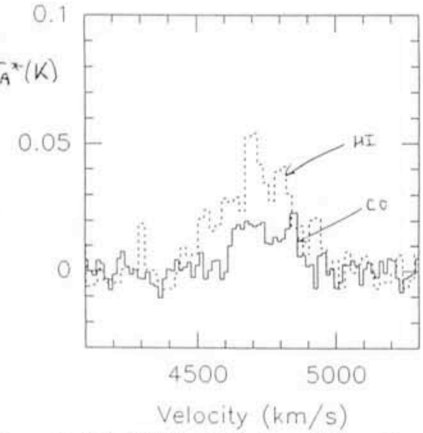

Figure 3: *NGC 7252: CO (1-0) and HI profiles towards this newly-born elliptical galaxy.*

merger between two equal-mass spiral galaxies, as suggested by its very perturbed appearance, with two tidal tails.

If the infrared luminosity L_{IR} is re-radiated by dust heated by the recent star formation, the ratio $L_{IR}/M(H_2)$ is an indicator of star-formation efficiency. These interacting and merging galaxies have the highest known ratios: $L_{IR}/M(H_2)$ of the order of 50 or greater, while it is of the order 1-3 in normal galaxies. There is also the possibility that a significant part of L_{IR} comes from dust heated by an active nucleus (in that case the emission region is highly confined towards the centre), so that the ratio $L_{IR}/M(H_2)$ is not a good indicator of star-formation efficiency. However, high $L_{IR}/M(H_2)$ ratios are still found in galaxies without nuclear activity.

The life time of the star burst can be extrapolated from these efficiencies. In time scales of a few 10^8 yrs, the merger remnants should become devoid of molecular gas. This result supports the currently well-developed idea that the merging of two spirals will form an elliptical galaxy, devoid of cold gas. An ideal object to test this hypothesis is the southern merger remnant NGC 7252, one of the pet galaxies of François Schweizer (1982). This object is conspicuous by its two tidal tails, that represent the "smoking gun" evidence of the merging of two spiral galaxies (Fig. 2). Numerous loops, shells and ripples add to the evidence. The luminosity profile is surprisingly regular and follows the $r^{1/4}$ law, characteristic of ellipticals, until a large distance. Yet this object was seen to be very rich in molecular gas (Dupraz et al. 1989): about $3\ 10^9\ M_\odot$, within 7 kpc. The observed line shape suggests that the CO emission comes from matter confined to a disk, which is also observed in Hα. This surprising result indicates that not all of the molecular gas is consumed in the star burst, as previously thought, or that matter continues to fall down onto the disk, long after the merging event.

At higher redshifts, the galaxies that can be detected in CO are all monsters: huge starburst galaxies, corresponding to interacting or merging objects, the frequency of mergers being probably higher in the past. The ultraluminous IRAS objects have luminosities larger than $10^{12}\ L_\odot$. Mirabel et al. (1988) have detected four of these monsters, possessing 1-6 $10^{10}\ M_\odot$ of molecular gas. Their $L_{IR}/M(H_2)$ ratio is between 20 and 80, much larger than in classic starburst galaxies, like Messier 82. The highest systemic velocity among these objects is 27,500 km/s, which demonstrates the ability of the SEST 15-m telescope to detect faint and broad emission lines.

This brief survey, far from exhaustive, already shows how exciting extragalactic work can be with the SEST 15-m telescope!

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Extragalactic Continuum Sources

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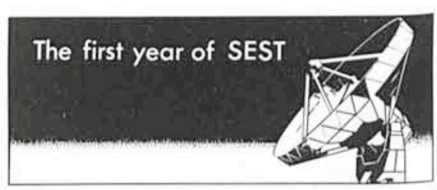

Introduction

As with most other high-frequency radio telescopes, continuum work occupies only a small fraction – currently about 5% – of SEST's total time. The importance of these observations in increasing our understanding of quasars and other extragalactic sources is, however, large.

The millimetre-to-IR observations probe the innermost parts of the radio-emitting regions of active galactic nuclei: the radio cores, possibly the beginnings of radio jets, become optically thin on mm-wavelengths, where also the outbursts reach their maximum stages. As these regions remain below the resolving power and above the standard frequencies of VLBI, high frequency flux measurements give us our only glimpses of the very cores, the still mysterious sites of energy generation and channelling in active galaxies. Long wavelengths ("long" in the case of quasars meaning everything longer than one centimetre) show only evolved structures, such as old, ejected knots; the millimetre regime is where the real action is.

Most events seen at centimetre wavelengths have their precursors on higher frequencies. This forewarning capacity is especially useful for space VLBI purposes in choosing the best "targets of opportunity" for observations. The millimetre spectrum and its variations can also tell if compact structure is present in the source, and whether it will be a good candidate for VLBI observations; with sufficient flux data it may even be possible to produce model maps of the sources. Clues to the nature of different radio sources must also be searched at high frequencies.

While SEST opens up completely new southern vistas, its location also presents some problems in continuum work. The continuum observer dreams of uninterrupted multifrequency lightcurves revealing the various constituents and processes found in Active Galaxy Nuclei (AGN), but the reality usually shrinks to a scatter of isolated flux measurements. In most cases, one would greatly benefit from supporting data on other frequencies, but there are not many Southern telescopes available for that purpose.

SEST Measurements

During its first year SEST has been used for most of the purposes outlined above, with the continuum work divided roughly equally between Swedish and Finnish groups. Most of the data have been obtained at 90 GHz, although the groups have been striving to get also more 230 GHz observations.

The obvious starting point has been to get acquainted with the new part of the sky. Several surveys of the southern skies are now in progress. N. Whyborn is observing a complete sample of bright, flat-spectrum radio sources below declination −25°, and a similar survey between 0° and −25° is in progress by E. Valtaoja. These surveys are first steps in gathering basic knowledge of Southern hemisphere sources: their high frequency spectra, variability, degree of compactness, etc., data which can be used both for statistical studies and for selecting exciting individual objects as targets for future investigations.

Selected subsets of sources have also been observed: southern BL Lacs and highly polarized quasars (H. Teräsranta), radio quiet quasars (A. Kus), and sources observed in TDRS satellite space VLBI experiments (R. Booth). As the sources typically are observed at two or more epochs for variability estimates, most of the work is still in progress.

The Finnish group has used SEST to extend their long-time monitoring programme to higher frequencies. About 12 of the most active and well-known equatorial blazers have been observed roughly semimonthly in Chile. Although the "high" (i.e., Northern) declinations of some of these sources have caused some grumbling in the programme committee, the SEST data fill a crucial gap between lower frequencies (Metsähovi, Itapetinga, Crimea) and IR observations (Hawaii) in what remains the most extensive international effort to understand the radio behaviour of AGN. Multifrequency monitoring has made possible the separation of outbursts from the underlying other components, showing that shocked jet models give at least a first approximation of what is going on in variable radio sources. Much remains to be done, however: even the best observed quasar, 3C 273, continues to behave in a highly erratic and surprising manner.

Harri Teräsranta from the Metsähovi Radio Research Station summarizes the experience of the first year as follows: "90 GHz flux measurements are now relatively routine work. The actual rms levels achieved with 30 min integration times have been from 40 to 80 mJy. 230 GHz observations require good weather, and it would be better to have the observing run spread over a longer time span with several shorter sessions to maximize the chances of success. The observing times should be nearly 1 hour for one source if rms values of 0.2 Jy are to be expected."

Future Programmes

The future will probably see a shift from general surveys to dedicated monitoring of selected sources, hopefully with increasing co-operation from other Southern telescopes to get the most out of the observations. With new receivers and increased experience, submillimetre observations will come to the forefront: one of the challenges is to follow the entire early evolution of a synchrotron flare in order to develop second-generation models for the growth of shocks in relativistic jets.

Still another field where SEST's impact will certainly be felt in the future is millimetre VLBI, both on the ground and in space.

Visiting Astronomers

(October 1, 1989 – April 1, 1990)

Observing time has now been allocated for Period 44 (October 1, 1989 – April 1, 1990). The demand for telescope time was again much greater than the time actually available.

The following list gives the names of the visiting astronomers, by telescope and in chronological order. The complete list, with dates, equipment and programme titles, is available from ESO-Garching.

3.6-m Telescope

Oct. 1989: Marano/Cappi/Held, Bender et al., Kudritzki/Husfeld/Gehren/Groth/Butler/Baade/Rosa/Humphreys/Hummer, Ögelman/Gouiffes/Melnick/Hasinger/Pietsch/Pedersen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Nissen/Schuster, Fleming, Guzzo/Tarenghi, Iovino/Shaver/Cristiani/Clowes/Pierre, de Lapparent et al.

Nov. 1989: de Lapparent et al., Guzzo/Collins/Nichol, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Gry/Jourdain de Muizon/Lagrange-Henri/Vidal-Madjar/Ferlet, Wampler, Molaro/Castelli/Bonifacio, de Boer et al., Schwope/Beuermann, Breysacher/Azzopardi/Lequeux/Meyssonnier/Westerlund, de Boer et al., Marano/Mignoli/Zitelli/Zamorani.

Dec. 1989: Barbieri/Clowes/Cristiani/Iovino/La Franca/Vio, Melnick/Gopal-Krishna/Steppe/van Drom, Ögelman/Gouiffes/Melnick, Hasinger/Pietsch/Pedersen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Ardeberg/Lindgren/Lundström, de Boer et al., Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Madejsky/Rabolli/Vega/Bassino, Hamann/Schmutz/Wessolowski, Tadhunter/Fosbury/Morganti/Danziger/Di Serego Alighieri.

Jan. 1990: Lortet/Testor/Schild, Ögelman/Gouiffes/Melnick/Hasinger/Pietsch/Pedersen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Perrier/Mariotti/Mayor/Duquennoy, Renzini/D'Odorico/Greggio/Bragaglia, Melnick/Gopal-Krishna/Steppe/Van Drom, Surdej et al., Chiosi/Bertelli/Bressan, Nasi/Ortolani/Vallenari/Gratton/Meylan, Heske/Jourdain de Muizon.

Feb. 1990: Jourdain de Muizon/D'Hendecourt, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Ögelman/Gouiffes/Melnick/Hasinger/Pietsch/Pedersen, D'Odorico, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Wehrse/Hessman, Bergeron/Petitjean/D'Odorico, Sparks/Macchetto/Ögerle, Nørgaard-Nielsen/Joergensen/Hansen.

March 1990: Boulesteix/Capaccioli/Corradi/Le Coarer, Duval/Boulesteix/Monnet/Corado, Ögelman/Gouiffes/Melnick, Hasinger/Pietsch/Pedersen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Reipurth/Dubath/Mayor, Capellaro/Held, Bender et al., Balkowski/Kraan-Korteweg/Maurogordato, Mazure et al.

3.5-m NTT

Jan. 1990: Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Schneider/Giraud/Wambsganss, Bignami/Caraveo/Mereghetti/Mignami, Mellier/Fort/Soucail.

Feb. 1990: Miley et al., Surdej et al.

March 1990: Barthel/Djorgovski/Tytler, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Tsvetanov/Fosbury/Tadhunter, Bergeron et al., Bender et al.

2.2-m Telescope

Oct. 1989: MPI TIME, Van der Kruit/De Jong RS, Hunt/Mandolesi/Wade, Ferraro/Brocato/Fusi Pecci/Buonanno, Piotto/Bresolin/Capaccioli/Ortolani, Bertola et al.

Nov: 1989: Bertola et al., Collins/Guzzo/Nichol, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, test new array (Moorwood), des Boer et al., Barbieri et al., de Boer et al., Appenzeller/Wagner/Weigelt/Barth/Weghorn/Grieger, Surdej et al.

Dec. 1989: Weigelt/Barth/Grieger/Weghorn, de Boer et al., Paresce/Panagia/Gilmozzi, Rafanelli/Capaccioli/Marziani/Schulz H. Tadhunter/Fosbury/Morganti/Danziger/Di Serego Alighieri, Reiputh/Olberg/ Cameron/Booth, Rafanelli/Capaccioli/Marziani/Schulz H.

Jan. 1990: Busarello/Longo/Feoli, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, MPI TIME.

Feb. 1990: Van der Veen/Blommaert/Habing, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Schwarz/Moneti, Pottasch/Manchado/Garcia Lario/Sahu, Nota/Clampin/Paresce/Ferrari, Falomo/Maraschi/Tanzi/

Treves, Hansen/Joergensen/Nørgaard-Nielsen, Dennefeld/Martin J.M./Bottinelli/Gouguenheim, Tosi/Focardi/Greggio/Marconi.

March 1990: Miley et al., Ortolani/Capaccioli/Piotto, Capaccioli/Bresolin/Della Valle/Piotto,Held/Capaccioli/Richtler/Wagner, Van Haarlem/Katgert, Bienayme/Crézé/Robin, Bender et al., Durret/Bergeron/Petitjean.

1.5-m Spectrographic Telescope

Oct. 1989: Thevenin/Jasniewicz, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Boisson/Collin-Souffrin/Joly/Ward, Johansson L./Bergvall.

Nov. 1989: Balkowski/Maurogordato/Proust, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Gehren/Steenbock/Reile/Axer/Burkert/Fuhrmann, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Cappi/Focardi/Gregorini/Garilli/Maccagni, Prieur/Oosterloo/Wilkinson/Sparks/Carter, Barbieri et al., Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson.

Dec. 1989: Longo/Busarello/Ceriello, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Pasquini/Brocato/Barbuy/Pallavicini, Hunger/Heber/Groote, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Pakull/Motch/Bianchi/Beuermann, Reipurth/Olberg/Cameron/Booth, Lub/De Ruiter.

Jan. 1990: Lub/De Ruiter, Lortet/Testor, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Gerbaldi et al., Renzini/D'Odorico/Greggio/Bragaglia, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Lundgren, Bhatia/Chiosi/Piotto/Ortolani/Bertelli/Vallenari/Malagnini/Macgillivray, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Courvoisier/Bouchet/Blecha.

Feb. 1990: Simon/Haefner/Pfeiffer, Ritter/Schoembs, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Ehrenfreund/Foing, Pottasch/Manchado/Garcia Lario/Sahu, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson.

March 1990: Van Genderen/Van der Hucht/Schwarz/De Loore, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Gerbaldi et al. Courvoisier/Bouchet/Blecha, Gahm, Bianchini/Sabbadin/Friedjung.

1.4-m CAT

Oct. 1989: Holweger/Lemke, Pasquini, François, Danks/Massa/Crane, North.

Nov. 1989: North, Spite E./Spite M. Maceroni/Van't Veer/Vilhu, Lagrange-Henri/Vidal-Madjar/Ferlet/Beust.

Dec. 1989: Vladilo/Molaro/Centurion/Monai, Foing/Crivellari/Beckman/Char/Jankov/Byrne/Lagrange-Henri/Schrijver, Pallavicini/Giampapa/Cutispoto, Foing/Crivellari/Beckman/Char/Jankov/Byrne/Lagrange-Henri/Schrijver, Vidal-Madjar/D'Hendecourt/Ferlet/Léger, Magain/Zhao.

Jan. 1990: Reimers/Toussaint, Schröder/Huensch/Reimers, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Pettersson/Westerlund, Gredel/Van Dishoeck/Black, Waelkens/Lamers/Waters, Cremonese/D'Onofrio/Marziani, Benvenuti/Porceddu.

Feb. 1990: Benvenuti/Porceddu, Reimers/Toussaint, Lilienthal/De Boer, Baade/Van Kerkwijk/ Waters/Henrichs/Van Paradijs, Pottasch/Parthasarathy/Manchado/Garcia Lario/Sahu, Clausen, Crane/Blades/Penprase.

March 1990: Vreux/Magain/Hutsémekers/Manfroid, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Lèbre/Gillet, Cayrel de Strobel, Gratton/Gustafsson/Eriksson, de Jager/Nieuwenhuijzen/Van Genderen, Lanz/Mathys/Gerbaldi/Faraggiana, Baade/Van Kerkwijk/Waters/Henrichs/Van Paradijs, Pallavicini/Schmitt/Tagliaferri.

1-m Photometric Telescope

Oct. 1989: Hoffmann/Geyer/Neukum/Gonano/Mottola, Di Martino/Neukum/Mottola/Gonano/Rebhan/Hoffmann, Hoffmann/Geyer/Neukum/Gonano/Mottola/Rebhan, Hunt/Mandolesi/Wade, Johansson L./Bergvall, Fleming, Liller/Alcaino/Alvarado/Wenderoth, Johansson L./Bergvall.

Nov. 1989: Johansson L./Bergvall, Bouvier/Bertout/Martin E., Heske, Richtler/De Boer/Seggewiss, Barbieri et al.

Dec. 1989: Barbieri et al. Vidal-Madjar/Lagrange-Henri/Beust/Ferlet/Foing/Char, Gieren.

Jan. 1990: Gieren, Courvoisier/Bouchet/Blecha, Reipurth/Olberg/Cameron/Booth, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Walker/Matthews/Wehlau, Bouvier/Bertout/Basri/Bouchet/Imhoff/Bastien/Malbet, Walker/Yang/Matthews, Cremonese/D'Onofrio/Marziani.

Feb. 1990: Krautter/Barwig/Schoembs/Starrfield, Simon/Haefner/Pfeiffer/Ritter/Schoembs, Schneider H./Weiss/Kuschnig/Rogl, Trefzger/Labhardt/Spaenhauer, Nieto/Bender/Capaccioli/Davoust/Poulain/Prugniel, Poulain/Davoust/Nieto/Prugniel.

March 1990: Poulain/Davoust/Nieto/Prugniel, Houdebine/Foing/Buttler/Panagi, Courvoisier/Bouchet/Blecha, Gerbaldi/Faraggiana, Van der Hucht/Thé/Williams, Gahm, Munari/Whitelock/Massone.

50-cm ESO Photometric Telescope

Oct. 1989: Catalano E.A./Schneider/Leone, Carrasco/Loyola.

Nov. 1989: Carrasco/Loyola, Bouvier/Bertout/Basri/Bouchet/Imhoff/Bastien/Malbet, Poretti/Antonello/Mantegazza, Maceroni/Van't Veer/Vilhu, Schober.

Dec. 1989: Schober, Cutispoto/Pasquini/Giampapa/Ventura/Pallavicini/Giampapa/Cutispoto, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund.

Jan. 1990: Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Schröder/Hünsch/Reimers, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Bouvier/Bertout/Basri/Bouchet/Imhoff/Bastien/Malbet, Sinacholopoulos.

Feb. 1990: Sinacholopoulos, Group for Long Term Photometry of Variables, Trefzger/Labhardt/Spänhauer, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini.

March 1990: Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Schneider H./Jenkner/Maitzen, Carrasco/Loyola.

GPO 40-cm Astrograph

Oct. 1989: Debehogne/Machado/Mourao/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Protitch-B./Javanshir/Wosczcyk.

Nov. 1989: Madsen/West.

Dec. 1989: Dommanget.

Jan. 1989: Dommanget, Duerbeck/Seitter/Tsvetkov.

Feb. 1990: Scardia, Debehogne/Machado/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Mourao/Protitch-B./Javanshir/Wosczyk.

March 1990: Debehogne/Machado/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Mourao/Protitch-B./Javanshir/Wosczyk, Munari/Lattanzi/Massone.

1.5-m Danish Telescope

Oct. 1989: DANISH TIME, Mayor et al., Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Johansson L./Bergvall, Focardi/Da Costa/Willmer/Alonso, Dennefeld/Martin J. M./Bottinelli/Gouguenheim.

Nov. 1989: Mazure et al., Jörsäter/Hester/Bergvall, Jörsäter/Hester/Lindblad/Van Moorsel, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson. DANISH TIME.

Dec. 1989: DANISH TIME. Mayor et al., Ardeberg/Lindgren/Lundström, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, Rafanelli/Schulz H./Marziani, Chiosi/Bertelli/Bressan/Nasi/Ortolani/Vallenari/Gratton/Meylan.

Jan. 1990: Chiosi/Bertelli/Bressan/Nasi/Ortolani/Vallenari/Gratton/Meylan, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fransson, DANISH TIME.

Feb. 1990: DANISH TIME, Andersen/Nordström/Mayor/Olsen, Nordström/Andersen, Griffin R.F./Griffin R.E.M./Mayor/Clube, Reipurth/Lindgren/Mayor, West, Della Valle/Cappellaro/Rosino/Turatto, Bender et al.

March 1990: Bender et al., Mermilliod/Mayor, DANISH TIME.

50-cm Danish Telescope

Oct. 1989: Group for Long Term Photometry of Variables.

Nov. 1989: Group for Long Term Photometry of Variables, Ardeberg/Lindgren/Lundström.

Dec. 1989: Ardeberg/Lindgren/Lundström, Foing/Crivellari/Beckman/Char/Jankov/Byrne/Lagrange/Schrijver, Group for Long Term Photometry of Variables, Sterken, DANISH TIME.

Feb. 1990: DANISH TIME, Gosset/Manfroid/Vreux, Vreux/Magain/Hutsémekers/Manfroid.

March 1990: Vreux/Magain, Hutsémekers/Manfroid, Franco.

90-cm DUTCH TIME

Oct. 1989: DUTCH TIME, Trefzger/Pel/Blaauw.

Nov. 1989: Van Paradijs/Van der Klis/Telting, DUTCH TIME.

Dec. 1989: Van Genderen, Lub/De Ruiter, De Loore/Hensberge/Verschueren/David/Blaauw.

Jan. 1990: De Loore/Hensberge/Verschueren/David/Blaauw, Van Genderen, DUTCH TIME.

Feb. 1990: DUTCH TIME, Van Kerkwijk/Waters/Henrichs/Van Paradijs, Lub/Dickens.

March 1990: Van Genderen/Van der Hucht/Schwarz/De Loore/DUTCH TIME.

PROFILE OF A KEY PROGRAMME

Coordinated Investigation of Selected Regions in the Magellanic Clouds

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The greatly enhanced observational possibilities for research in the Magellanic Clouds, such as bigger telescopes and the CCD as detector, has led the way to studies hitherto unimagined. The possibility to reach 60 kpc distant stars of fifth absolute magnitude (i.e. down to main-sequence stars fainter than the Sun) or to obtain stellar spectra to do a fine-analysis of atmospheric temperature and composition has mightily raised the importance of the astrophysical laboratory called Magellanic Clouds. In particular the study of the intricately interwoven processes of formation of stars from progenitor gas clouds and the evolution of stellar complexes can in our times superbly be investigated by observing the Magellanic Cloud constituents.

However, in spite of all new possibilities, correlation of the individual achievements does only slowly provide deeper insight into the history and evolution of the Magellanic Clouds. The practical reason for that is that most programmes have accumulated moderate amounts of data aimed at a limited scientific goal. The net effect has been that intrinsically valuable building blocks for structural understanding could not be fitted together, e.g. because they came from disjunct regions of the Magellanic Clouds.

Research on the Magellanic Clouds has been fairly strong in Europe but was mostly based in separate institutes. We are much obliged to Dr. H. van der Laan for inviting those of us who had indicated their interest to intensify Magellanic Cloud investigations under the Key Programme scheme to München. As Dr. van der Laan mentioned in his account of the beginnings of the Key Programme process (1988, *The Messenger* No. 55), we met upon his invitation in September and explored the directions of our research. It soon became obvious that what each of the participating groups had in mind would benefit greatly from the results to be obtained by the other groups, and it was realized that joining forces would enhance the value of each individual project.

Our coordinated programme aims at obtaining a deeper insight into the stellar populations of the Magellanic Clouds by addressing the history of the various star types in relation with spatial structure. The road to this lofty goal will be marched in parallel by our groups, with observational programmes as follows. We have defined 6 regions in the Magellanic Clouds (4 in the LMC, 2 in the SMC) in which a large variety of observational projects will be carried out. These regions have been selected based on both existing knowledge and on the expected returns from the coordinated investigation. They have been defined in such a way that they contain a mixture of young and old field population, are gas-dusty or very clear, and contain young and old clusters. They measure $30' \times 30'$ and comprise the field of NGC 330 and N 27 in the SMC and fields containing NGC 1818, N 159, NGC 1978 and N 49, and SN 1987 A in the LMC. In all they cover less than 1% of the Magellanic Clouds.

In each of the 6 regions spectroscopic surveys will be completed to classify stars down to approximately 15th magnitude. This will account for the more massive stars in the regions. Furthermore, faint Planetary Nebulae and H II regions will be searched for. In two small fields (with a size of about 6 CCD frames) within each region, CCD photometry in many colours will be obtained to as faint a limit as possible in order to investigate the nature and mass function of the stars over a large range of masses.

The aspects of chemical and structural evolution are addressed with spectroscopy at high dispersion. The luminous hot and cool stars of the field as well as of clusters will provide metal abundances. Related information will come from the analysis of emission lines from emission-line nebulae. H II regions and SNR will show abundances of the present, while the analysis of Planetary Nebulae will result in abundances from a past epoch. Very important is the measurement of interstellar absorption lines. On the one hand, they will provide additional information on the abundances in the Magellanic Cloud interstellar medium, while the strength of the various absorption components will give insight into the depth structure, in particular one related to the information from radio lines, such as H I 21-cm and CO from the ESO SEST Magellanic Cloud survey.

The end product of the programme will be a coherent body of data on stellar populations, chemical composition, and spatial structure, showing likely similarities as well as differences between the defined regions. Data of this kind will allow us and others to gain insight into the history of star formation and structural evolution of the Magellanic Clouds.

One aspect of our key programme, we feel, deserves some emphasis in this description. The decision to do coordinated research in a collaborative effort of a large number of groups at different institutes in Europe requires a fairly high degree of organization of time plans and exchanges between the participating groups. We hope that our cooperation at a wide European level will stimulate much intensified contacts between many more research groups in Europe.

Also in view of these aspects it was decided to organize a European Colloquium on "Recent Developments of Magellanic Cloud Research". The colloquium was held in Paris in May this year and aimed at reviewing the progress made since the IAU Symposium of 1983. The proceedings will be distributed by the Observatoire de Paris.

Identification of High Redshift Galaxies with Very Large Gaseous Halos

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Over the last several years, considerable efforts have been aimed at understanding the properties of objects at high redshift. The main studies concern optically selected samples of field galaxies (Koo 1986, Koo and Kron 1988, Broadhurst et al. 1988) and rich clusters of galaxies (Gunn and Dressler 1987, Gunn 1988), and radio selected objects first from the 3C sample of bright sources (Spinrad et al. 1985, Djorgovski 1988) and more recently from samples of fainter radio sources (Chambers et al. 1987 and 1988, Koo 1988, Lilly 1989). Our approach is to select high redshift objects with metal-rich, very extended gaseous envelopes giving rise to absorption line systems in quasar spectra. These objects may exhibit properties closer to those of normal galaxies than to those of rather extreme objects associated with powerful radio sources.

Galaxies at z < 1 with Large Gaseous Halos

The early suggestion of Wagoner (1967) and Bahcall and Spitzer (1969) that the absorption-line systems may arise in intervening galaxies was strengthened by statistical analysis showing that the distribution of the number of CIV absorption redshifts per line of sight is Poissonian (Young et al. 1982), and was confirmed by identification of the absorbing galaxies (Bergeron 1986, Cristiani 1987, Bergeron 1988 and references therein). Present searches for absorbing galaxies have only been attempted for z < 1 systems. We had estimated that, at these redshifts, the galaxies responsible for Mg II absorption systems should be bright enough ($m_v <$ 23) and well separated on the sky from the quasar image ($\theta \sim 0.7$ arcsec at z = 0.5) to be easily detectable. These estimates were based on the observed density of Mg II systems per unit redshift assuming a given galaxy luminosity function and a radial-luminosity scaling law (Bergeron 1988).

At present there are 15 identifications of Mg II absorbing galaxies in the redshift range 0.15 to 0.8, most of them done with the ESO Faint Object Camera Spectrograph at the 3.6-m telescope. The galaxies giving rise to z < 1, Mg II systems have the following properties:

– they have large gaseous envelopes as implied by the average angular separation of 6.8 arcsec or 2.3 R_H (R_H is the Holmberg radius and equals 22 kpc for $H_0 = 50$ km s^{-1} Mpc^{-1}) for $\bar{z} = 0.44$,
– they are fairly bright, $-22.2 < M_r < -20.2$,
– they all show sign of present or recent stellar formation activity, having a very blue continuum (down to $\lambda_r \sim 2200$ Å) and usually strong [O II] emission with rest equivalent width larger than 15 Å,
– they are mostly field galaxies.

The intervening galaxies are always the resolved object closest on the sky to the quasar. This is not due to an observational bias since galaxies as faint as the LMC could have been detected as an absorber up to z ~ 0.5. A deep r image of the field around the quasar Q 2128-123 (Bergeron and Turnshek, in preparation) taken at the Las Campanas 100-inch telescope in condition of good seeing (FWHM = 0.95 arcsec) is shown in Figure 1; as could be seen from the fainter detected objects within the field, there is no absorbing galaxy candidate closer on the sky to the quasar than the galaxy 8.6 arcsec north-east of the quasar identified by Bergeron (1986) as the object giving rise to the z = 0.4299 Mg II absorption system.

A general trend found both for field (Koo and Kron 1988, Broadhurst et al. 1988, Dressler 1988) and cluster (Gunn 1988) galaxies is the increasing fraction with redshift of galaxies showing sign of enhanced stellar activity (blue continuum and [O II] emission). For field galaxies the fraction of "active objects" is about 40 % at z ~ 0.5 and for galaxies in cluster centres it reaches 20 % at z ~ 0.9. Comparison with the properties of Mg II absorbing galaxies suggests that

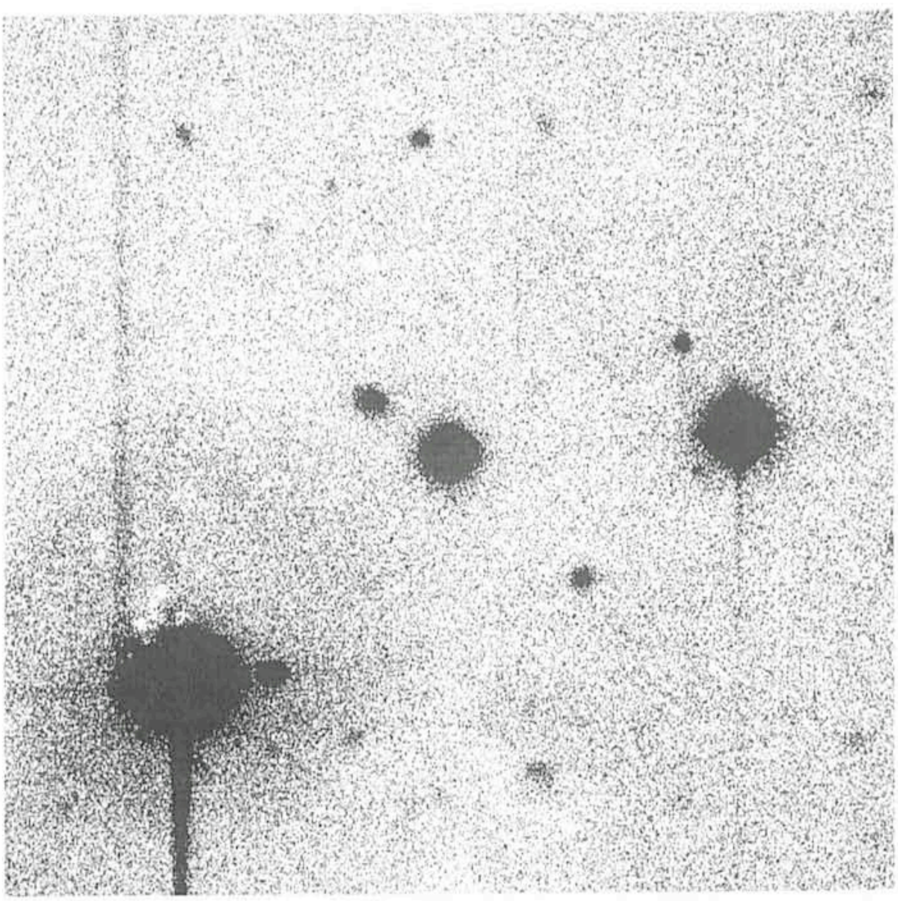

Figure 1: *r image of an 80 × 80 arcsec field centred on the quasar Q 2128-123. North-east is at the top left corner. The Mg II absorbing galaxy is the resolved object 8.6 arcsec north-east of the quasar. The spatial resolution is FWHM = 0.95 arcsec.*

at z ~ 0.5 about 1/3 of field galaxies have very large gaseous envelopes. Such a large fraction is also implied by the very similar values found for the gaseous halo dimensions from direct observations and from statistical analysis of Mg II absorption line samples, since for the latter we had assumed that half of the galaxies are gas-rich and with large halos.

Galaxy Surveys at z > 1

Almost all the galaxies that have been identified so far at z > 1 are associated with powerful radio sources (Spinrad et al. 1985, Djorgovski 1988, Lilly 1989). The extreme cases discovered are at z = 3.4 with a dominant older stellar population (Lilly 1988) and at z = 3.8 for steep radio surces (Chambers et al. 1989). These high redshift galaxies are intrinsically bright with M_V absolute magnitudes in the range −22.0 to −24.5. They have a very high rate of star formation and an extremely disturbed morphology. Therefore, they constitute a special class of galaxies which cannot be directly compared to the z < 1 galaxy samples to derive properties such as the galaxy luminosity evolution. The aim of another ESO Key Programme "A Study of the Most Distant Radio Galaxies" by G. Miley and collaborators is to extend the identification of radio sources to larger and fainter samples of ultra-steep spectrum radio sources. There is also an on-going identification survey of weak radio sources which has revealed a few galaxies at z ~ 1.2–1.5 all with emission lines of [C II, C III] and [Ne IV] (Koo 1989). The cluster survey done by Gunn and collaborators also contains potential candidates at z > 1 with on-going spectroscopic identification but no result has been communicated so far.

Searching for the intervening galaxies responsible for z > 1 absorption systems will provide an independent sample of high redshift galaxies, whose properties can be directly compared to those of z < 1 absorbing galaxies. Our proposed survey will allow to determine the evolution of galaxies with gaseous halos, more specifically:

- to find the evolution of the halo size with redshift,
- to confirm that the correlation between strong stellar formation activity and the presence of gaseous halos holds at z > 1 and find if this stellar activity increases with the size and mass of the gaseous envelopes,
- to derive the luminosity function of galaxies with large gaseous halos and its evolution with redshift.

Detecting z > 1 intervening galaxies in a Vri imaging survey should not be an impossible task, since the galaxies are expected to be neither extremely faint, nor very close on the sky to the quasar. Extrapolating our results obtained at z ~ 0.5–0.8, we expect, in the assumption of no luminosity evolution, that intervening galaxies at z ~ 1.6 will have r magnitudes of about 24. Further, at z ~ 1.6, the average sizes of the absorbers derived from statistical analysis of CIV (Young et al. 1982, Sargent et al. 1988) and Mg II (Lanzetta et al. 1987, Sargent et al. 1989) absorption line samples are larger than those at z = 0.5 (Mg II) by factors of 1.9 and 1.4 respectively. Therefore, the angular distance between the quasar and the absorbing galaxies should be on an average the same for Mg II systems at z = 0.5 and 1.6, i.e. around 7 arcsec.

At z > 1 the redshift of the intervening galaxies can be identified from the [Ne IV] λ 2424, C II] λ 2326, C III] λ 1909 emission lines and also from He II λ 1640 and CIV λ 1549 at z > 1.5. The Mg II λ 2799 doublet is also observable but it may be in absorption, as for two emission line galaxies of our z < 1 sample, thus more difficult to detect.

The Sample

From our lower redshift survey, we have found that low excitation (Mg II) absorbers are associated with bright galaxies of high central surface brightness. Since we do not know whether this also applies to high excitation (CIV) absorbers, we first primarily select low excitation Mg II and/or Fe II absorption systems. The latter also usually show CIV absorption at the Mg II or Fe II redshift. These low excitation systems constitute about 1/5 to 1/4 of the metal-rich absorbers at z = 1.5 (Lanzetta et al. 1987, Sargent et al. 1988 and 1989, Caulet 1989).

Selecting specific quasar fields is of crucial importance if less than one absorber is expected on an average for a given redshift range. This is the case for Mg II absorption systems at z < 2. From high redshift Mg II absorption surveys, one finds that the average number of Mg II absorbers expected per (quasar) line of sight in the redshift range 1.0–1.5 is 0.36. To increase further our chances of detection we will give higher priority to multiple absorption systems spanning more than 500 km s^{-1}, which suggests the presence of a cluster along the line of sight, and to quasars with several Mg II absorption systems at very different redshifts from unrelated intervening galaxies.

The proposed sample is based on data published by Young et al. (1982) Bergeron and Boissé (1984) Boissé and Bergeron (1985) Foltz et al. (1986) Lanzetta et al. (1987) Sargent et al. (1988 and 1989) and Bergeron (unpublished), and it will be updated when new absorption line surveys become available. It includes 53 quasars all with Mg II and/or Fe II absorption at z < 2, out of which there are 8 quasars with low excitation multiple systems, 11 quasars with at least 2 low-excitation systems in the redshift range 1.0–1.5 and 2 quasars with a low-excitation system at the quasar emission redshift.

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The Structure and Dynamics of Rich Clusters of Galaxies

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Background

Rich clusters of galaxies are of great interest for several reasons. As the largest bound structures that can be fairly easily found and studied in detail, they represent a formidable constraint for theories of the formation of large-scale structure in the Universe. In addition, they provide an ideal laboratory for the study of the behaviour of galaxies in an environment of high galaxy-density; quite frequently in the presence of a hot, X-ray emitting, intracluster gas, that may have a mass comparable to the total visible mass in galaxies. As rich clusters can be detected out to fairly high redshifts, they also allow one to study the evolution of the galaxy population in clusters over an appreciable fraction of the Hubble time. Even the evolution of their global structure on such time-scales is amenable to study (Gunn, 1989).

The significance of rich clusters as a boundary condition for theories of large-scale structure formation applies to a large range of scales.

First, the internal structure and dynamics of clusters contain information about their evolutionary "age", and probably also to some extent about the initial conditions from which structure on these scales has arisen. In their central regions, two-body relaxation and non-elastic collisions between galaxies (involving e.g. dynamical friction and merging) have a characteristic time-scale that is shorter than the Hubble time, so that memory of the initial conditions has quite likely been erased. However, the overall relaxation time is considerably larger than the Hubble time, even for a rich cluster with a moderate velocity dispersion.

From a detailed analysis of the kinematics of the galaxies in a cluster one can also get an idea about the distribution of the dark matter, in relation to that of the visible matter, if one assumes the cluster to be in a steady state (see e.g. Merritt, 1987, and Sharples et al., 1988). This is very important for an understanding of the role that dark matter has played in the formation history of clusters as a class.

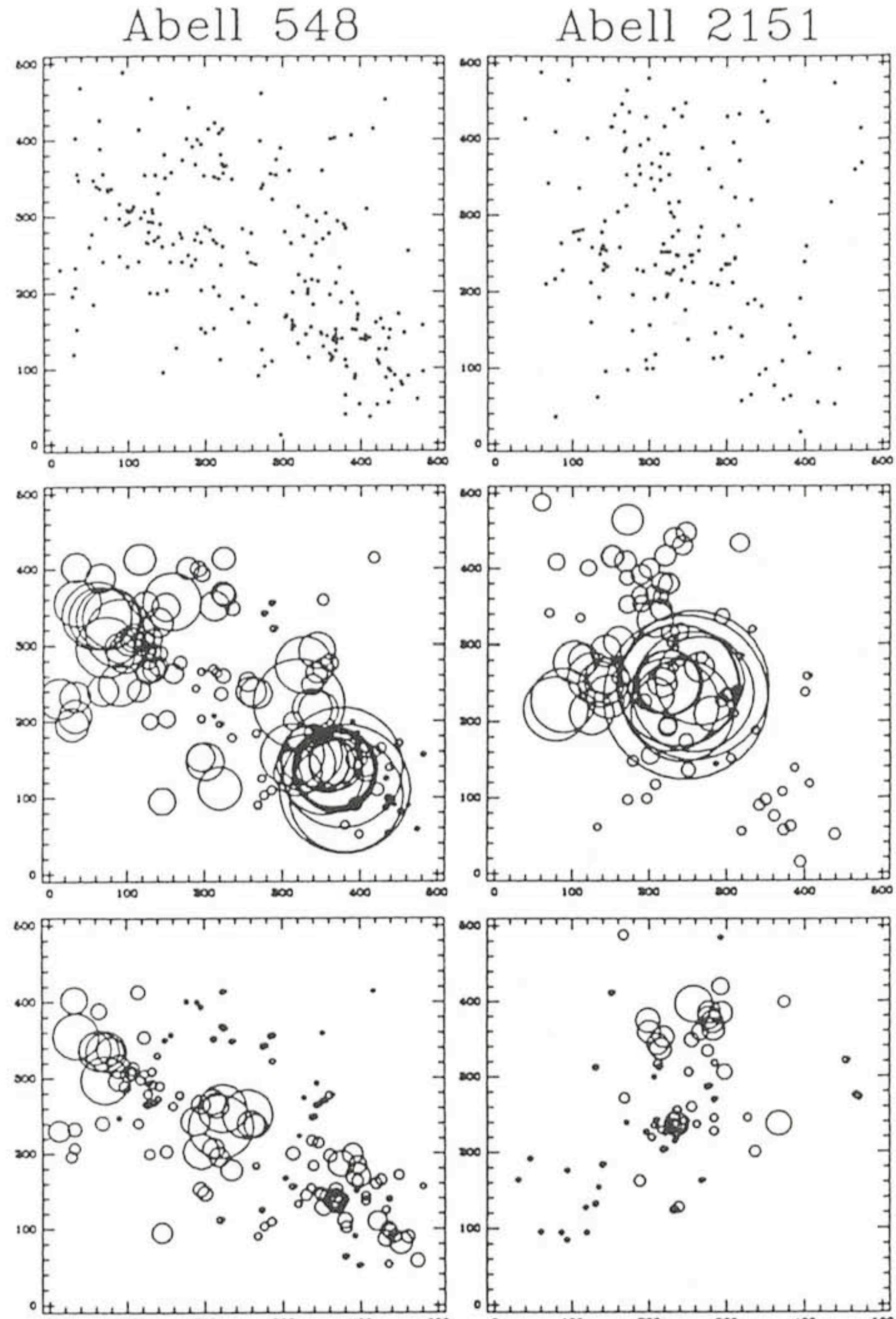

Figure 1: *Substructure in the clusters A 548 and A 2151 (from Dressler and Shectman, 1988). The upper panels show the distribution of the galaxies brighter than about 16 in V (from Dressler, 1980), in areas of about 8 h^{-2} Mpc^2. The middle panels show the deviation of the local kinematics (for each galaxy with a radial velocity, from its ten nearest neighbours with radial velocities) from the global kinematics. The diameter of the circle scales with the magnitude of the deviation. The lower panels show Monte Carlo models (derived from the observations by randomly reassigning the measured radial velocities). These models are selected because they show the largest amount of substructure among 11 such models made for each cluster.*

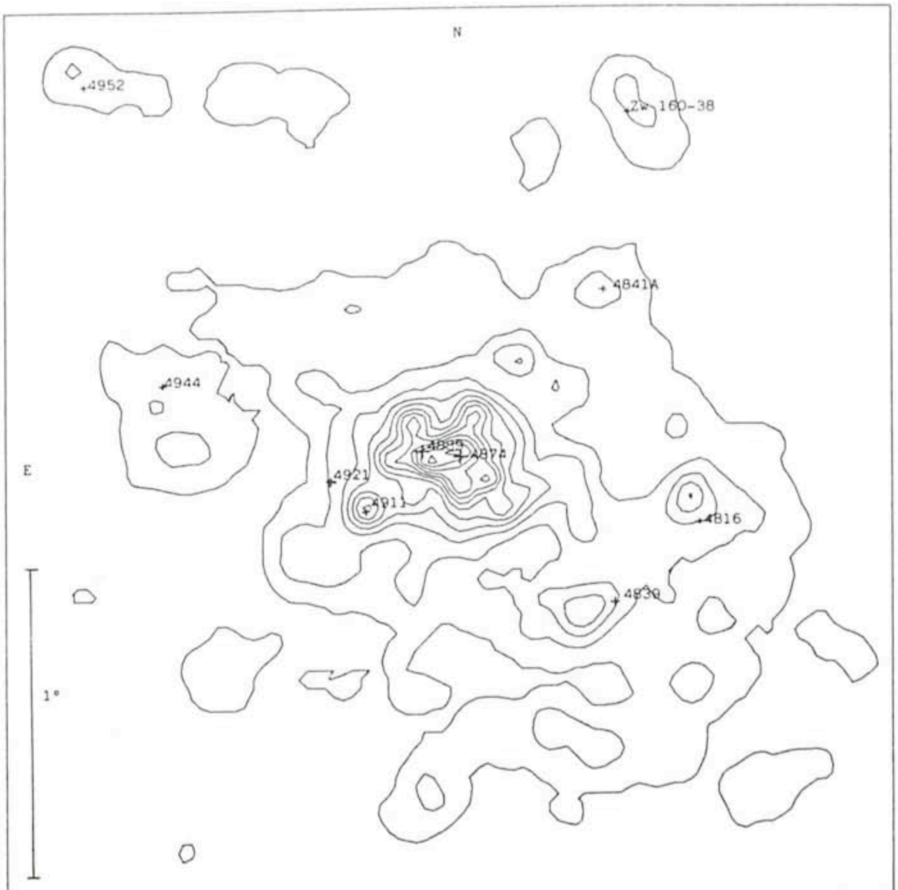

Figure 2: *Isopleth map of the distribution of the 1630 galaxies down to a b-magnitude of about 20, which are believed to be cluster members, in the central 3 × 3 degree area in the Coma cluster (from Mellier et al. 1988). From the available radial velocities, it is concluded that the high-density peaks around the brighter galaxies (indicated by numbers) represent "old", evolved substructure in a cluster which as a whole is probably less evolved (i.e. dynamically "younger").*

The second aspect that relates to theories of structure formation is the state of motion of the population of rich clusters as a whole, in relation to the general expansion of the Universe. The peculiar velocities that clusters may have with respect to the Hubble flow could, in principle, reveal the characteristics of the mass distribution on very large scales, of up to 50 Mpc or more. Such peculiar motions have been claimed to exist (Bahcall et al., 1986), but the evidence has been questioned by other authors.

Goals of the Programme

The purpose of our Key Programme is basically two-fold.

In the first place we will obtain detailed kinematical information for a carefully chosen sample of rich southern clusters. This will allow us to study the amount and nature of substructure. Secondly, we will get more global information on the dynamical state of a larger, complete sample of rich clusters. This will provide accurate mean velocities to be used in a study of the peculiar motions with respect to the Hubble flow. In addition, the latter data will yield global velocity dispersions, which we hope to correlate with other global properties of the clusters, such as e.g. the luminosity function, mix of different galaxy types, etc.

The question of substructure is an important one, both observationally and theoretically. Some time ago, Geller and Beers (1982) claimed that significant substructure exists in more than 40 per cent of the clusters in a sample defined by Dressler (1980). On the basis of the same data, West et al. (1988) reached the conclusion that there was very little evidence, if any, for significant substructure. Rhee et al. (1989) reached the same conclusion as did West et al., on the basis of a complete sample of more than 100 rich clusters. Note that all these results were based on projected 2-dimensional galaxy distributions.

The negative results seemed to be in agreement with theoretical predictions (by West et al., 1988) which showed that, independent of the formation scenario (Cold or Hot Dark Matter), substructure is not expected to survive in the central parts of clusters. These predictions did not take into account the effects of inelastic encounters.

Using radial velocity data, Dressler and Shectman (1988) showed that 3 out of the 5 clusters for which they had more than 100 radial velocities had distributions of position and radial velocity which were not consistent with smooth phase-space distributions. In other words: substructure would seem to be rather common, judged from a 3-dimensional projection of 6-dimensional phase-space.

Yet, the subject is far from closed. Consider, for example, the various results on the Coma cluster. Fitchett and Webster (1987) and Mellier et al. (1988) report significant substructure in 2-dimensional maps. On the contrary, Dressler and Shectman (1988) find no evidence for substructure when they include radial velocities.

Given this undecided state of affairs, we want to study the rate of occurrence and the character of substructure on the basis of good radial velocity data for a well-defined sample of clusters.

Peculiar velocities of clusters with respect to the Hubble flow have the potential of deciding between competing scenarios for the formation of structure on very large scales. The Cold Dark Matter scenario (CDM), which seems fairly successful in many respects, does not predict large peculiar velocities (White et al., 1987). The local velocity field, as traced with ellipticals (e.g. Lynden-Bell et al., 1988) is already rather problematic for CDM; large peculiar velocities of clusters would be even more so.

Given the discriminatory power of the test involving peculiar motions of clusters, we want to complement the northern sample on which Bahcall et al. based their analysis, with a completely independent southern sample.

Observational Strategy of the Programme

We will observe about 100 rich southern clusters with Optopus on the 3.6-m telescope. In the present set-up Optopus yields simultaneous spectra for up to 30 galaxies per exposure, but in the near future this will be increased to 50.

For a sample of 30 clusters we will aim at about 150 radial velocities per cluster (from several Optopus exposures), or at least 100 velocities for cluster members (after the field galaxies are removed). The results by Dressler and Shectman (1988) indicate that this will allow a reliable study of substructure. The composition of the sample (30 clusters evenly distributed over Bautz-

Morgan type, at a redshift of about 0.05) should ensure that the results will have a general validity. This is also important for a study of the general distribution of dark matter in these clusters, to be based on the same data.

For a complete sample of 70 to 80 clusters with $z < 0.1$ we will get between 20 and 30 radial velocities per cluster, from a single Optopus exposure. These will yield unbiased estimates of the mean cluster velocity (for a study of peculiar velocities), and of overall velocity dispersions (to be correlated with other global cluster properties).

The candidate galaxies for spectroscopy are found from automatic scans of film copies of SERC IIIa-J survey plates, obtained with the Leiden Observatory automatic measuring machine Astroscan. This machine will also produce accurate photographic photometry, to be calibrated with CCD sequences for which time on the 1.54-m photometric telescope has been granted.

With an anticipated yield of over 5000 new radial velocities, possibly other useful information from the spectra, and new photometry, it is hard to imagine that this programme will not provide a better description and understanding of the class of rich galaxy clusters. We look forward not only to answers to the questions that we presently pose, but also to new questions raised by the new data.

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Surface Photometry Catalogue Presented

On June 14, 1989, Andris Lauberts and Edwin Valentijn presented their new "Surface Catalogue of the ESO-Uppsala Galaxies" during a Colloquium in the Auditorium at the ESO Headquarters. The appearance of this catalogue is the crowning event of many years of hard work by the authors. It is now available, both in printed form and on magnetic tape. The book may be obtained from the ESO Information Service and the computer readable version from Centre de Données in Strasbourg, cf. the announcement in *Messenger* 56, page 34. On the photo, Ed Valentijn (left) and Andris Lauberts (middle) present the first printed copy of their Catalogue to the ESO Director General, Professor Harry van der Laan, at the time of the Colloquium.

Operating Manuals Now Available

A number of Operating Manuals have recently become available. The following have already been distributed to institutes, etc. in the member states:

- **B & C Spectrograph**
- **CASPEC**
- **CAT/CES**
- **ECHELEC**
- **EFOSC**
- **IR Photometers**
- **PISCO**

The following three manuals will be ready for distribution later: **Dutch Telescope, CCD,** and **Optical Photometers.**

Copies of these manuals can be obtained from Visiting Astronomers' Service, ESO Headquarters, Karl-Schwarzschild-Strasse 2, D-8046 Garching bei München, F. R. Germany.

The Proceedings of the

1st ESO/ST-ECF Data Analysis Workshop

held on April 17–19 in Garching, will become available towards the end of September 1989.
The 230-page volume, edited by P.J. Grosbøl, F. Murtagh and R.H. Warmels, will be sold at a price of DM 30.–. This price includes packing and surface mail and has to be prepaid.
Payments have to be made to the ESO bank account 210002 with Commerzbank München or by cheque, addressed to the attention of

ESO
Financial Services
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München

Please do not forget to indicate your complete address and the title of the Proceedings.

VLT Operations – a First Discussion

P. SHAVER, ESO

The VLT will be a unique observatory. With its four 8-metre independent elements and 17 foci it will offer unprecedented flexibility, in addition to its huge light collecting power. It will be equipped with technologies which are only now being realized, including adaptive optics and the potential for interferometric imaging. In view of these unique features, as well as the large capital expenditure involved, it is desirable that innovative ideas on possible modes of operation be explored, ideas which may resemble those of space observatories both in style and scale. It is also desirable that such a study be made in the early phases of design and construction of the VLT, so that the perceived requirements can be incorporated into the design of the VLT itself and its instrumentation.

To this end, an in-house VLT Operations Working Group was established two years ago, and its recommendations have now been published as a discussion paper. The recommendations are not meant to be definitive – the mix of operating modes will undoubtedly evolve with time and experience. Nevertheless they will provide some guidance through the design and construction of the telescope and instruments.

The Working Group was comprised of staff from all divisions of ESO: the Projects and Technology Divisions, the Science Division, the ST-ECF, and of course La Silla. With such a wide spectrum of participants, virtually all points of view were represented, from the extreme pragmatic to the extreme utopian. There was fortunately some convergence over time, and the report both reflects this wide divergence of views and presents the confluence of recommendations.

In order to preserve the flexibility inherent in the VLT concept, it was considered imperative that no operational mode be "designed out", and in particular that all the major observational modes – *classical* (astronomer at telescope), *remote* (astronomer in Europe) and *service* (by ESO staff in Chile or Europe) – be fully accommodated in the design of telescope and infrastructure.

Flexible scheduling, however, was seen as a major objective from the outset. Flexible scheduling implies service observing, hence an Operations Group. This Operations Group could be located in Chile or Europe; the latter would then imply remote observing. The potential advantages of flexible scheduling/service observing are many: adaptability to changing meteorological conditions (e.g. periods of exceptional seeing), optimal use of dark time, efficient packing and scheduling of observations by a group intimately familiar with the instruments, accommodation of special observations (short observations, monitoring observations, simultaneous observations with other observatories), regular monitoring and long-term calibration of instruments, suitability for archiving (homogeneous data base), increased accessibility (e.g. to non-optical astronomers and theoreticians).

There are also disadvantages – lack of spontaneity in the observations, less direct experience for the astronomer, and especially far greater complexity – and for experimental observations involving user-supplied instrumentation it is obviously completely inappropriate. The flexible scheduling/service observing mode can therefore only be offered as one possible option, perhaps limited to straightforward, well-defined types of observations.

It is desirable, both for flexible scheduling and more conventional observing modes, that the VLT and its instrumentation be capable of switching rapidly from one mode to another. It is therefore recommended that a stable suite of multimode instruments be provided which cover the major observational possibilities and are mounted on the telescope for long periods of time to facilitate rapid changeovers between observing modes and long-term calibration. The reliability of these instruments should be enhanced by standardization and modularity of components.

Another major recommendation which follows from the above is that an Operations Group be formally established as soon as possible to fully test a vertically-integrated (from proposal to archive) service/remote observing operation using the NTT in a few well-defined modes, in order to determine how practical and comprehensive such an operation can be.

It also follows that the communications link between Garching and Chile should be further enhanced, both to support this expanded remote observing capability and to increase the integration of the organization through greater daytime communications.

These are just the summary recommendations. The full report is available on request from the secretary of the Science Division at ESO Garching, and written comments from members of the community are most welcome.

ESO at World Tech Vienna

The Institute of Astronomy of the Vienna University and ESO presented themselves in a joint stand at the "World Tech Vienna" Science and Technology Fair which took place at the Austria Centre in the "UN City" from June 18 to 22, 1989. At this time, science ministers and other high-ranking officials met here for the 7th Eureka Minister Conference. These events drew at lot of attention from the public and the media.

The ESO stand was well received by the visitors, and the VLT was shown no less than four times on Austrian TV during that week. On the photo, one of their teams record the closing of a VLT dome.

C. Madsen (ESO)

Polishing of VLT Mirrors: ESO and R. E. O. S. C. Sign Contract

The European Southern Observatory and R. E. O. S. C. Optique (Recherches et études d'optique et de sciences connexes), located at Ballainvilliers near Paris, France, have reached agreement on a contract for the polishing of four giant mirror blanks for the ESO Very Large Telescope (VLT).

This contract was signed on July 25, 1989, at the ESO Headquarters by Professor Harry van der Laan, Director General of ESO, and Mr. Dominique Ruffi de Ponteves, Chairman and General Manager of R. E. O. S. C. In short speeches, both parties expressed satisfaction about the conclusion of this important contract.

The photo shows Mr. D. Ruffi de Ponteves (centre), Dr. D. Enard (ESO, right of centre) and the ESO Director General (right), at the cocktail after the signing ceremony.

The four blanks will be made at Schott Glaswerke, Mainz, F. R. Germany; cf. *Messenger* **53,** page 2. They will be the largest ever produced and will be made of Zerodur, a glass ceramic material. Each will have a diameter of 8.2 metres, an area of more than 50 square metres and thickness of only 17.5 centimetres.

The first blank is expected to be ready in 1993 and will then be transported from Schott to R. E. O. S. C. by road and water in a specially constructed case.

At R. E. O. S. C., it will first be coarsely figured on a giant grinding machine. When the surface of the mirror approaches the desired form, the mirror will be transferred to a second machine with which the final, highly delicate polishing will be performed. Both of these very complex machines will be constructed on the R. E. O. S. C. premises during the next years.

After thorough testing, the mirror will be packed for transport to the VLT observatory in Chile. It is expected to arrive there in 1995, soon after completion of the mechanical structure of the first of the VLT's four unit telescopes.

The polishing schedule of the other three mirrors aims at delivery in Chile at one-year intervals, i.e. in 1996, 1997 and 1998, so that the entire VLT array of four telescopes can be assembled in 1998.

When ready, the VLT mirrors will have the best possible figure of all large ground-based telescopes. The optical performance will rival that of the recently installed ESO New Technology Telescope (NTT).

As is the case for the NTT, the optimal shape of the large and flexible VLT mirrors will be ensured by "active optics". In the VLT system about 200 computer-controlled precision actuators will support each of the 8-m mirrors.

R. E. O. S. C. and ESO have collaborated on earlier projects. In 1975, this firm successfully polished the large fused-silica mirror for the ESO 3.6-m telescope that entered into operation the following year. With its excellent optical quality, this "classical" 3.6-m telescope has since been a rich source of important observational data for European astronomers.

R. E. O. S. C. has also polished a very thin 1-metre mirror (thickness 18 mm) of Zerodur for ESO. It was used at the ESO Headquarters in the prototype "active optics" system on which the highly successful New Technology Telescope is based.

The decision to entrust R. E. O. S. C. with this important task is a key event in the VLT project. It also means that this enormous project, a flagship of European science and technology and soon to become the largest optical telescope in the world, is keeping to its original time schedule.

From ESO Press Release 5/89

STAFF MOVEMENTS

Arrivals

Europe:

ANDREANI, Paola (I), Associate

DOBBELS, Geert (B), Remote Control Operator

FAUCHERRE, Michel (F), Experimental Physicist/Astrophysicist

HALD, Birgit (DK), Secretary/Administrative Assistant

HINTERSCHUSTER, Renate (D), Designer/Draughtswoman (Mech.)

HOPPE, Elisabeth (D), Typist/Secretarial Assistant

LAGRANGE-HENRI, Anne-Marie (F), Fellow

ORIGLIA, Livia (I), Associate

PALMA, Francesco (I), Procurement Officer

Chile:

ANCIAUX, Michel (B), Telescope Control Engineer

DUBATH, Pierre (CH), Student

Departures

Europe:

BERNOTAT, Petra (D), Secretary

ELLES, Daniel (F), Procurement Officer

FRANÇOIS, Patrick (F), Fellow

JOHANSSON, Lennart (S), Fellow

LAUBERTS, Andris (S), Associate

MEURS, Evert (NL), Fellow

MORGANTI, Raffaella (I), Fellow

TSVETANOV, Zlatan (BG), Associate

Chile:

DUGUET, Bernard (F), Administrator

PEDERSEN, Holger (DK), Astronomer

Breaking of Ground Heralds New Premises for Blank Manufacture

Dr. Tietze, Technical Head of the SCHOTT Optics Division, breaks the ground at a location point of the new factory. With Dr. Tietze from left to right are Mr. Schuster and Mr. Adolphs, both members of the SCHOTT Board of Directors, and Dr. Eden, a former member of the SCHOTT Board of Directors, now retired.

This photograph was taken at the location of the future casting tank. Around the first 1.8-m Zerodur blank produced with the new spin-casting technique developed at SCHOTT are, from left to right: M. Tarenghi of ESO, Dr. Tietze, Technical Head of the SCHOTT Optics Division, Mr. Schuster of the SCHOTT Board of Directors, Dr. Eden, a now retired former member of the SCHOTT Board of Directors, Dr. Adolphs, also of the SCHOTT Board of Directors, Dr. Muller, Project Manager of the 8-m Blank Production and Mr. Hubler, Commercial Head of the SCHOTT Optics Division.

A major milestone for the VLT Project took place in Mainz on 6 July 1989 with a symbolic turning of the soil at the location of the future VLT mirror blank manufacturing site. The importance and complexity of such a production requires the construction of a complete new factory designed and dedicated to the manufacture of the VLT 8 m Zerodur blanks. A building measuring 70 m × 40 m will house the entire complex. It will include the casting tank, the annealing furnaces, the grinding machine, and all other equipment necessary. Completion of the new factory will be at the end of 1990 when the casting of the first blank will take place.

M. Tarenghi (ESO)

NTT News

The commissioning time of the NTT following the first light reported in the last issue of the *Messenger* has continued with modifications and improvements to the hardware and software of the telescope and building. New additions include two rails which will be used for the installation and maintenance of the EMMI instrument which have been installed on a floor of the instrumentation room. A carbon fiber sky baffle for the M3 unit has also been implemented; it will have two working positions, one for optical observations and the second for infrared observations.

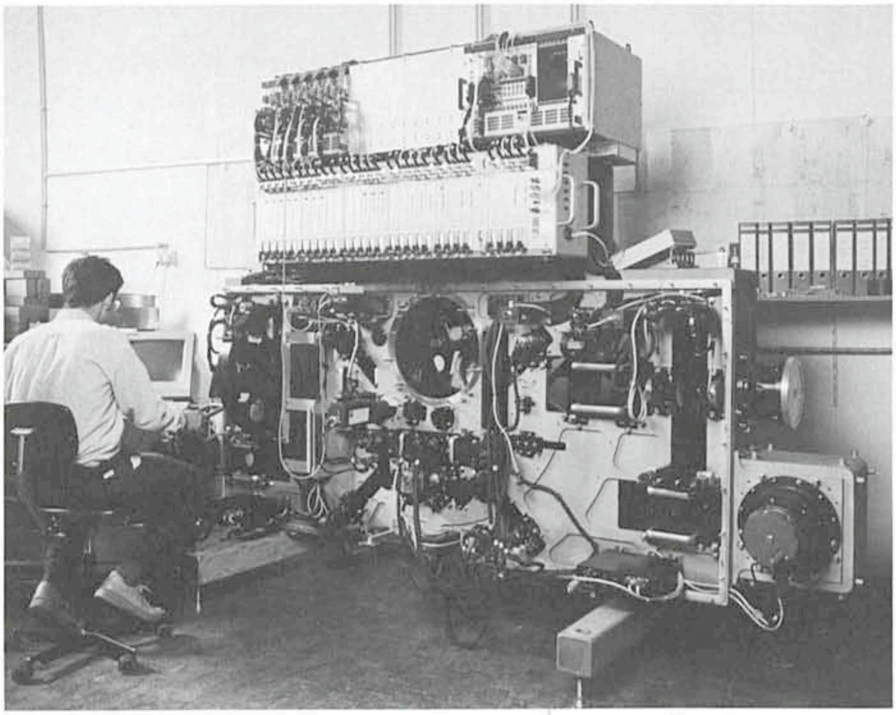
More tests of pointing and tracking were performed and by the end of July the telescope pointed better than 1.6 arcseconds r.m.s. In the months to come, the final tuning will be completed, and October/November will be dedicated to the erection of the first of the two adapters. We expect to have EFOSC 2 working at full capacity by the end of this year; see also the article about this new instrument on page 66 in this *Messenger* issue. *M. Tarenghi (ESO)*

Status Report on EMMI

The ESO Multi-Mode Instrument for one Nasmyth focus of the NTT is in the final phase of its integration and testing in the laboratory in Garching. All of the mechanical functions have been thoroughly tested and installed. The electronic hardware has also been integrated and an engineering version of the control software is fully operating. The coated optics for the red arm (high efficiency in the range 400–1000 nm) have been delivered and will be installed in September; the final tests with the detector, a 1024 × 1024 Thomson TH 31156 CCD, will then start. The blue arm optics (high efficiency in the range 300–500 nm) have been manufactured and coated: they are expected to arrive at ESO in October. Integration of the instrument in Chile is foreseen for the beginning of 1990. The form for Applications for Observing Time for Period 45 includes a description of the observing modes of the instrument which are likely

to be offered initially. These are direct imaging and medium dispersion spectroscopy in the blue and red channels and grism, long slit or slitless spectroscopy in the red channel.
August 1989.

Optical Instrumentation Group



A picture of EMMI as it stands in the integration laboratory in Garching in late July 1989. The mechanical functions are mounted and cabled and they are being tested with an engineering version of the control software. On the top of the instrument the control electronics for the 29 moving functions. At the bottom right of the instrument the grating unit of the red arm, with the attachment for the detector above it.

New ESO Preprints

June – August 1989

SCIENTIFIC PREPRINTS

654. G. Contopoulos and B. Barbanis: Lyapunov Characteristic Numbers and the Structure of Phase-Space. *Astronomy and Astrophysics.*
655. R. M. West and M. Tarenghi: The Optical Counterpart of the Strong Southern Radiosource PKS 1343–601 (13S6A). *Astronomy and Astrophysics.*
656. I. V. Igumentshchev, B. M. Shustov and A. V. Tutukov: Dynamics of Supershells: Blow-out. *Astronomy and Astrophysics.*
657. D. Baade: A Search for Line Profile Variability in Dwarfs and Giants of Spectral Types B8–B9.5 (I.) Observations and Measurements; *Astronomy and Astrophysics Suppl.* (II.) Results and Discussion; *Astronomy and Astrophysics.*
658. J. H. Lutz et al.: He 2–104: Link Between Symbiotic Stars and Planetary Nebulae? *Publ. Astron. Soc. Pac.*
659. M. Tapia et al.: Three-Micron Spectroscopy of Three Highly Reddened Field Stars. *Astronomy and Astrophysics.*
660. B. Reipurth and S. Heathcote: HH 123 – a Herbig-Haro Object in the High-Latitude Cloud L1642. *Astronomy and Astrophysics.*
661. T. Le Bertre et al.: Optical and Infrared Observations of Four Suspected Protoplanetary Objects. *Astronomy and Astrophysics.*
662. M.-H. Ulrich: Observational Evidence for Accretion Disks in Galactic Nuclei. Invited Review to appear in "Theory of Accretion Disks", NATO Advanced Research Workshop, MPA Garching, March 1989 (F. Meyer, W. Duschl, J. Frank and E. Meyer-Hofmeister, eds.; Kluwer Academic Publishers, Dordrecht, the Netherlands).
663. L. B. Lucy et al.: Dust Condensation in the Ejecta of SN 1987A. Paper presented at IAU Colloquium No. 120 "Structure and Dynamics of Interstellar Medium". Eds. G. Tenorio-Tagle, M. Moles and J. Melnick. Lecture Notes in Physics (Springer-Verlag).
664. (I.) S. di Serego Alighieri et al.: Polarized Light in High Redshift Radio Galaxies. Submitted to *Nature.*
(II.) S. di Serego Alighieri: Imaging Polarimetry. To appear in the Proceedings of the 1st ESO/ST-ECF Data Analysis Workshop, Grosbøl et al. eds. ESO Conference and Workshop Proceedings No. 31. 1989.
665. P. Crane et al.: Cosmic Background Radiation Temperature at 2.64 mm, 1.32 mm and 0.6 mm. To appear in the Proceedings of the Moribond Astrophysics Conference.
666. B. Binggeli, M. Tarenghi and A. Sandage: The Abundance and Morphological Segregation of Dwarf Galaxies in the Field. *Astronomy and Astrophysics.*
667. C. Tadhunter and Z. Tsvetanov: Anisotropic Ionizing Radiation in NGC 5252. Submitted to *Nature.*
668. F. Ferrini, F. Palla and U. Penco: Fragmentation Theories and the IMF. To appear in *Physical Processes in Fragmentation and Star Formation,* Rome, June 1989, eds. R. Capuzzo-Dolcetta, C. Chiosi and A. Di Fazio, Reidel, Dordrecht.
669. R. M. West: Post-Perihelion Observations of Comet Halley. II (r = 10.1. AU). *Astronomy and Astrophysics.*
670. P. Benvenuti and I. Porceddu: Diffuse Absorption Bands and the 2175 Å Feature. *Astronomy and Astrophysics.*

TECHNICAL PREPRINTS

3. J. M. Beckers and F. Merkle: A Survey of Present Efforts in Astronomical Adaptive Optics. To be published in the SPIE Proceedings No. 1130. International Congress on "Optical Science and Engineering", Paris, 24–28 April 1989.
4. M. Sarazin and F. Roddier: The ESO Differential Image Motion Monitor. *Astronomy and Astrophysics.*
5. M. Tarenghi and R. N. Wilson: The ESO NTT (New Technology Telescope): The First Active Optics Telescope. To be published in the SPIE Proceedings No. 1114 (1989). Symposia on "Aerospace Sensing", Orlando, 27–31 March 1989.
6. L. Noethe et al.: Active Optics: From the Test Set Up to the NTT in the Observatory. To be published in the SPIE Proceedings No. 1114 (1989). Symposia on "Aerospace Sensing", Orlando, 27–31 March 1989.
7. R. N. Wilson and L. Noethe: Closed Loop Active Optics: Its Advantages and Limitations for Correction of Wind-Buffet Deformations of Large Flexible Mirrors. To be published in the SPIE Proceedings No. 1114 (1989). Symposia on "Aerospace Sensing", Orlando, 27–31 March 1989.
8. F. Merkle and J. M. Beckers: Application of Adaptive Optics to Astronomy. To be published in the SPIE Proceedings No. 1114 (1989). Symposia on "Aerospace Sensing", Orlando, 27–31 March 1989.
9. M. Faucherre, F. Merkle and F. Vakili: Beam Combination in Aperture Synthesis from Space: Field of View Limitations and (U, V) Plane Coverage Optimization. To be published in the Proc. of the SPIE Intern. Congress on Opt. Science and Engin., Top. Conf. 1130: New Technology for Astronomy", Sept. 1989.
10. J. M. Beckers: Plans for High Resolution Imaging with the VLT. Paper presented at the 1989 Frühjahrstagung der Astronomischen Gesellschaft on April 11–14 in Friedrichshafen.
11. J. M. Beckers: Polarization Effects in Astronomical Spatial Interferometry. Paper presented at the SPIE Conference No. 1166 on "Polarization Considerations for Optical Systems II" on August 9–11 in San Diego.

REPORT ON ESO WORKSHOP:

"Extranuclear Activity in Galaxies"

About 80 participants attended the ESO Workshop on Extranuclear Activity in Galaxies, held in Garching on May 16–18, 1989. The meeting was followed by an informal session on Cen A on May 19, 1989 where survivors from the previous three days were present. Additional colleagues from ESO and from the neighbouring Max Planck Institutes could be met at the usual ESO reception at the end of the first day.

The scientific programme featured 10 keynote contributions which in comprehensive reviews covered a wide range of observational, interpretative and theoretical issues bearing on the workshop's general theme. These larger overviews were supplemented by shorter contributions, selected to match the subject of the workshop as closely as possible. In addition, time had been reserved to digest a substantial number of interesting posters. The programme for the Cen A session was finalized during the days of workshop and staged a variety of new exciting data that demonstrated once more the unique status of the nearest radio galaxy. Vital organizational matters were smoothly handled by secretaries Christina Stoffer and Britt Sjoeberg. The meeting was favoured by a week of good weather and ended in a natural way in the local beer garden.

All in all the papers presented during this workshop provide an up-to-date overview of this quickly developing field of study. An issue that featured prominently during these days concerns the question whether the nuclear radiation field in many or in most active galaxies is anisotropic, which may explain the asymmetries often observed for extranuclear activity. A related and even more fundamental consideration is whether local energetic sources may account for at least certain forms of extranuclear activity or can be ruled out. For these and other questions it is instructive to compare highly energetic (though mostly distant) radio galaxies with the moderately energetic active galaxies, even when not leading to obvious solutions. It is quite remarkable in fact that nowadays in so many of the objects extended emission may be found. The material presented at this workshop clearly indicates that for a proper understanding of these extranuclear phenomena a broad range of topics has to be considered, including both a description of the nuclear activity and knowledge about the material surrounding the nucleus.

The Proceedings will be published by the European Southern Observatory and are expected to be available early this autumn (see box).

E. Meurs (ESO) and
R. Fosbury (ST-ECF)

REPORT ON ESO WORKSHOP:

"Low Mass Star Formation and Pre-Main Sequence Objects"

The Workshop on low mass star formation and pre-main sequence objects took place in Garching on July 11–13, 1989.

About 170 participants from 20 countries attended the meeting. During three days, 26 reports were presented on recent advances in both observational and theoretical studies of the formation and early evolution of low mass stars. Additionally, 85 poster papers were displayed, presenting newly completed or ongoing star formation research programmes (see photo). A special poster session described ten prominent southern molecular clouds with active low mass star formation. The Workshop gave a lively overview of a dynamic and rapidly growing field of astronomy.

The Proceedings will be published by the European Southern Observatory and are expected to be available around the middle of October 1989 (see box).

B. Reipurth (ESO)

The following ESO Workshop Proceedings will become available in October 1989:

Extranuclear Activity in Galaxies

The price of this volume, edited by E. Meurs and R. Fosbury, is DM 40.– (including packing and surface mail).

Low Mass Star Formation and Pre-Main Sequence Objects

This volume, edited by Bo Reipurth, contains approximately 500 pages and is offered at a price of DM 50.– (including packing and surface mail). Payments have to be made to the ESO bank account 2102002 with Commerzbank München or by cheque, addressed to the attention of

ESO, Financial Services
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München

Please do not forget to indicate your complete address and the title of the Proceedings.

ESO FELLOWSHIPS 1990–1991

The European Southern Observatory (ESO) intends to award up to six post-doctoral fellowships tenable in the ESO Headquarters, the Scientific-Technical Centre which is located in Garching near Munich.

The main areas of activity are:

– to do research in observational and theoretical astrophysics;
– to carry out a programme of development of instrumentation for the La Silla telescopes;
– to develop future telescopes involving new technology;
– to provide data reduction facilities to users of the ESO instruments;
– to provide photographic facilities for atlases of the southern sky;
– to foster cooperation in astronomy and astrophysics in Europe.

Fellows normally participate in one or more of the above. In addition there is the possibility of participating in the activities of the European Coordinating Facility of the Space Telescope (ST-ECF) which has been established at ESO.

Fellows will normally be required to spend up to 25% of their time in supporting activities such as introduction of users to data reduction facilities, remote control operations and testing new instrumentation.

Fellowships are to be taken up between January and October 1990.

Most of the scientists in the Centre come from the Member States of ESO, but several are from other countries. In addition to regular staff members, the Centre comprises visiting scientists, post-doctoral fellows, and graduate students.

Applicants normally should have a doctorate awarded in recent years. The fellowships are granted for one year, with normally a renewal for a second year and occasionally a third year.

Applications should be submitted to ESO not later than October 15, 1989. Applicants will be notified in December 1989. The ESO Fellowship Application form should be used. Three letters of recommendation from persons familiar with the scientific work of the applicant should be sent to ESO directly. These letters should reach ESO not later than October 15, 1989.

Enquiries, requests for application forms and applications should be addressed to:

European Southern Observatory, Fellowship Programme, Karl-Schwarzschild-Straße 2, D-8046 GARCHING b. München, Federal Republic of Germany.

News About "Remote Control" at ESO

A New Video Film

A new video film about Remote Control (duration 12 minutes) has been produced by the ESO Information Service. It gives an introduction to this subject to the general public, but it will also be useful for astronomers, who are not very familiar with this observing facility at the ESO Headquarters in Garching.

The ESO Information Service (address on the last page) will make available VHS copies of this video *on loan* to institutes and organizations in the ESO member countries, upon written request. The letter must specify the desired loan period. Due to the limited number of casettes available, it may not always be possible to accommodate a request.

It is also possible to buy the casette at a cost of 70 DM (VHS, Super-VHS or Umatic-lowband). Please send your order (with payment) to the ESO Information Service.

New Link to Become Available in Late 1989

Meanwhile an intense period of remote observations is going on in Garching. From July 18 to August 20 there were observations practically every night, either with the 2.2-m or the CAT telescope.

At the same time preparations are made to be ready with the necessary equipment (multiplexers, gateways, modems, codecs) late this year, when the 64 Kbit/s link will begin to be tested between ESO Garching and La Silla. This link will eventually be used to remotely control the NTT.

A "Remote Control Manual" for users has also been prepared and can be obtained from the Visiting Astronomers Section at the ESO Headquarters in Garching.

G. Raffi (ESO)

Adriaan Blaauw Receives Bruce Medal

Professor Adriaan Blaauw, distinguished Dutch astronomer and former ESO Director General (1970–1974), recently received one of the most prestigious awards in astronomy, the Bruce Medal. This took place on June 23, 1989, at the time of the centennial celebration of the Astronomical Society of the Pacific.

At the award ceremony, Professor Frank Drake, President of A.S.P., mentioned Adriaan Blaauw's numerous and distinguished services to astronomy over many years. These include the fundamental work done in the 1950s and 1960s on galactic structure, the nature of associations, and the kinematics of early-type stars, as well as his involvement in the founding of ESO and his service to the IAU, in particular as President (1976–1979).

We at ESO heartily congratulate Adriaan Blaauw to this well-deserved honour.

R. West (ESO)

Booking of Visitor Facilities in Garching

The visitor support in Garching is undergoing some changes which will be described in detail in the next issue of the *Messenger*.

Effective immediately, kindly address all inquiries concerning the booking of visitor facilities at the Headquarters (MIDAS or IHAP for data reduction; PDS or Optronic measuring machines for work with photographic plates; observations at La Silla under remote control from Garching; guest rooms; financial support if applicable) to Ms. Elisabeth Hoppe.

The ways to contact her are:

○ by phone: +49-89-32006-473
○ by electronic mail:
ESOMC1::VISAS (SPAN)
VISAS@DGAESO51 (EARN/Bitnet)
○ by telex: 52828220 eod
○ by telefax: +49-89-3202362
○ in person: office No. 225

or by ordinary mail at the ESO Headquarters' address.

Please note that all arrangements for observing trips to La Silla continue to be handled by Mrs. Christa Euler (phone +49-89-32006-223).

D. Baade (ESO)

The Research Student Programme of ESO

With reference to the article by Professor Harry van der Laan in the *Messenger* (**55**, p. 12), in which the details about this new programme are outlined, it is now the intention to appoint a number of students, registered at a recognized university in an ESO member state. Note that there is no fixed deadline for the applications.

Potential candidates or their supervisors may request the brochure about the ESO Research Student Programme (available in late September 1989) and application forms from the Personnel Administration and General Services at the ESO Headquarters, Karl-Schwarzschild-Strasse 2, D-8046 Garching bei München, F.R. Germany.

ESO'S EARLY HISTORY, 1953–1975

IV. Council and Directorate Set to Work; The Initial Programme of Middle-Size Telescopes*

A. BLAAUW, Kapteyn Laboratory, Groningen, the Netherlands

„Es würde mir als lohnende Aufgabe erscheinen, den Rest meines wissenschaftlichen Lebens dem Aufbau des ESO zu widmen."
From a letter of O. Heckmann to J. H. Oort of December 1, 1961.

Introduction

Once the ESO Convention had been signed, in October 1962, and the ratifications were in sight (completed January 1964), many activities developed: by the ESO Council, the now "legal" successor of the ESO Committee, and by the ESO Directorate headed by Heckmann. In the present and the next two articles I shall describe developments over the six years which followed, leading to the dedication ceremonies on La Silla in the spring of 1969. These ceremonies marked the completion of what we may now call ESO's first phase.

In these developments we distinguish two main lines. In Europe: building up ESO's organizational structure including financial, personnel, legal and many other matters as well as the design and construction of telescopes and auxiliary instrumentation of the "Initial Programme" defined in the Convention. In Chile: the extensive programme of infrastructure and constructions; building up the Observatory on La Silla and the facilities in Santiago and La Serena. In the present article we deal with activities in Europe, and in the two following articles turn to those in Chile.

Heckmann Becomes ESO's First Director, November 1962

The need for executive leadership was felt soon after the ESO Committee had undertaken to realize the ESO project, but particularly so in the late 1950's, and names of candidates were proposed. The most obvious choice was Charles Fehrenbach, in view of his accomplishments in instrumentation and in building up the Haute-Provence Observatory. However, these and other obligations in French astronomy made it impossible for him to accept. As a second possibility my name was mentioned, but obligations with regard to the directorship of the Kapteyn Laboratory assumed in 1957 made me, too, refrain; instead I took over the Secretariat of the ESO Committee from Bannier from early 1959 [1]. This was a temporary solution, and the need for a director remained.

The solution was found when in the course of 1961 Otto Heckmann, a member of the ESO Committee, appeared to seriously consider a suggestion, made from various sides, to take the task upon himself. The matter was discussed between him and Fehrenbach during their joint visit to American observatories in the summer of 1961 to which we shall return below [2]. Soon after this, responding to a remark in a letter of Oort, Chairman of the EC, of November 27, 1961, Heckmann wrote on December 1, 1961 [3]:

„– – – *Es würde mir als lohnende Aufgabe erscheinen, den Rest meines wissenschaftlichen Lebens dem Aufbau des ESO zu widmen. Da ich aber mit der Universität Hamburg und der Hamburger Sternwarte sehr fest verknüpft bin, so ist die Lösung dieser alten Bindungen schwierig* – – –".

In the meeting of the EC of June 18, 1962, Heckmann accepted, first for one year only, from November 1, 1962, and subsequently on a long-term basis. Heckmann was then 60 years old. He put his shoulders under the ESO task until his retirement per January 1, 1970: determinedly, and with plenty of drive. After the necessary preparations he felt ready for the job in the spring of 1963, so that by circular letter of April 17, 1963, signed by Bannier and Heckmann, executive authority and financial responsibility were transferred per May 1, 1963 from Bannier as Treasurer of the EC to Heckmann as Director [4].

Heckmann's first associate at Directorate level was André Muller who had been heavily involved in the site tests, first in South Africa and next in Chile. As Superintendent for Chile his main responsibility would become the supervision of the extensive construction programmes. Muller's employment as an associate of Heckmann started per January 1, 1963, but since at that time ESO did not yet possess the administrative set-up for formalizing the appointment, he first remained on the payroll of the University of Groningen to whom ESO reimbursed his salary [5]. Muller was the first staff member to become permanently employed by ESO.

Per April 1, 1963, Heckmann appointed the accountant H.W. Marck, and the next appointee – apart from temporary secretarial help – was J. Bloemkolk as Manager per October 1, 1963 [6]. Bloemkolk's assignment was meant to be in Chile, but it was fairly soon changed into one covering the administrative business of the Director's Office. Another important appointment was that of Jöran Ramberg as Assistant Director per November 1, 1963. A staff member of Stockholm Observatory, Ramberg had since November 1961 contributed to the development of ESO as a Secretary of the Instrumentation Committee, the role of which will be described below. He would become Heckmann's right hand in the development of instrumentation and buildings.

After the ratifications, from early 1964, ESO staff underwent rapid growth which we shall not follow in detail; we will have occasion to refer to certain staff members individually in the context of their tasks. This may be the proper occasion, though, to acknowledge the dedicated role of Otto Heckmann's wife, Johanna ("Hanna") Heckmann-Topfmeier who closely accompanied her husband in almost all areas of his comprehensive task, and thereby became intimately acquainted with the ESO project. Whereas at formal occasions she remained in the background, she used to take an appreciable share in the daily administrative chores of the Office; energetic, cheerful – and, as an unpaid employee, not without a bit of embarrassment for Council . . .

Mrs. Johanna Heckmann-Topfmeier, wife of Otto Heckmann. Mrs. Heckmann volunteered as an assistant to her husband in many of his administrative and organizational tasks. From a slide in the ESO Photographic Archives taken in February 1969 at ESO Headquarters in Santiago by Heckmann, and marked "Hanna" in his handwriting.

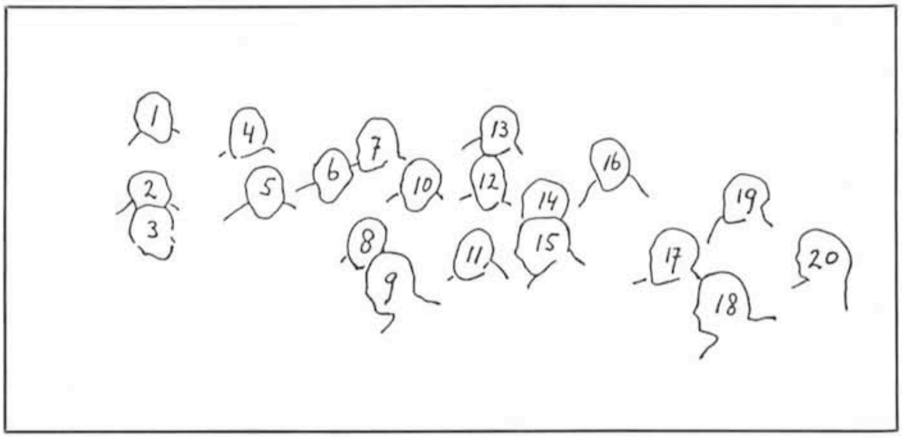
* Previous articles in this series appeared in the *Messenger* Nos. 54, 55 and 56.

Council and Finance Committee

Article V of the ESO Convention defines the constitution and tasks of the Council. It consists of two delegates per Member State of whom at least one should be an astronomer. The Financial Protocol attached to the Convention (and referred to in its Art. V.2.b.) defines the constitution and task of the Finance Committee (henceforth to be denoted by FC). It is, next to Council, the most authoritative administrative body. Contrary to other committees that help ruling the organization and for which the membership is determined by Council (like for instance the Instrumentation Committee) members of the Finance Committee are government representatives (Art. III of Fin. Prot.), one per Member State, and thereby form the direct link to the national financial authorities. No major financial decision is taken by Council without having been submitted first to the FC. Council policy and FC's counsel have always been intimately interwoven.

The accompanying table gives the dates and places of the meetings and the names of the Presidents of Council and of the FC over the period ending with the year 1969. The first Council Meeting, held in the French Ministry of Foreign Affairs right after the ratifications of the Convention, took place on February 5 and 6, 1964 and elected J.H. Oort as its first President. Oort resigned from this office at the Stockholm meeting of June 1965, to be succeeded by Bertil Lindblad – an election honouring Lindblad's important contribution to the creation of ESO. Unfortunately, on June 25 Lindblad passed away, after which Oort again chaired the Council Meeting on Nov. 30/Dec. 1, 1965. This meeting elected G.W. Funke, the non-astronomical Swedish Council delegate as President. After Funke had completed his three years in office – the maximum term allowed by the Convention – the Council in its meeting of Dec. 3 and 4, 1968 elected as President the non-astronomical delegate from the Netherlands, J.H. Bannier.

The first meeting of the FC took place on February 6, 1964 at Paris, immediately following the first Council Meeting. Its first President was J.H. Bannier, who was in office until he assumed the Presidency of the Council in December 1968. He was succeeded as FC President by the German government delegate K.F. Scheidemann.



On February 5–7, 1963, shortly after the ESO Convention had been signed, the ESO Committee at the invitation of the CERN Directorate held its 19th meeting in CERN's Council Room. The photograph, taken during a tour of the CERN laboratories, shows:
1. P. Bourgeois (Belgium), 2. M. Deloz (Belgium), 3. A. Reiz (Denmark), 4. ??, 5. G.W. Funke (Sweden), 6. J.H. Bannier (Netherlands), 7. B. van Geelen (Netherlands), 8. W. Fricke (German Federal Republic), 9. C. Zilverschoon (CERN), 10. Ms. B. Rijken (ZWO, Netherlands), 11. A.B. Muller (Netherlands), 12. J.H. Oort (Netherlands), 13. Ch. Fehrenbach (France), 14. O. Heckmann (German Federal Republic), 15. H. Siedentopf (German Federal Republic), 16. ??, 17. B. Lindblad (Sweden), 18. ??, 19. ??, 20. Ms. T. Stuit (Kapteyn Laboratory, Netherlands).

Earliest Developments in Instrumentation

Of the many tasks facing Council and Directorate in Europe, the development and realization of the observational equipment was the central one. From the outset it had been agreed that in accordance with Baade's proposal, the nucleus of the equipment should be a powerful reflector and a large Schmidt telescope. For the first one, the natural example was the 120-inch reflector of Lick Observatory with its up-to-date design by the Lick staff. It came into regular operation in February 1960 [7]. Aiming at a still larger size such as that of the Mt. Palomar 200-inch (in regular operation since November 1949 [8]) would have been too ambitious for ESO; exceeding the size of the Mt. Wilson 100-inch, the leading instrument of the past decades, was an interesting proposition. The Schmidt would be an essential auxiliary: the Palomar Schmidt, in operation since January 1949 [9] had proven to be indispensable as survey instrument for the work with the large telescopes. For both instruments, the design might be copied and thus time and costs be saved. We shall see, though, that ESO would prefer modified solutions.

As a third instrument, the first meeting of the ESO Committee, in June 1953, proposed a meridian circle, although a strong tradition in positional astronomy did exist in the Southern Hemisphere, established by the Observatories of the Cape and in South America. However, compared to the Northern Hemisphere their number was too small. Moreover, positional astronomy was a strong component of the work of several European observatories and overall coverage of the sky essential for the establishment of the fundamental reference system. As we shall see, not a meridian circle but a modern alternative would be acquired by ESO: a Danjon astrolabe. Other additional middle-size instruments, suggested at early EC meetings, included a copy of the Lick Double Astrograph and a copy of the Marseilles GPO. Only the latter would later be realized, it played a role in the site tests in South Africa (see article II). We shall return below to the further specification of the middle-size instruments.

The principal concern of the EC in the

MEETINGS OF COUNCIL AND FINANCE COMMITTEE, 1964–1969

COUNCIL

No.	Date	Place	President
1	1964 February 5–6	Paris	J.H. Oort
2	1964 May 26–27	Obs. Haute-Provence	J.H. Oort
3	1964 December 2–3	Hamburg	J.H. Oort
4	1965 June 1–2	Stockholm	J.H. Oort
5	1965 Nov. 30/Dec. 1	Hamburg	(B. Lindblad †) Chairman: J.H. Oort
6	1966 April 1	Santiago de Chile	G.W. Funke
7	1966 November 21–22	Hamburg	G.W. Funke
8	1967 June 1	Hamburg	G.W. Funke
9	1967 December 1	Hamburg	G.W. Funke
10	1968 July 2–3	Brussels	G.W. Funke
11	1968 December 3–4	Hamburg	G.W. Funke
12	1969 March 22	Santiago de Chile	J.H. Bannier
13	1969 June 16	Hamburg	J.H. Bannier
14	1969 December 15–16	Hamburg	J.H. Bannier

FINANCE COMMITTEE

No.	Date	Place	President
1	1964 February 6	Paris	J.H. Bannier
2	1964 May 26	Obs. Haute-Provence	J.H. Bannier
3	1964 July 7	The Hague	J.H. Bannier
4	1964 November 17	Bergedorf	J.H. Bannier
5	1965 June 1	Stockholm	J.H. Bannier
6	1965 November 11	Bergedorf	J.H. Bannier
7	1966 March 31	Santiago de Chile	J.H. Bannier
8	1966 June 28	Bergedorf	J.H. Bannier
9	1966 November 15	Bergedorf	J.H. Bannier
10	1967 May 3	Bergedorf	J.H. Bannier
11	1967 November 21	Bergedorf	J.H. Bannier
12	1968 June 11	Bergedorf	J.H. Bannier
13	1968 November 19	Bergedorf	J.H. Bannier
14	1969 February 20	Bergedorf	K.F. Scheidemann
15	1969 October 3	Bergedorf	K.F. Scheidemann
16	1969 December 15	Hamburg	K.F. Scheidemann

early years was, however, a different matter; it realized that for the further planning, both financially and as to time schedule, it had to engage expertise in telescope design, not necessarily by an astronomer. Two names figured in the EC's deliberations already in the middle 1950's: those of B.G. Hooghoudt and of W. Strewinski, both well qualified. The engineer Hooghoudt was responsible for the successful design of the mechanical parts of the Dwingeloo radio telescope in the Netherlands which became operational in 1956. He did so as employee of the funding foundation ZWO, the director of which, Bannier, was prepared to make Hooghoudt's services available to ESO. The engineer W. Strewinski, an employee of the firm of Heidenreich and Harbeck at Hamburg, had been responsible for the design and construction of the Schmidt telescope recently acquired by the Hamburg-Bergedorf Observatory under Heckmann's directorate. This telescope was completed in 1955 [10], after which Strewinsky created his own design bureau.

The EC's and Council's ideal would have been to engage both experts in close collaboration in the context of a design bureau, but attempts towards this end were not successful. To some extent this was due to their very different personalities and background, but there was also the dragging uncertainty in the realization of the ESO project in the early years which forced the engineers to undertake other projects besides ESO. Concern about the failure to build up a strong design bureau, first among the EC, then among Council, is a recurrent theme in their meetings [11]. Eventually the two engineers became engaged in separate parts of the project. Hooghoudt collaborated in general logistic planning and became responsible for the design and the construction of the 1-m Photometric Telescope. He also, after a visit of observatories in the United States, prepared for the May and October 1957 meetings of the EC a report on design considerations for a large telescope [12]. Strewinski became deeply involved in the design and construction of the ESO Schmidt telescope and in the early design stage of the large telescope, a natural follow-up of his early close collaboration with Heckmann.

ESO's Oldest Committee, the Instrumentation Committee

In the earliest stage of ESO, when striving towards the Convention and conducting the site tests were the EC's main concern, the question of the future instrumentation was not yet prominent but the EC meeting of July 1958 did appoint an Instrumentation Committee (henceforth denoted by IC) consisting of O. Heckmann, A. Couder, R. Coutrez and J. Ramberg. However, little progress was made during the following two years. In July 1960 Fehrenbach was added to the IC and soon afterward, when the prospects for financing became more favourable, the IC became very active. Its meeting of January 3, 1961 at Paris was henceforth denoted as Number 1 in the long series to follow. Those up to the year 1970 are listed in the accompanying box. The rapid succession of meetings early in 1961 reflects the enhanced activity. The IC soon created subcommittees for dealing with particular aspects of the instrumentation; their meetings will not be systematically recorded here.

By the time of the completion of the required ratifications of the Convention, early 1964, the IC had met twelve times. Its chairmanship alternated between Heckmann and Fehrenbach until Heckmann became Director per November 1, 1962. From then on Fehrenbach chaired the IC, a task to which he would dedicate himself over almost ten years, till 1972. The first Secretary of the IC was J.

No.	Date	Place	Chairman/President	Minutes made by	Minutes in Files ESO Head of Adm.	Remarks, Ref. to EHA.
1	1961 January 3	Paris	O. Heckmann	J. Ramberg	+	
2	1961 February 22–24	Obs. H.-Provence	Ch. Fehrenbach	G. Courtès?	+	
3	1961 April 18–19	Paris	Ch. Fehrenbach		–	Agenda in I.C. 1.9.c. Report in letter by Minnaert to Oort + Blaauw in EHA – I.C. 1.9.c.
4	1961 June 9–10	Tübingen	Ch. Fehrenbach		–	Agenda in I.C. 1.9.c.
5	1961	Paris	?		–	
6	1961 November 11–12	Bergedorf	O. Heckmann	J. Ramberg	+	
7					–	
8	1962 June 16–17	Uccle	?		–	
9	1962 October 17–18	Stockholm + Saltsjöbaden	O. Heckmann	J. Ramberg	+	
10	1963 January 29–30	Utrecht	Ch. Fehrenbach	J. Ramberg	+	
11	1963 May 14–15	Paris	Ch. Fehrenbach	J. Ramberg	+	
12	1963 October 1	Heidelberg	Ch. Fehrenbach	J. Ramberg	+	
13	1964 March 11–12	Liège	Ch. Fehrenbach	J. Ramberg	+	
14	1964 June 25–26	Bergedorf	Ch. Fehrenbach	J. Ramberg (Assistent Dir.)	+	
15	1964 September 4	Hamburg	Ch. Fehrenbach	J. Ramberg	+	
16	1965 January 18–19	Bergedorf	Ch. Fehrenbach	J. Ramberg	+	
17	1965 May 18–19	Bergedorf	Ch. Fehrenbach	J. Ramberg	+	
18	1965 December 2	Bergedorf	Ch. Fehrenbach	J. Ramberg	+	
19	1966 January 18	Paris	Ch. Fehrenbach	J. Ramberg	+	
20	1966 May 26–27	Obs. H.-Provence	Ch. Fehrenbach	F. Dossin	+	
21	1966 October 12	Paris	Ch. Fehrenbach	F. Dossin	+	
22	1966 November 23	Bergedorf	Ch. Fehrenbach	F. Dossin	+	
23	1967 May 2	Bergedorf	Ch. Fehrenbach	F. Dossin	+	
24	1967 December 18	Bergedorf	Ch. Fehrenbach	F. Dossin	+	
25	1968 July 4–5	Bergedorf	Ch. Fehrenbach	A. Behr + S. Laustsen	+	
26	1968 November 5–6	Bergedorf	Ch. Fehrenbach	A. Behr + S. Laustsen	+	
27	1969 January 15–16	Bergedorf	Ch. Fehrenbach	A. Behr + S. Laustsen	+	
28	1969 May 8	Bergedorf	Ch. Fehrenbach	A. Behr + S. Laustsen	+	
29	1969 June 2	Nice	Ch. Fehrenbach	A. Behr + S. Laustsen	+	

Ramberg who continued to act in this capacity until May 1966, long after he had joined the ESO Directorate.

Attempts to reconstruct the early proceedings of the IC are hampered by the fact that the ESO Historical Archives do not (yet) contain the minutes of the IC meetings. Fortunately, many of these minutes do form part of the Files of the ESO Head of Administration; lacking from these are minutes of meetings Nos. 3, 4, 5, 7 and 8 pertaining to the period April 1961 to June 1962 but these are, of course, interesting ones for the earliest developments. We therefore have to consult the reports on the IC's proceedings presented at the meetings of the EC which in most cases are fairly detailed. Information is also contained in a number of letters, for instance for meeting No. 3 in a letter by M. Minnaert

Second Meeting of the ESO Council, with their advisors on May 26–27, 1964, at Observatoire de Haute-Provence.
From left to right:
Left-hand photograph: J.H. Bannier, M. Deloz, K. Walters (legal advisor to the Director), J. Ramberg, O. Heckmann, J.H. Oort.
Right-hand photograph: B. Lindblad, G. Funke, A. Reiz (Observer for Denmark), J. Rösch, A. Blaauw.
The left-hand photograph is part of the ESO Historical Archives contributed by J.H. Bannier, the right-hand one was contributed by the author.
Most likely, more photographs of the session were taken . . .

to Oort and Blaauw of May 1, 1961 [13].

One of the first things the IC set out to do, was acquainting themselves with instrumentation developments elsewhere in the world, especially in the United States. This was in line with the policy the EC had stressed from the beginning and which had led to Hooghoudt's 1957 report, and the EC was encouraged by the generous way in which American institutes offered their help in building up ESO. Thus, immediately after the Assembly of the International Astronomical Union in California in the summer of 1961, Heckmann and Fehrenbach made an extensive tour along observatories in the United States and Mexico and visited prominent astronomers among whom I.S. Bowen, N.U. Mayall, D. Shane, A.E. Whitford and G. Haro. Their report [14] was discussed at the 15th meeting of the EC, in November 1961. It deals with questions of telescope design, the choice of the site, design of domes and, finally, with matters of general policy. From this last section, let me quote a few paragraphs:

"Nos amis américains ont confirmé notre opinion que la responsabilité de toute la construction doit être prise par les astronomes. C'est à nous de décider les solutions de principe, d'accepter et de contresigner tous les plans.

– – – La réussite de nos collègues du Mont-Palomar s'explique en grande partie par la collaboration intime des astronomes et des ingénieurs travaillant tous à Pasadena et se réunissant très régulièrement.

Ces heureuses circonstances paraissent difficiles à réaliser par notre groupe européen. Une collaboration active de certains d'entre nous est néanmoins absolument nécessaire.

Il faut créer rapidement un bureau d'Ingénieurs – – –. La construction d'un Centre d'Etudes et probablement d'un laboratoire d'optique nous paraît également indispensable. – – –".

The first paragraph stresses the desirability of the complete involvement of the astronomers themselves in design and construction, and reflects a change in attitude sometimes encountered in previous telescope acquisition when much more of the ingenuity and responsibility was with the firm who delivered the telescope, sometimes even "off the shelves".

The report also led to discussion of the question with whom the ultimate authority for decisions on matters of instrumentation should be; with the IC, or with the EC (or, later, the Council). This led to a task description for the IC implying a considerable degree of authority [15]:

"– 1. The IC prepares all technical and financial aspects of the instrumentation in order to enable the Council to take the necessary decisions;

– 2. The IC makes all necessary instrumental and technical decisions within the frame of the budget and of the decisions of the Council."

Based on this task description, the Instrumentation Committee has played a very influential role in ESO's early development.

Naturally, because the large telescope and the Schmidt form the nucleus – the *raison d'être* – of ESO, their history should figure prominently in these reviews. Yet, we shall in the present article confine ourselves to the acquisition of the middle-size telescopes because these constituted the outfit on La Silla when the Observatory started regular operation in the late 1960's. The early histories of the Schmidt and the Large Telescope, both having become operational only in the course of the 1970's, will be central themes to be treated after I have dealt with the phase concluded in 1969. For the Schmidt, this will then also comprise the impressive associated survey projects.

The Middle-Size Telescopes

One of the IC's first assignments was the specification of the telescopes which, as part of the "initial programme" of the Convention would be referred to as:

"c. not more than three telescopes with a maximum aperture of 1 meter;" and

"d. a meridian circle;"

For two of the three telescopes mentioned under (c) the IC meeting of April 1961 arrived at the following recommendations: one telescope designed primarily for photo-electric photometry – it would become known as the Photometric Telescope – and one telescope designed primarily for spectroscopic work – to become the Spectrographic Telescope. We shall first deal with these two, and subsequently see how the two remaining items were filled in with the GPO and the Astrolabe.

The procedure chosen by the IC for the realization of these two instruments reflects in an interesting way ESO's international character. It "planted" the planning and construction in the fertile soil of the various national interests. Thus, the Photometric Telescope became a concern of astronomers in the Netherlands, especially of those of the Kapteyn Laboratory at Groningen where photo-electric photometry was being developed by J. Borgman and collaborators. Also involved in this project was M. Minnaert of Utrecht who, with Borgman, acted as liaison with the IC. Similarly, the Spectrographic Telescope was delegated to French astronomy, especially to the group around Ch. Fehrenbach at Marseilles and the Haute Provence Observatory. (The early planning of the Schmidt Telescope, to be described later, under the supervision of Bergedorf Observatory's director, Heckmann, reflects this same policy.) The policy of the EC to delegate development and realization of the middle-size telescopes to the above groups also resulted from a wish of the EC, to gain experience with different firms which might become useful for the construction of the large telescope [16].

The 1-Metre Photometric Telescope

Early 1961 the group involved at the Kapteyn Laboratory formulated the most essential specifications for the design of this telescope [17]:

– optimum definition on the optical axis, but image quality outside the axis good enough for offset purposes;

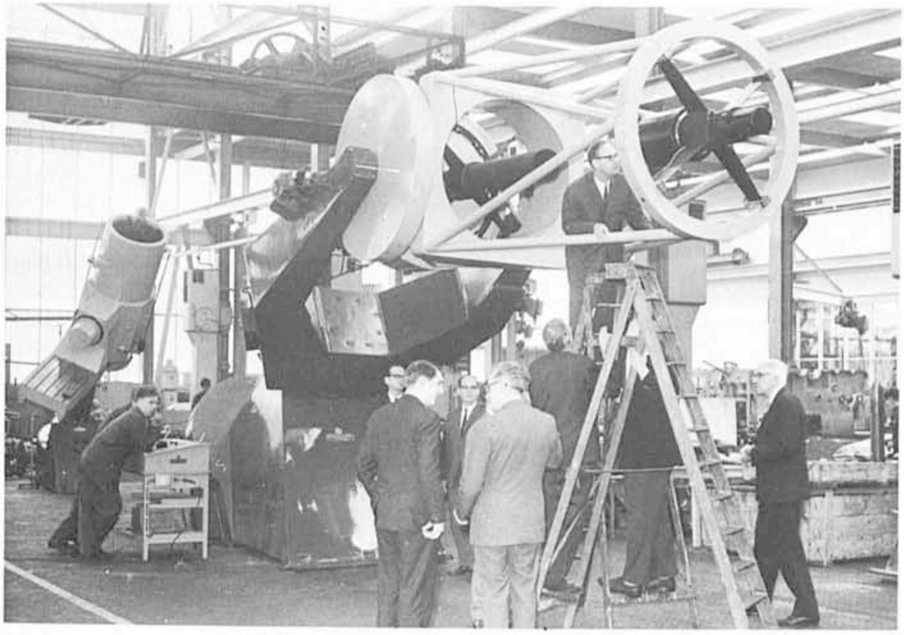
– fairly rapid switching between widely different directions; for this purpose aiming at a short telescope tube;

– provision for heavy photometric equipment at the Cassegrain focus and for at least one more photometer or spectrograph at another (Nasmyth) focus, with the possibility of rapid interchange;

– in connection with these specifications, preference for a fork mounting.

These specifications had been the subject of consultation with the engineer Hooghoudt, and reference was made to the 90-cm light-collector type telescopes in use at McDonald Observatory and at the Leiden Southern Station as possible examples.

At the April 1961 meeting of the IC, offers for the mechanical parts had been received from six firms, but the IC developed strong preference for the Dutch firm of Rademakers to whom Hooghoudt was consultant engineer [18]. Decisions to this effect and on the choice of a fork mounting – not an English mounting – were taken at the June 1961 meeting of the IC [19, 20]. For the optics of the telescope offers were received from five firms covering a variety of glass sorts (including regular glass and low-expansion Tempax and Silica) [21], and at the June 1962 meeting of the EC the IC reported that orders had been placed: for the mechanical parts with the Rademakers-Hooghoudt combination, for the main mirror with Jenoptik in Jena and for the secondary mirrors with Hereaus. The construction was supervised for the IC by Borgman and Minnaert. Meanwhile, preparations were made for the design and construction of the main photometer for the telescope.



The 1-m Photometric Telescope Nearing Completion. *By the end of the year 1964 the 1-m Photometric Telescope was almost ready to be delivered by the Firm of Rademakers at Rotterdam. It is shown here in their assembly hall on the occasion of a visit of the ESO group charged with the supervision of the construction. The photograph shows from left to right: (1) extreme left background: unidentified; (2) J. Doornenbal, mechanic, employee of ESO; (3) J. van der Ven (at that time at Rademakers, later to be employed by ESO); (4) J. Ramberg, Assistant Director of ESO; (5) on lowest step of ladder, B. G. Hooghoudt, consulting engineer for ESO; (6) high on ladder, the author of this article (Kapteyn Laboratory); (7) on lowest step of ladder, O. Heckmann, Director of ESO; (8) M. Minnaert (Utrecht Observatory).*
From a photograph in the ESO photographic archives, marked "7 DEC. 1964".

The October 1962 meeting of the IC delegated this to Borgman, Minnaert and Siedentopf.

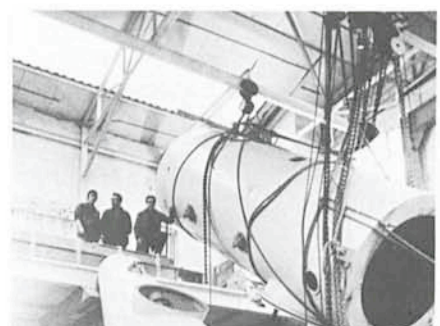
By the end of 1963, when the completion of the telescope would be a matter of little more than a year only, it had become clear that the telescope would not be used in South Africa. However, ESO was still a long way from completing its building programme in Chile, and potential users of the telescope were anxious to start soon. Therefore, it was suggested at the November 1963 meeting of the EC that a provisional, simple housing be acquired, and the May 1964 meeting urged an immediate decision on the matter. At that time the Convention had been ratified and the ESO Directorate had taken developments firmly in hand. It ordered from the United States a dome of light construction, popular among advanced amateur astronomers (Astro-Dome), and this was mounted on La Silla in the course of 1966. In October and November of that year the telescope was mounted in this provisional shelter under the supervision of the engineer Hooghoudt and the firm of Rademakers (after the telescope had arrived in Chile in the middle of 1965 and then stored in ESO's ware house at La Silla). In December 1966 the first photometric work was done by Borgman and collaborators with a simple photometer borrowed from the Kapteyn Laboratory. The ESO photometer for this telescope, constructed at the Kapteyn Laboratory, was mounted in the middle of 1967.

The Photometric Telescope has been described in detail by Hooghoudt in ESO Bulletin No. 1 of November 1966 which also contains a description of the photometer by M. de Vries. The telescope was moved to its permanent dome in the fall of 1968. The provisional dome has, since then, been used for several purposes and now houses the Leiden 90-cm telescope. A polarimeter for the 1-m telescope, installed at the end of 1968, was designed by A. Behr of the Hamburg Observatory and constructed under his supervision at Göttingen Observatory. A description by Behr is in ESO Bulletin No. 5 of December 1968.

The Spectrographic Telescope

Main specifications for this telescope, drawn up by the group around Fehrenbach at Marseilles and Haute-Provence and initially also planned in the 1-metre category, included: provisions for using both the Cassegrain and the Coudé focus, and an English mounting [22]. Offers were received from the same six firms as for the Photometric Telescope and preference was then given to the firm of REOSC in Paris with whom the French group had experience in the delivery of spectroscopic equipment. REOSC had also built the GPO telescopes. As an alternative, the IC had considered acquiring a replica of the Kitt Peak 36-inch telescope with some modifications [23]. This idea was given up, however, when in 1961 an appealing alternative was suggested by the French: a duplicate of the 1.5-metre spectrographic telescope for which the Haute-Provence Observatory was about to complete design studies [24]. Construction of two identical telescopes would result in prices exceeding only little the price of one 1-m telescope. The French design, envisaging a Coudé focus only, would have to be slightly adapted. Doubts arose whether the increase of the "Convention-size" from 1 to 1.5 metre would be acceptable for the ESO Council, but this never became a serious problem.

The offer of REOSC was accepted in principle by the EC meeting of February 1963 and became final after the ratification of the Convention [25]. A glass blank for the main mirror was ordered from Sovirel, Parra Mantois, and blanks for the secondary mirrors from Corning. For the spectrographs, design studies – with strong contribution from the French group – were taken up by the IC early in 1963 and for the Coudé spectrograph the order was placed at REOSC in October 1965. The two telescopes were



The 1.5-m Spectrographic Telescope Nearing Completion. *The Spectrographic Telescope in the assembly hall of the firm of REOSC, shortly before its shipment to Chile. From a photograph in the ESO photographic archives, marked "REOSC 91-Ballainvilliers" in envelope marked "February 1968".*

completed in the course of 1967 and the optics for ESO's copy tested in the Haute-Provence duplicate before being shipped to Chile. In the middle of 1968 the telescope was installed in its dome on La Silla under the supervision of the director of REOSC, A. Bayle. At the December 1968 Council Meeting Fehrenbach, just back from a stay on La Silla, could report that the instrument worked satisfactorily. For the first spectroscopic work, a Cassegrain spectrograph was borrowed from Marseilles Observatory. It would soon be replaced by ESO's own Cassegrain spectrograph "Chilicass". The Coudé spectrograph was finished by the end of 1968 and became operational on La Silla in the course of 1969.

A detailed description of the Spectrographic Telescope and the Coudé spectrograph was published by Fehrenbach in ESO Bulletin No. 3 of February 1968. The Cassegrain spectrograph is described by A. Baranne, E. Maurice and L. Prévot of Marseilles Observatory in ESO Bulletin No. 7 of Sepember 1969 and by Maurice in ESO Bulletin No. 11 of February 1975. The Coudé spectrograph was described by H.J. Wood, B. Wolf (staff members of ESO) and Maurice (of Marseilles) in ESO Bulletin No. 11 of February 1975.

The GPO (Grand Prism Objective)

We have seen in article II that around the year 1960 the GPO was introduced by its owner, the Marseilles Observatory, into the site testing activities in South Africa as one of the projects which would allow testing in combination with astronomical research. Eight years later, in the course of 1968, having meanwhile become ESO property, it started regular work on La Silla.

The ESO GPO was a duplicate of the GPO installed at the Haute-Provence Observatory (OHP). These twins represented an improvement of the smaller size instrument of this type at the OHP (the Petit Prism Objectif) developed earlier by Fehrenbach. Main motivation for this development had been the prospect of measurement of radial velocities of faint stars in a wholesale manner. The GPO consists of a photographic and a visual tube, each of 4 metre focal length. The photographic one has a doublet objective lens of 40 cm aperture, in front of which is mounted an objective prism of the type developed by Fehrenbach. This consists of two components, one of flint glass and one of crown-barium, and the angles of the two components are chosen in such a way that at wavelength 4175 Å the light traverses the combination without deflection. Hence, by taking two exposures with the prism in opposite orientations, one obtains on the photographic plate for each star two nearly coincident spectra in opposite directions, and the relative displacement of the spectral lines in the two is a measure of the radial velocity of the star. For a more detailed description we refer to the article by Fehrenbach in ESO Bulletin No. 1 of November 1966.

The possibility that the GPO planned for South Africa might become property of ESO was alluded to already in the late 1950's at the time when – as we saw in article I – the prospects for French participation in ESO were very low. For instance, it is mentioned in the report on a discussion on December 23, 1958 at Paris when Oort, chairman of the EC, discussed this participation with Danjon and Fehrenbach in the company of the French government representative Bayen [26]. The decision to incorporate the GPO into the ESO project was taken at the EC meeting of mid-July 1960. As described in article II, at that epoch plans for the Marseilles project had advanced to the stage where the choice of its location became desirable.

At the July 1960 meeting of the EC Fehrenbach presented three possibilities and the related financial schemes: (a) Execution of the project without financial involvement of ESO, in which case it would be located in a town in the Southern Karroo offering logistic help but of no interest for ESO; (b) Execution at Zeekoegat, one of the potential sites for ESO, requiring financial support from ESO for various technical provisions; and (c) Incorporation of the project into ESO, implying financial contribution of ESO for these services and future ESO ownership of the telescope and associated equipment.

The French delegation at the meeting expressed strong preference for the last one of these possibilities as it would strengthen their efforts to persuade the French government to participate in ESO. The costs of the instrument already expended should be considered as part of France's first financial contribution. (The costs mentioned on this occasion were 330,000,– Francs; the amount of 60,361.96 US dollars was mentioned in the context of French payment at the July 1963 meeting of EC.) Delegates from most of the countries represented at the July 1960 meeting were in favour of the proposition for a variety of reasons: the GPO was considered a valuable asset to ESO; it opened the possibility to soon undertake an international research programme; and it would contribute to the site tests. At Heckmann's proposal, the meeting resolved that the GPO would be considered as one of the instruments belonging to the "initial programme" of the – still unsigned – Convention.

The observational programme conducted by the Marseilles Observatory at Zeekoegat was concluded at the end of 1965. A series of publications by Fehrenbach and his collaborators M. and A. Duflot, A. Florsch and N. Carozzi in the Communications of ESO Nos. 1–7 over the years 1962–1966 are based on this work with the GPO. The mechanical parts were then shipped to Chile and the optics returned to France for overhaul. After the telescope had been assembled and mounted in its dome on La Silla, it resumed its work with results that soon turned out to be of superior quality due to the better observing conditions on the new site.

The Astrolabe

Among the tasks delegated to the IC was the definition of the instrument for positional astronomy. Initially, a meridian circle was the obvious choice, but meanwhile other observatories undertook such projects [27]. This led the relevant Working Group of the IC to modify the proposition and suggest at the June 1962 meeting of the IC the acquisition of an astrolabe.

A modern version of the astrolabe had been developed by Danjon and put to use at several French and other observatories. It has turned out to be a very useful instrument as it avoids to a large extent the systematic errors inherent to the meridian circle. Its limitation was in the restriction to bright stars, but for the main purpose, the improvement of the fundamental system with all-sky coverage, this was no serious drawback. The Dutch foundation ZWO possessed a Danjon astrolabe, left over from geodetical work in the Geophysical Year, and offered it for half the price [28].

In a letter of June 7, 1962 B. Guinot, head of the Astrolabe Service of the Paris Observatory and member of the Working Group, suggested to the EC that this astrolabe be made available for ESO [29]. As ESO's planning at that epoch was still in terms of South Africa, a location near the French station at Zeekoegat was envisaged. The switch from meridian circle to astrolabe was endorsed by the EC, and the acquisition proposed in the budget for 1964 as discussed at its February 1963 meeting [30]. By that time, however, the probability of establishing ESO in Chile had become so strong that the site remained uncertain for a while.

Once the decision in favour of Chile had become final, an interesting solution emerged: a collaborative agreement between ESO and the University of Chile, by which the astrolabe was to be installed at Cerro Calán Observatory near

Santiago. The agreement dates from 29 April 1965 [31]. ESO provided the astrolabe with chronograph equipment and a building to house the instrument, and the University of Chile its chronometric facilities. But most important: the observations would be conducted and supervised by the staff of Cerro Calán. After overhaul in Paris, the instrument was installed on Cerro Calán in November and December 1965 with the collaboration of Guinot. Since then it has made, under the supervision of F. Noël, solid contributions to the Fundamental Reference System in the Southern Hemisphere and to research on the Earth's rotation; a first demonstration of the appreciable systematic errors in the southern FK4 declinations was published by Anguita and Noël in 1969 [32]. In ESO Bulletin No. 4 of June 1968 Noël describes the nature of the project and the first years of operation.

ESO Chooses its Emblem

Not only heavy tasks kept the ESO Committee busy. After the Convention had been signed, it acquired its emblem for which at the October 1962 EC meeting Bannier presented some designs by the artist Mrs. G. M. Pot. The Committee had no problem in making up their mind; according to the minutes it chose the design "in which the stars show at their best". The emblem's stars – the Southern Cross – still show well, as is apparent from the front page of this *Messenger*.

References and Notes

Abbreviations used:
EC = ESO Committee (the Committee preceding the ESO Council).
ECM = ESO Committee Meeting.
IC = Instrumentation Committee.
EHA = ESO Historical Archives (see the article in the *Messenger* of December 1988).
FHA = Files Head of Administration at ESO Headquarters.

[1] Circular letter by Oort to EC members preparatory to the ECM of May 1959, in EHA-I. A. 1.9., and minutes of that meeting.
[2] See letters of Oort to Danjon and Funke of May 30, 1962, in EHA-I. C. 1.1.c.
[3] In EHA-I. C. 1.1.d.
[4] In EHA-I. C. 2.1.g.
[5] See correspondence between ZWO and University of Groningen in the years 1962 and 1963 in EHA-I. C. 2.1.e.
[6] Information provided by the Personnel Department of ESO; also: minutes of the ECM of July 1963, p. 12.
[7] *Publ. Astron. Soc. of the Pacific* **72,** 225, 1960.
[8] I.S. Bowen, *Publ. Astron. Soc. of the Pacific* **62,** 95, 1950.
[9] I.S. Bowen, *Publ. Astron. Soc. of the Pacific* **61,** 243, 1949.
[10] Jahresberichte Hamburger Sternwarte 1954 and 1955; *Sky and Telescope* **15,** Nov. 1955, p. 10.
[11] See, for instance, minutes ECM of Oct. 1957, June 1961, Oct. 1962, Nov. 1963, Council Meetings of May 1964 and April 1966 and correspondence between Fehrenbach, Heckmann and Oort of June 1964 in EHA-I. A. 2.9. and I. A. 2.10.
[12] Minutes ECM of April and Oct. 1957; the EHA do not contain the written report.
[13] In EHA-I. C. 1.9.c.
[14] In EHA-I. C. 1.9.a., Visite des Observatoires Américains.
[15] Minutes ECM of November 1961.
[16] See, for instance, the letter by Blaauw to Fehrenbach of April 6, 1961 in EHA-I. C. 1.9.c.
[17] EHA-I. C. 1.9.c.
[18] See letter by Minnaert to Oort and Blaauw of May 1, 1961 in EHA-I. C. 1.9.c.
[19] See Minnaert's letter to Van Geelen of 10 October 1961 in EHA-I. C. 1.9.c.
[20] Maps EHA-I. C. 1.9.f/k contain preparatory correspondence, technical descriptions, and the tender of Rademakers.
[21] Minutes IC of November 1961.
[22] See ref. No. 18.
[23] Minutes ECM of June 1961.
[24] Minutes ECM of November 1961.
[25] EHA-I. C. 1.9.e. contains the Cahier de Charges with drawings and the Marché de Gré à Gré of REOSC of May 20, 1963.
[26] In EHA-I. C. 1.1.c. See also correspondence between Fehrenbach and Oort of October 1958 in EHA-I. A. 2.1.
[27] The Yale and U.S. Naval Observatories planned an instrument in Argentina and the Pulkovo Observatory one in Chile, whereas Greenwich Observatory contemplated a collaborative project with the Cape Observatory and Hamburg Observatory one with Perth.
[28] Minutes Council Meeting of May 1964, p. 10.
[29] Letter by Guinot to Blaauw and follow-up correspondence with Van Geelen in EHA-I. C. 1.9.d.
[30] EHA-I. A. 1.19. and I. A. 2.6.
[31] ESO Ann. Report 1965, p. 10.
[32] *Astron. Journal* **74,** 954. 1969.

Field Strömgren Photometry with a CCD

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Introduction

The chemical evolution of the Galaxy is somehow coupled to its formation. The location of stars with a certain metallicity may therefore also depend on the Galaxy's dynamical history.

Laws describing the galactic distribution of the various stellar populations introduced to understand the construction of the Galaxy are often based on detailed studies of the solar vicinity. We have been interested in studying particularly the F stars in a few galactic directions of interest, e.g. the SGP, to search for [Fe/H] gradients in space and time. Such studies are mostly based on accurate photoelectric photometry but the cry for data in more remote volumes has been acute lately and as large telescopes are not available for extended photometric surveys we have tried to use a medium sized telescope with a CCD instead.

Stars with a metal content down by a factor of 2.5 relative to the Sun have been suggested to form a spheroid with a local scale height in the range from 600 to 1 000 pc and the stars with [Fe/H] ≤ -0.8 another system with a scale height of several kpc. Strömgren photometry of F stars seems well suited to trace the metal variation with age and distance. The intermediate band photometry thus permits computation of distances based on individual absolute magnitudes. Distances based on a colour – absolute magnitude relation as $(b\text{-}y)_o - M_V$ may be quite uncertain. For an F star with $(b\text{-}y)_o = 0.3$ the width of the main sequence band is observed to be 2 mag at least. The scale height of the most metal poor stars thus suggests that observations of objects several kpc from the plane should be performed.

According to current models of the Galaxy, it is only several kpc from the plane that extreme population II stars will dominate. Our observing parameters are set by the detection of an F9 star 5 kpc from the plane. The V magnitude is about 18 at this distance. The most critical colour is, however, the u-band, partly because the F stars are cool and partly because this band falls in the wavelength range where the CCD's R.Q.E. is smallest, only 10 to 20 %. The stellar metallicity may be computed without u but the band is required for estimating M_V. An F9 star has $(b\text{-}y) = 0.4$ and $(u\text{-}b) = 1.5$, $V = 18$ then implies that

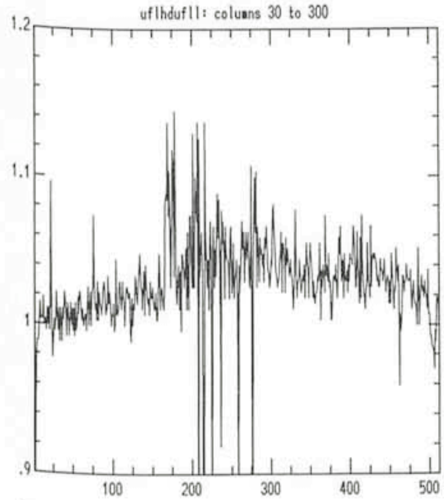

Figure 1: *The ratio of a u flat field with original intensity about 650 ADU to a u flat with original intensity 75 ADU. Both flat fields are normalized to a unit median sensitivity. The abscissa indicates the row number and the average is taken through column 30 to 300. The ratio of the two flat fields is seen to show a variation of ~3%.*

$u \geq 20$ mag. So the problem concentrates on how one obtains high-precision Strömgren photometry for stars with $u \sim 20$. Depending on the actual chip available, the necessary integration times may be estimated. We used ESO CCD # 8 which required 70 to 80 minutes to go down to the 20th mag in u with a S/N of 30.

Photometric Procedure

As an objective of our study is to make possible a distinction between F stars with [Fe/H] = 0.0, −0.4 and less than −0.8 representing the disk, the intermediate population II and the extreme population II respectively, we require a standard error of 0.02 (or better) in the colours v, b and y to have a one-sigma difference in [Fe/H] only. A similar accuracy of u and thus of c_1 gives a relative distance error of 20%.

For the CCD observations, we try to adopt the procedure established for photo-electric measurements with extinction determination in all four colours and with copious standard star observations each night.

Standard Stars

No primary standard stars are faint enough to be used with a CCD on a 1.5-m telescope; instead we have been using secondary standards down to the 14th mag from the literature. Standards were exposed with a defocused telescope and with sufficiently long exposure times so the uncertainty in the shutter timing was of no importance and the images still did not saturate. As a second approach we also tried to use open clusters with deep uvby photometry allowing several stars in a single frame but this may result in difficult transformations of the m_1 index because of the cluster's narrow metallicity range. About 20 standards in each colour is preferable per night. With the extinction determination, one third of the night is spent on the photometric calibration of the system.

Flat Fielding

Correct flat fielding is of the outmost importance when an accuracy of 0.02 mag or ~2% is required. It would of course be most convenient if a scientific frame with its astronomical objects and background could be flat fielded with a single, well-defined, response frame. Considering the possible intensity range in a frame bracketed by the background and a source, the CCD's response surely must be linear. However, we may have seen indications that this is not quite the case. The response seems to obey a power law, response $\sim I^{1.03}$, valid for intensities from a few hundred to several thousands. Figure 1 shows the ratio of two u flat fields at a low and a high intensity. A three per cent variation is noted. A non-linearity means that we cannot use identical flat fields inside a stellar image and for the background. Using a flat field pertaining to the background level or to some intermediate level leaves the stars slightly too bright. For a y = 17 mag star we make an error in the range Δy = 0.01−0.02 mag.

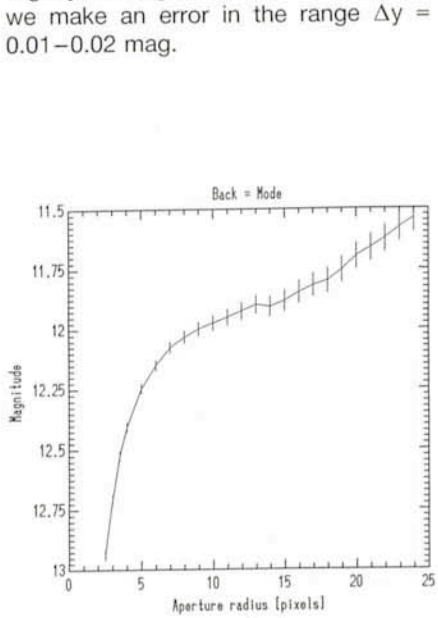

Figure 2: *Aperture-magnitude versus aperture. The star brightens with aperture. The tic marks on the curve indicate a one-pixel step. The magnitudes are computed with a background estimated as: mode = 3× median − 2× mean. Due to the large stellar images the background is measured in an annulus with radii 35 and 45 pixels.*

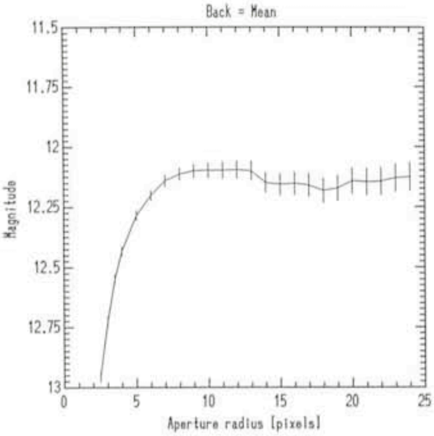

Figure 3: *As Figure 2, but the mode is now replaced by mean and a convergence is established.*

Background Subtraction

After correcting for the sensitivity variation across the frame, we noticed that the background depended on the brightness of the star and that the stellar magnitudes did not converge with aperture.

From the seeing conditions during our runs and the scale of the Danish 1.5-m telescope we expected stellar images of 5 pixels or smaller.

Figure 2 shows the variation of the stellar magnitude with aperture when we use the background suggested by the DAOPHOT photometry package. The star brightens with the aperture. Obviously we don't correct for all the signal in the background. DAOPHOT derives the background as, mode = 3× median − 2× mean. A good background estimator in crowded regions like a globular cluster, but apparently not in the sparsely populated general field. We replaced the mode by the simple mean and the result is shown in Figure 3 where we obtain a good convergence after ~10 pixels. For the faint programme stars we thus use a stellar radius of 12 pixels and not the 2−3 suggested by the seeing measurements.

Transformation to the Standard System

The instrument magnitudes resulting from the aperture photometry are then corrected for extinction and transformed to our secondary standard system by means of our standards. We are using the transformations for the whole range of apparent magnitude of our programme sample. We have approximately three stars per frame at the SGP, also indicating that our limiting magnitude is about V = 20 mag, so the transformation is used 6 magnitudes beyond the fain-

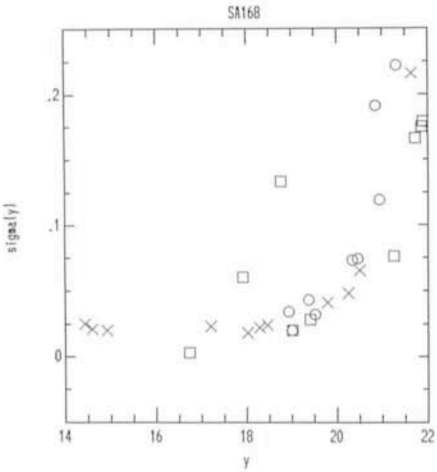

Figure 4: *σ_y versus y for three frames in SA 168. The magnitudes are in the instrumental system, but the transformation coefficient is about unity.*

test standard stars. Our results are surely depending on the detector linearity. m_1, c_1, and (b-y) have almost linear transformations whereas V includes, as expected, a more significant colour term.

Results

Figure 4 shows as an example the variation of σ_y with y for three frames in the selected area SA 168 and apparently σ_y stays below the maximum acceptable error 0.02 mag down to about the 19^{th} mag. The three other colours have an identical behaviour.

Towards the SGP we have so far identified about 39 F stars, $0.2 < (b\text{-}y) < 0.4$ mag, in the whole magnitude range down to V = 20 and in a solid angle only ~one tenth of a square degree. 33 of these stars also have good u measurements, so the sample already is of some significance.

When u, v, b and y are obtainable with an error 0.02 mag, the study's objective to investigate the [Fe/H] variation of the F stars beyond D = 5000 pc from the plane seems within reach. We have $\sigma_{[Fe/H]}$ = 0.4 dex and $\Delta D/D \sim 20\%$ or better. However, we do not see how the error may be improved to better than ~0.01 mag or ~1% implying that the best obtainable error is 0.3 dex in the metal content [Fe/H]. Regarding F stars, observations are just feasible at 5 kpc from the plane with a 1.5-m telescope.

It will be particularly interesting to see the relative population shift with distance, but also to see if there exist stars with solar metallicity at these remote distances.

As our general results are not too encouraging concerning the obtainable errors we want to stress that it seems possible to do CCD photometry – also in the u region – in the field without having to establish standards in each frame.

We should mention that the reduction of the several thousand frames forming the basis of this note have been performed with the MIDAS, IRAF and DAOPHOT packages.

δ-Scuti Stars in NGC 6134

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The CCD camera on the Danish 1.5 m telescope has been used to obtain exposure time series of small areas in open clusters. The purpose is to study the frequencies of different types of pulsating variables. Very low noise levels have been reached by the use of differential photometry carefully considering the error sources.

Noise Levels

To illustrate the high precision one can obtain with CCD's, we present the data from one night in late May 1988 on NGC 6192. Exposure times were 20 seconds and exposures were collected each minute for nearly 7 hours. The time series has some gaps, when tapes had to be changed or the seeing and the tracking checked. The resulting 370 frames were reduced with the DAOPHOT package and relative magnitudes determined for all reasonably isolated stars. A small set of not too bright, well isolated stars define the reference.

Two corrections turned out to be of critical importance. A colour correction to eliminate differential extinction effects on stars of different colours. And a correction for non-linearity of the CCD. The CCD (# 8) turned out to have a nonlinear response at high exposures before saturation of the order of two per cent. Consequently, for the bright stars, the change of seeing introduces a variation due to the non-linearity. We were able to correct for this effect using the large number of exposures and large number of stars we have.

All time strings were transformed into power amplitude spectra. Figure 1 presents the mean amplitude in three frequency intervals for stars over a range of 7 magnitudes. For high frequencies the amplitudes scatter very little about a

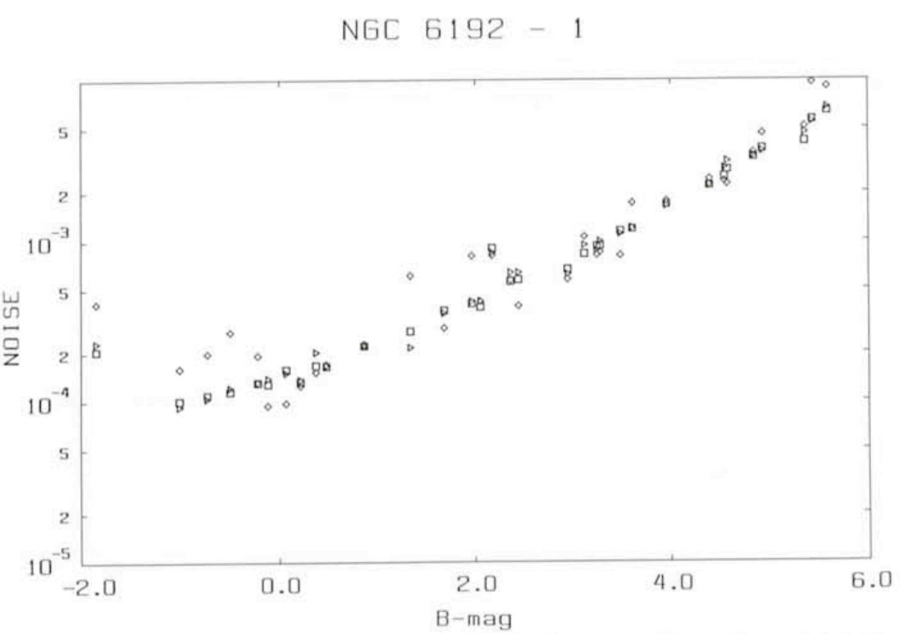

Figure 1: *The noise level for different frequency intervals. Squares correspond to periods in the range 3–10 min, triangles 10–60 min and diamonds 1–2 h.The abscissa is the B magnitude relative to a set of reference stars on the frame.*

TABLE 1: *Properties of the δ-Scutii stars in NGC 6134*

#	B(mag)	$(B-V)_o$	M_B	A	P(hours)
5	12.73		1.11	0.0252	4.161
29	13.04	0.275	2.10	0.0176 0.00785	2.329 1.089
40	12.50		0.89	0.00838	3.358

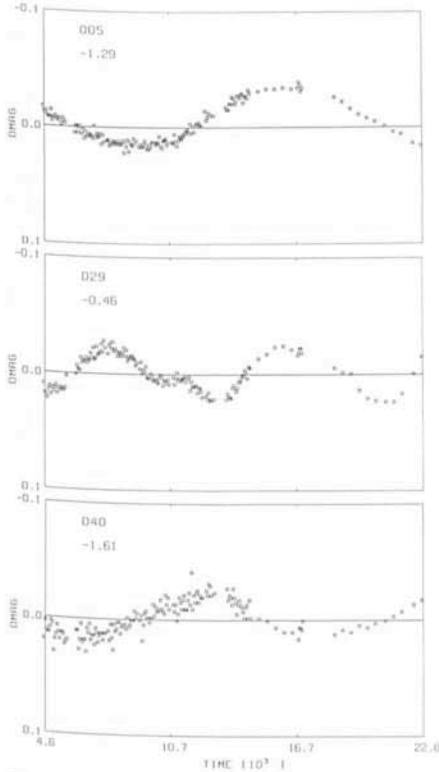

Figure 2: *Light curves for three stars in NGC 6134. Time is given in units of thousand seconds. The curves are labeled by a running number and the same relative magnitude as used in Figure 1.*

line, mainly determined by the photon statistics. The brightest star is overexposed. A noise level of 0.0001 mag is reached for the brighter stars. One of the high points for the lower frequency band corresponds to a variable, the others are caused by the influence of close neighbours. Other time series give similar diagrams, and under reasonable weather conditions the noise limit reached does not seem to contain any instrumental effect. We do not seem yet to have reached a lower limit, where the instrumental noise starts to dominate. Gilliland and Brown (Ref. 1) reached the same conclusion using a Tektronix 512 × 512 chip.

Variables in NGC 6134

In NGC 6192 only one variable star of unknown type was found (Ref. 2). In the older cluster NGC 6134 ($t \approx 10^9$ y), three δ-Scuti stars have been located. The light curves from one night are plotted in Figure 2. An additional short time string was obtained 8 days later and helps to define the periods better. Two of the stars pulsate in only one mode, whereas the third has at least two modes. The periods and amplitudes are given in Table 1.

Star number 40 is the brightest and slightly overexposed which is reflected in the increased noise compared to the fainter star number 5.

The result of our search for δ-Scuti stars so far indicates that these stars are common only in fairly old clusters like NGC 6134 or NGC 2660 (Ref. 3). They seem to be nearly missing in young clusters. We still need to verify the suspected high number of δ-Scuti stars in NGC 2660, which could not be observed during our last expedition in May-June 1988.

The reason, why some stars in the instability strip near the main sequence pulsate and others do not, is still unknown, but the studies of clusters will be able to tell more precisely under which conditions pulsation is favoured.

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Imaging Polarimetry of High Redshift Radio Galaxies with EFOSC

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Most of our visual perceptions of the world around us, particularly in daylight, are derived from radiation which has been reflected or scattered. Consequently, we are continually bathed in linearly polarized light, even if only the loyal followers of M. Minnaert (1954) use the phenomenon of "Haidinger's Brush" to make themselves aware of it. At night, by contrast and with the exception of the Moon and planets, most of the astronomical sources we see are both self-luminous and highly spherically symmetric. Polarized light in astronomy is therefore the exception rather than the rule but, when it is observed, it can prove a valuable diagnostic either of exotic radiation mechanisms or of anisotropic scattering geometries.

In the study of active galactic nuclei and quasars, the measurement of optical polarization, both from synchrotron sources in nuclei, jets and "hot-spots" and from scattering around obscured sources, is a fruitful field of interest which is producing some remarkable new results. "Hidden" Seyfert 1 nuclei are being found in Seyfert 2 galaxies by looking at the polarized flux produced by the scattering of nuclear light from either dust particles or electrons which have a more direct line of sight to the activity than do we (Schmidt and Miller 1985).

At radio wavelengths, radio galaxies are known to be highly anisotropic ob-

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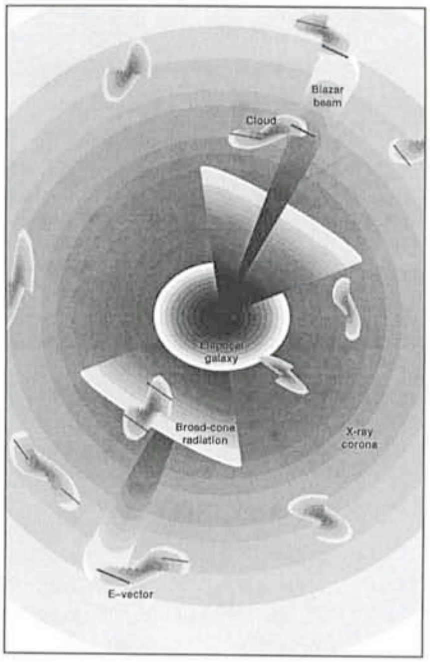

Figure 1: *An illustration of what may be producing the apparent optical elongation of high redshift radio galaxies. Beamed radiation from the active nucleus – either a broad cone due to equatorial obscuration and/or a narrow cone due to relativistic beaming – is scattered by dusty clouds which may be a common feature of young galaxies. In some cases, particularly massive clusters, there may be sufficient Thomson optical depth from electrons in the hot intracluster medium to produce wavelength independent scattering. In either case, the scattered radiation will be polarized with an E-vector perpendicular to the line joining the cloud to the nucleus.*

jects with narrow jets powering extended double-lobed sources. Much effort has been expended in trying to relate the axis of this radio structure to optical properties such as the apparent axes of the elliptical galaxy counterpart and to the extended emission line regions (EELR) which are often found associated with this type of activity. Although there are relationships, they are not strikingly obvious at low redshifts.

It was a surprise then when the discovery was made (McCarthy et al. 1987, Chambers et al. 1987) that the very distant, powerful radio galaxies at redshifts greater than about 0.6 had optical (rest-frame ultraviolet) images that are strikingly extended, in both emission lines and continuum, along the radio axis and look quite unlike their closer counterparts in the rest-frame optical band. Until we get ultraviolet images, with the Hubble Space Telescope, of a good sample of low redshift radio galaxies, we will not really know if we are seeing a qualitatively new phenomenon in the distant objects or whether it is just something which is being revealed by the different spectral balance of components at these wavelengths. The suggestion that the phenomenon really is new may be supported by the observation that at least some of the same objects are also elongated in K-band images around 2.2 μm – emitted in the rest frame at around 1 μm (Chambers et al. 1988, Rawlings and Eales 1989).

The solution to the problem is particularly important because these objects occupy such a prominent position in studies of the formation and early evolution of galaxies. Although probably very closely related to quasars, these high redshift sources are seen as galaxies and the most distant ones we can find. The fact that they are tracked down and identified by virtue of their activity may, in this case, be a hindrance and certainly demands caution in interpreting their observed properties solely in terms of stellar evolutionary processes.

What could cause these optical elongations? The most favoured interpretation has been that the directional forms of activity – the radio jets – have somehow induced star formation processes along their tracks which would show up as blue coloured extensions. Although theoretical studies show that this process may be feasible (De Young 1989, Rees 1989), there are few, if any, known examples of it occurring in powerful low redshift galaxies, suggesting that the circumgalactic environment would have to have evolved significantly. In addition, it has proved difficult to reconcile the observed colours from the infrared to the ultraviolet with a single burst of star formation although this may not be an insurmountable difficulty if more complex evolutionary models are used. The association of the extended images with non-thermal emission appears unpromising because, although the radio and optical major axes are aligned, there is no detailed correspondence be-

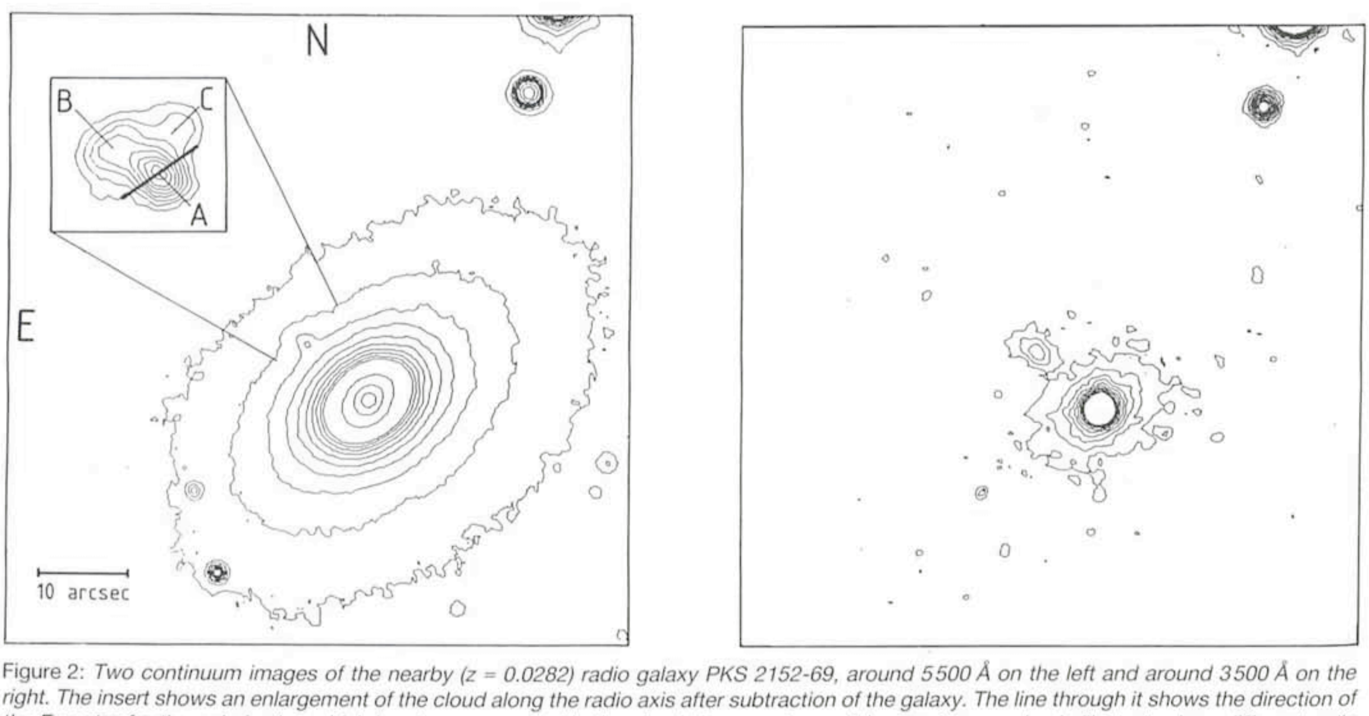

Figure 2: *Two continuum images of the nearby (z = 0.0282) radio galaxy PKS 2152-69, around 5500 Å on the left and around 3500 Å on the right. The insert shows an enlargement of the cloud along the radio axis after subtraction of the galaxy. The line through it shows the direction of the E-vector for the polarization which has been measured in the cloud. A comparison of the two images clearly illustrates how different radio galaxies can be in the UV and might explain the elongation along the radio axis observed at high redshift, where these objects are observed in their rest frame UV.*

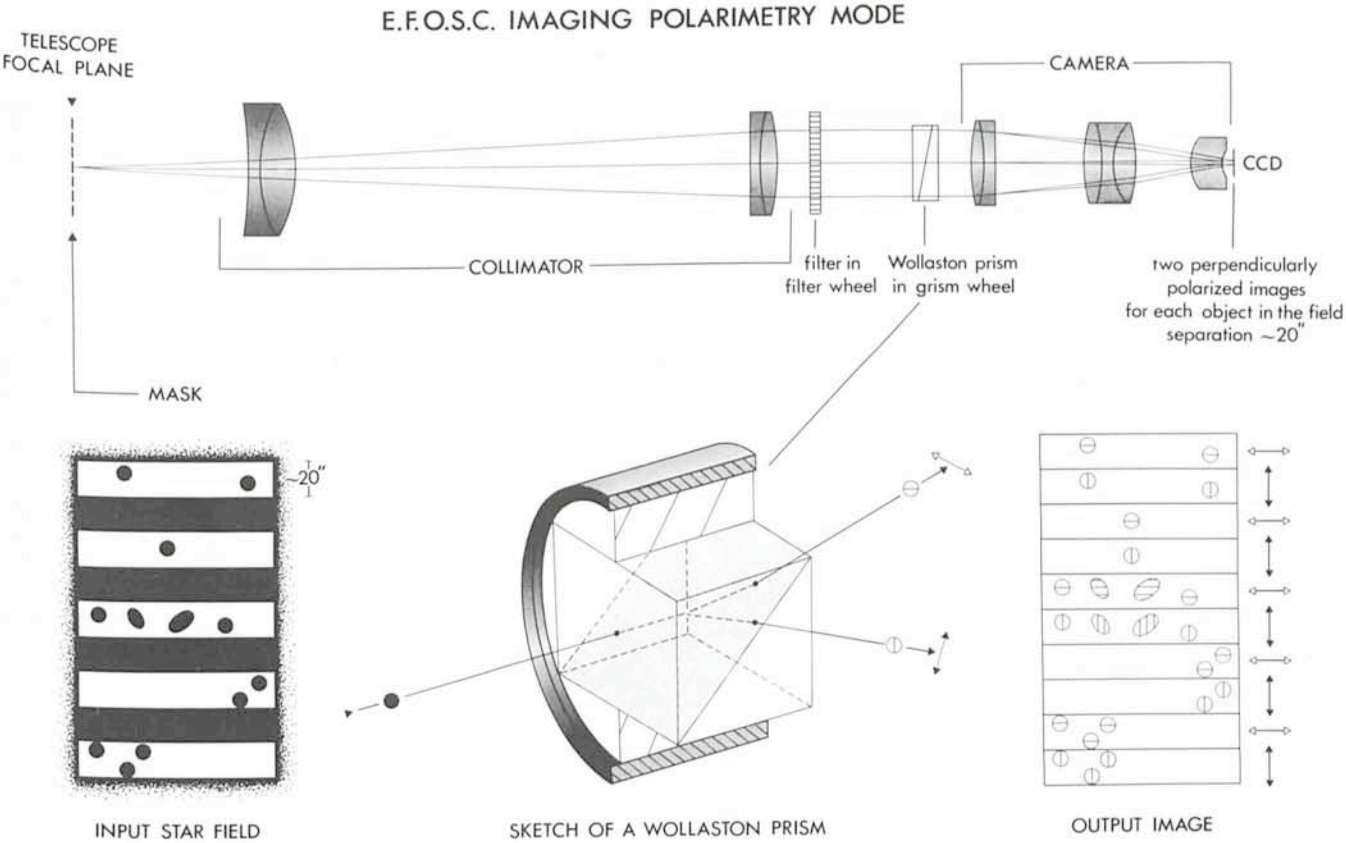

Figure 3: *An illustration of how the Wollaston prism in the collimated beam of EFOSC produces on the CCD two images with perpendicular polarization for each object in the field.*

tween their structures as there is with the radio-optical jets and hot-spots known at low redshift.

The third explanation, involving the scattering from matter – either dust or electrons – in an anisotropic radiation field, is in retrospect perhaps a natural choice given what is known now about the intrinsic and extrinsic mechanisms which can cause such anisotropy. We were, in fact, led to this suggestion by a series of detailed studies of a bright southern hemisphere radio galaxy known as PKS 2152-69 which is notable for its extreme extranuclear activity. This bright, 13th magnitude, galaxy shows a detached cloud at a projected distance of about 8 kpc along its radio axis which radiates emission lines from species up to and including Fe^{9+} (Tadhunter et al. 1988). Associated with it is a continuum source remarkable for its blue colour ($f_\nu \propto \nu^{+3\pm1}$) which, incidentally, is quite unlike known synchrotron sources which are rather red.

In addition to its colour, we also measured a linear polarization of 12 ± 3% with the electric vector perpendicular to the line joining the cloud to the nucleus (di Serego Alighieri et al. 1988). Since we were unable to think of an emission mechanism which would produce such a blue and polarized source, Rayleigh-like scattering of a bright, beamed nuclear source seemed to be the only consistent solution. This would produce polarization in the correct orientation and, like the blue sky, a bluer spectrum than the source. Thomson scattering from electrons, while producing polarization, would not explain the blue colour and so we proposed fine dust particles as the scattering medium. Although such dust could well be destroyed in the intense radiation field of the beam, new material could be supplied by the orbital motion of circumgalactic clouds.

We are led, then, to a picture of a radio galaxy with a Blazar-like "searchlight" beam of radiation shining out through a dusty envelope in the general direction of the radio axis (Fig. 1). Unless the beams impinge upon clouds, they remain essentially invisible. From the sequence of continuum images we have of PKS 2152-69 (Fig. 2) it is clear that scattering from the cloud is almost completely swamped by starlight in the visible part of the optical spectrum. In the near ultraviolet, however, where the stars are faint and the scattering is strong, the cloud becomes comparable in brightness to the rest of the galaxy. Is this then not a natural explanation for the extensions seen at high redshift which we see in the optical at rest wavelengths between 2000 and 3000 Å? The most direct test of the hypothesis is to look for linear polarization which would have to have the correct orientation – perpendicular to the elongation.

We have therefore measured the polarization of two high redshift radio galaxies, 3C277.2 (z = 0.766) and 3C368 (z = 1.132), chosen because they are brighter members of the class and are accessible from La Silla (di

Polarimetry of high redshift radio galaxies.

Object	Filter	$\Delta\lambda_{rest}$ (Å)	Magn.	P %	P_{corr} %	θ Degr.	PA_{rad} Degr.
3C277.2	B	2150–2850	B = 22.0	21 ± 4	21 ± 4	164 ± 6	61
3C277.2B	B		B = 22.5	6 ± 7	0 ± 7		
3C368	V	2250–3000	V = 21.4	7.6 ± 0.9	7.6 ± 0.9	85 ± 4	18
3C368	R	2650–3750	R = 20.5	2.8 ± 1.2	2.5 ± 1.2	92 ± 15	18

These results refer to the integrated light from each source. 3C277.2B is an extended object 7 arcsec to the North East from 3C277.2. $\Delta\lambda_{rest}$ is the rest frame wavelength range covered by the observation and PA_{rad} is the position angle of the radio axis (McCarthy et al., 1987).

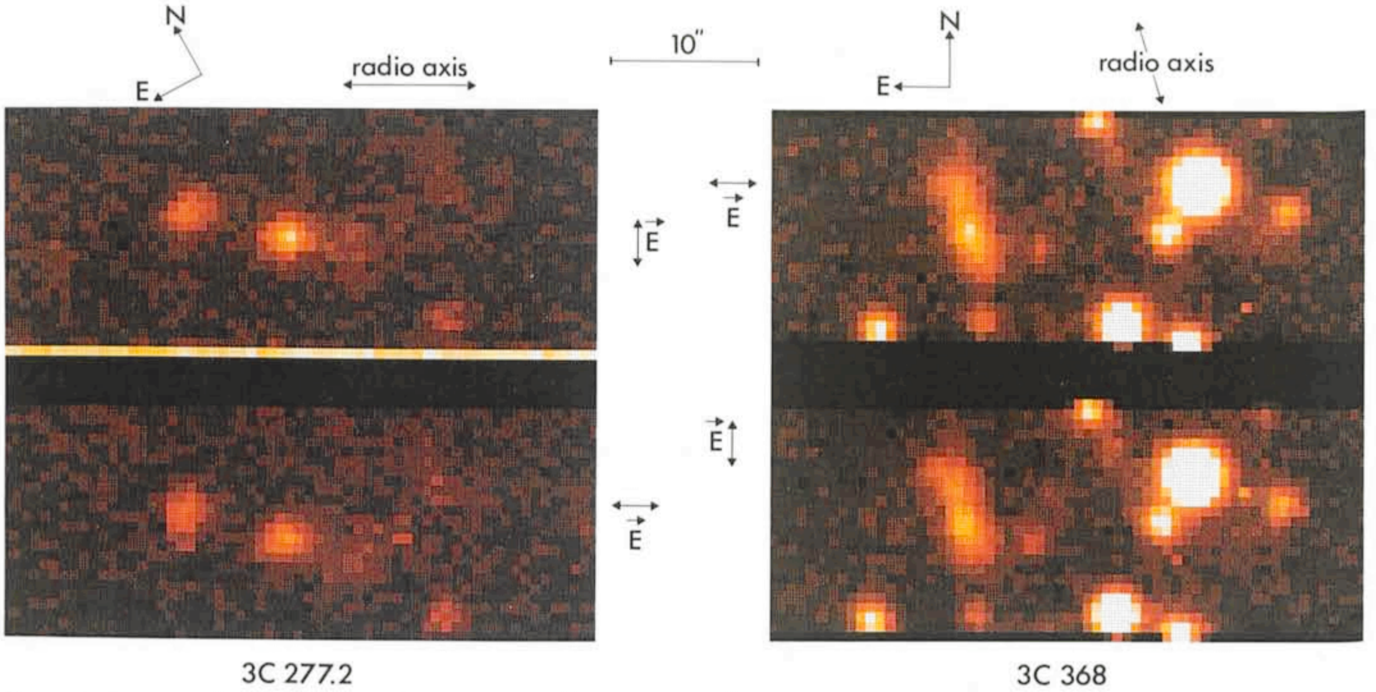

Figure 4: *EFOSC frames of 3C277.2 (left, B filter + Wollaston prism) and of 3C368 (right, V filter + Wollaston). 3C277.2 is clearly brighter on the top strip, where the E-vector is vertical while the radio axis is horizontal. The object on the left is 3C277.2B. 3C368 is clearly elongated and is brighter in the top strip which has a horizontal E-vector, while the radio axis is approximately vertical (along the elongation).*

Serego Alighieri et al. 1989). Observations were made in two runs in July 1988 and April 1989 with EFOSC on the 3.6-m telescope. The results are shown in the table.

The EFOSC polarimeter mode (Dekker and D'Odorico 1986, di Serego Alighieri 1989), with its focal plane masks of 20 arcsec which are sufficiently large to accept the entire image of these distant objects, is uniquely suited for this type of observation (Fig. 3). It is not easy however, since the galaxies are faint ($V \geq 21$) and the most critical part of the process is undoubtedly the precision with which the sky signal can be estimated and subtracted. The principle of the instrument is to image an object, simultaneously, in orthogonal linear polarizations; the simultaneity ensuring that the method is insensitive to seeing and transparency changes. Although the problem can be solved with just two exposures at different position angles – and indeed the polarization of 3C277.2 is so strong that it is obvious from the raw images (Fig. 4) – better error estimates can be made by obtaining a sequence of measurements at different angles and plotting a function $S(\varphi)$ of the brightness ratio of the two images versus position angle, φ.

The curve obtained for 3C368 is shown in Figure 5 and the fitted $P\cos 2(\theta-\varphi)$ curve gives the degree of linear polarization P and the position angle of the E-vector θ. Instrumental polarization, which is small, generally less than 1%, is measured from bright stars in the field which are assumed to be unpolarized. The whole process is checked by making measurements of a set of faint stars, bracketing the galaxy in brightness; although these could be polarized by interstellar extinction effects, particularly at low Galactic latitudes, it does give a rather direct check on the error estimates. The measurements for some faint stars are also shown in Figure 5. Since the sky subtraction is so critical, we devoted considerable effort to selecting the best method and we obtained the best results with the MIDAS command MODIFY/PIXEL, improved with the help of Richard Hook at the ST-ECF. This command replaces a subsection of the image selected with the cursor by an interpolation on the surroundings. The difference between the original image and the replaced one is then integrated (e.g. with INTEGRATE/APERTURE) to obtain the sky-subtracted intensity of the object in the subsection.

The derivation of the degree of polarization and its angle from a set of brightness measurements involves the forming of a ratio, close to unity, of CCD counts which are subject to photon statistical and readout noise and an error resulting from the sky subtraction, followed by a fitting process. The analytical propagation of error estimates through this procedure in not straightforward and so we chose to do it using Monte-Carlo techniques. The starting points of this were sets of repeated measurements of the sky signal made using an aperture identical in size with that used for the galaxies. The results are shown as 1σ errors on the values given in the table.

Another worry in the interpretation of the measurements, particularly for 3C 368 which is at low latitude, is the estimate of Galactic interstellar polarization. We have used first the relationship between the maximum interstellar polarization P_{ISM} and the Galactic extinction derived by Hiltner (1956). Using computer readable extinction maps (Burstein 1988, priv. comm.) we find that $P_{ISM} \leq 0.05\%$ for 3C277.2 ($b = 79°$) and $P_{ISM} \leq 1.2\%$ for 3C368 ($b = 15°$). In the case of 3C368 the position angle of the E-vector of the polarization induced by the interstellar medium of the Galaxy (Mathewson and Ford 1970) would be close to the one measured for the object. A better check would then be to measure the polarization of another (hopefully normal) galaxy in the same field whose light, unlike faint field stars, would be subject to propagation along the whole pathlength through the Galaxy. Such an object was found in the field of 3C368 and its polarization in V was found to be less than 0.5% in the position of the radio galaxy E-vector. A similar check could be performed on 3C277.2 – which is at high latitude and therefore unlikely to show interstellar effects – by measuring a faint companion galaxy, 3C277.2B. This also turned

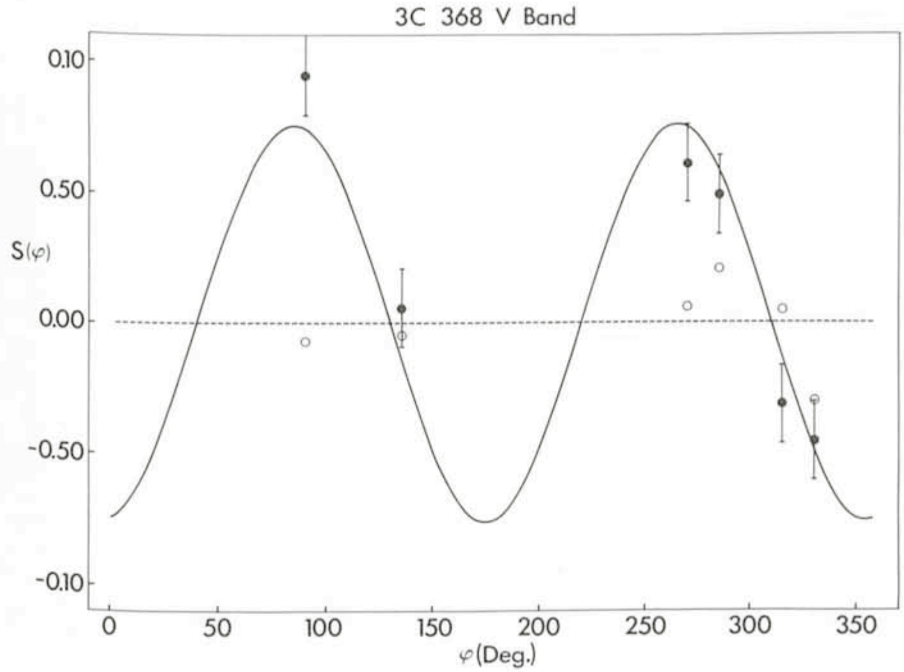

Figure 5: *The measurements (•) of S(φ), the component of the normalized Stoke parameters for linear polarization, for the V images of 3C368 and the fitted cosine curve. Also shown (o) is the average S(φ) for faint stars in the same frames.*

out to be unpolarized as shown in the table.

Finally, there is a statistical bias in the measurement of polarizations close to zero simply because, being the length of a vector, it is a positive definite quantity. This can be corrected using a standard technique (Wardle and Kronberg 1974) and the results are shown as P_{corr} in the table.

The single most important conclusion that can be drawn from these results is that a significant fraction of the light that we see in the optical band cannot be coming directly from stars and this means that the colours cannot be interpreted simply in terms of stellar populations. This has profound and unfortunate consequences for the method of using distant radio galaxies as tracers of normal galaxy evolution. On the positive side, however, it does – if interpreted as light scattering of beams of radiation emanating from active nuclei – lend considerable support to the ideas which are seeking to unify the properties of radio galaxies, quasars and BL Lac objects or Blazars by supposing that their different apparent properties are simply a result of their particular orientation with respect to us, the observer.

In the case of 3C 368, we were able to show that not all of the polarized flux was coming from the nucleus and so the extended structure must also be polarized. 3C277.2 is really too faint to investigate the extension separately using current techniques but clearly a task for the future is to test carefully that the extended structures really are polarized and see if the E-vector is accurately perpendicular to the radius-vector from the nucleus. This is a strong prediction of the scattering model. In addition, the wavelength dependence of the polarized flux can, in principle, distinguish between scattering by electrons and by dust. In 3C368, our two measurements, in V and R, already favour the dust hypothesis in this object although there is no reason why Thomson scattering could not play a role, particularly in massive clusters where there could be a large column density of coronal gas (Syunyaev 1982).

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SN 1987 A: Two Years of Six-colour Photometry with the Danish 0.5-m Telescope

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For several years, a Brazilian-Danish-Spanish group has collaborated on studies of a particular type of variable stars, the so-called eclipsing binaries. Part of the work has consisted of observing the binaries with the Danish 0.5-m telescope in order to obtain accurate light curves in the Strömgren four-colour *uvby* system. In early 1987 we began yet another two-month observing run. Jens Viggo Clausen (Copenhagen) started in late January, one of us

(LPV) took over in mid-February, and BEH arrived on La Silla on February 23, expecting to continue a normal and rather uneventful observing period. On the following day, we added a most abnormal variable, the newborn supernova in the Large Magellanic Cloud, to our observing list!

The observations of SN 1987 A have continued regularly until New Year 1988/89 when the observer, Patricia Lampens from Brussels, together with BEH, who has coordinated the observations, decided that SN 1987A had become so faint that it was time to stop. In the meantime, 20 different observers have, during 27 observing runs, participated in the observations. Coordinating the observations, making everybody use the same comparison stars – and finding out which code names they gave to which comparison star – and maintaining a reasonably constant observing procedure throughout has been a fascinating and sometimes exasperating experience. It has been gratifying, though, to note how willingly every single observer has joined in collecting the data, even though it did mean taking time from their own observing programme.

The immediate task on February 24, 1987, was obvious enough for experienced observers of variable stars, namely to find at least two comparison stars that lie near SN 1987A in the sky, are of approximately the same spectral type, of constant brightness, and of about the same brightness as the supernova. Only, we did not know how bright the supernova would turn out to be and we knew for certain that its spectral type would change drastically during the next weeks and never would appear like that of ordinary stars. We ended up by selecting four comparison stars, two hot ones and two cool ones, and fortunately three of them actually turned out to be of constant brightness.

Deciding which auxiliary equipment to use with the telescope was simple. To the Danish 0.5-m telescope is permanently attached a six-channel photometer designed for observations in the photometric system that the late professor Bengt Strömgren devised: four bands of intermediate width (17–33 nm), situated in the ultraviolet *(u)*, violet *(v)*, blue *(b)*, and yellow *(y)*, plus two bands centred on the blue Balmer line of hydrogen $H\beta$, 3 and 14 nm wide, respectively. We chose to observe through both the *uvby* section and the $H\beta$ section, in the hope that the $H\beta$ observations would give more detailed information on the spectrum near 486 nm than one can get from the intermediate band observations.

A point that worried us while we were waiting to begin the observations on the evening of February 24 was whether the supernova would be too bright to be observed with our telescope without damaging the detectors. As it turned out, SN 1987A obligingly never became too bright for the Danish 0.5-m telescope. Fortunately, three neutral filters are available in the photometer, so when the supernova approached peak magnitude in April 1987, it was sufficient first to attenuate the light through v and b, and later to insert a filter that reduced the light through all *uvby* bands. The $H\beta$ filters are so narrow that they never presented a problem.

One lesson was hard to learn: the Strömgren system is constructed with the purpose of deriving temperature, surface gravity, absolute magnitude, and chemical composition of stars. In order to obtain useful results, the photometric observations must be very accurate, to better than 0.5%. The light curves for eclipsing binaries, our ordinary observing programme, must be of similar accuracy, and we are usually very concerned about the photometric quality of the night. With the supernova we had to accept that poor observations might be better than no observations at all and with reluctance we took data on nights of abominable photometric quality. March 1987 provided quite a few such nights on La Silla!

Inborn Properties of the *uvby* System

During the data reduction, it became evident that the *uvby* system is devised for precise studies of the physics of ordinary stars and not for obtaining light curves of a supernova. Let us give two examples.

We wanted to present light curves in the six colours. However, normally only the colour difference b-y and the double differences m_1 (= $(v\text{-}b)-(b\text{-}y)$) and c_1 (= $(u\text{-}v)-(v\text{-}b)$) are used and nowhere in the literature could we find a definition of the zero points for m_1 and c_1. When we asked Professor Strömgren, he confirmed our guess: since there had never been a need for defining the zero points precisely, he had simply added a constant to the original m_1 and c_1 values so that for most stars they would have conveniently small positive values. It was even worse for the $H\beta$ observations. The idea of observing through two bands of different widths, but at the same central wavelength is that the magnitude difference $H\beta$*(narrow)* minus $H\beta$*(wide)* provides the strength of the $H\beta$ line, while the observation is independent of the atmospheric transmission and therefore can become very accurate. Nobody had ever looked separately at the data from each band. We ended up by choosing precise but somewhat arbitrary definitions (Helt et al. 1987).

We also wanted to know how a certain magnitude value could be translated to flux received, expressed in Watts per square metre per Angstrom. In order to do this, one must know how the combined telescope and photometer system transmits and detects light of different wavelengths. Again, such transmission functions were not available because no one had needed them before. Thanks to the cooperation of Ralph Florentin they were calculated in time for the ESO Workshop on SN 1987A in July 1987.

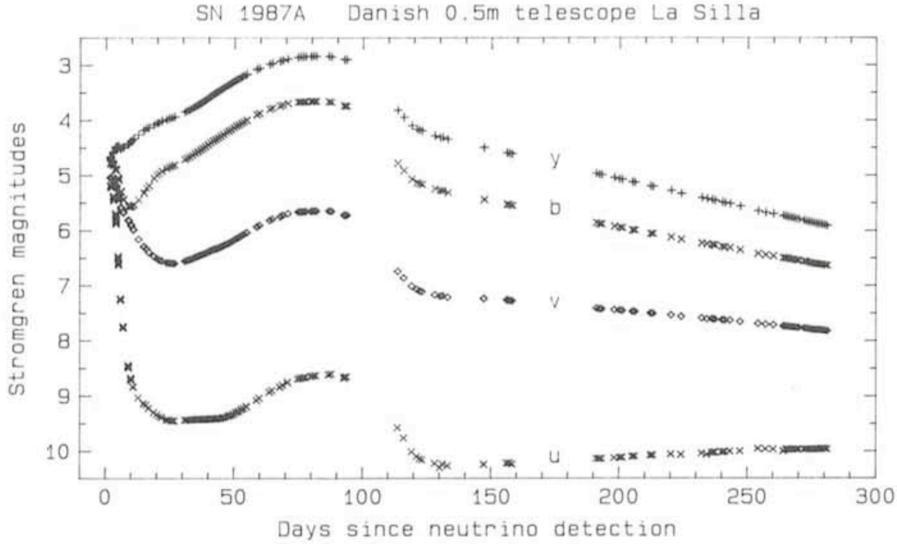

Figure 1: *The light curves of SN 1987A through the four intermediate bandpass Strömgren filters y = yellow, b = blue, v = violet, and u = ultraviolet.*

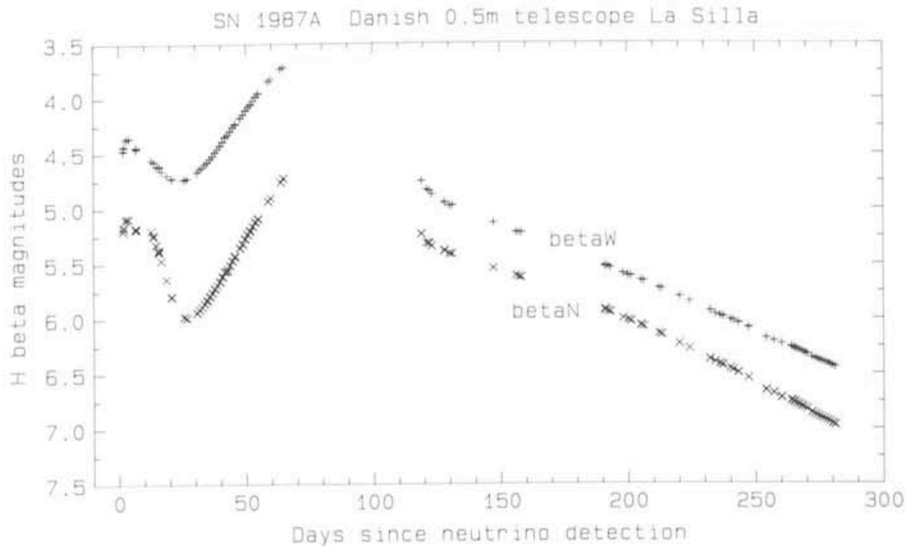

Figure 2: *The light curves of SN 1987A through the two Hβ* filters of bandpass 14 nm (betaW) and 3 nm (betaN).

How to Collect Data from 20 Astronomers Scattered over Europe and South America

Combining observations made by so many astronomers has not always been easy. The Danish 0.5-m telescope is frequently used for long term observing programmes and the observers are normally in no great hurry for reducing their data. The fact that the accompanying figures show light curves only up to December 1987 illustrates this.

Ever since the observations started, it was evident that we should not attempt to transform the observations to the *uvby* standard system. The observations are taken on the instrumental system. Therefore they provide precise information on the light from the supernova through, by now, well known transmission bands. Were we to transform the observations to the standard system, this information would be seriously degraded and we would obtain nothing in return. However, many observers perform transformation to the standard system as a built-in routine in their reduction procedure, and some have found it difficult to calculate values on the instrumental system.

The Light Curves

Figure 1 shows the supernova light curves in *uvby* and Figure 2 the light curves in *Hβ(wide)* and *Hβ(narrow)*. As zero point for time we have taken February 23.316, the time when neutrinos were detected in Japan (Hirata et al. 1987) and in the United States (Bionta et al. 1987) and presumably the time when the supernova collapse took place. All the light curves show the now familiar rise to a broad maximum in May, around day 80–90, followed by the rapid decline and the linear, slow decline corresponding to the phase where the emission of light is powered by radioactive decay of Cobalt 56 to Iron 56.

All transmission bands are so narrow that none of the light curves give a good description of the development of the continuum – with the possible exception of *y* during the first very few days. Instead, they reflect (1) the development of various emission and absorption features with time and (2) the change with time in radial velocity of the atmosphere layers which causes absorption features to move into the bands from the short wavelength side and out of them on the long wavelength side. This was particularly important until around day 20. During that period the radial velocity observed for the absorption features varied from about −17,000 km/s to a level near −5000 km/s. This means that, for instance, the effective wavelength of the *Hβ* bands (486 nm) corresponded to absorption of rest wavelength about 515 nm during the first observations we made and to 495 nm on day 20. So, although we still use the names *Hβ(wide)* and *Hβ(narrow)* and the light curves of course do reflect the changes in *Hβ* emission, they are also strongly influenced by any absorption present with rest wavelengths ranging from 515 nm to 495 nm.

If we compare the six light curves during the first 20–30 days, we see that there is much more structure in the *Hβ (narrow)* light curve than in the other five curves. Clearly, the *uvby* and *Hβ(wide)* transmission bands reflect changes in the continuum as well as the overlying absorption and emission lines, while *Hβ (narrow)* is extremely sensitive to the various features developing and moving through its 3 nm wide transmission band.

For the first three days, both *Hβ (wide)* and *Hβ(narrow)* increase. At this time they measure continuum plus almost pure *Hβ* emission. Then *Hβ (narrow)* decreases at the same time as several absorption features appear in the spectrum on top of the *Hβ* emission peak (see Hanuschik and Dachs 1988, spectra of Feb. 27.0, 28.1). *Hβ(narrow)* increases again near day 11 and finally reaches the broad minimum as late as around day 25. The nearby intermediate transmission band *b* displays the minimum already at day 9.

At the latest time shown by the present light curves we again note the differing behaviour of *Hβ(narrow)* as compared to *Hβ(wide)*. The more rapid decline of *Hβ(narrow)* from day 220 may indicate that at this time *Hβ(narrow)* begins to measure the redward wing of the *Hβ* absorption line (see Catchpole et al. 1988, spectra of October 13, November 3).

We expect the light curves to be useful in several respects: they can serve for comparison with model atmospheres, they can be used for calibration of spectra, and they can, combined with other photometry over a wider wavelength range, help to determine the bolometric magnitudes, i.e., the total flux integrated over all wavelengths.

Acknowledgements

We wish to express our gratitude to all observers who actually performed the numerous observations. Also, we thank ESO and The Danish Board for Astronomical Research for allotting observing time throughout all relevant observing periods.

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CCD Spectroscopy of P_γ (10939), P_δ (10049) and Corresponding Balmer Lines in 30 Doradus

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Understanding the physical and dynamical evolution of galactic and extragalactic H II regions requires a knowledge of the dust component and its distribution. To date the extinction A_V has been derived by various methods: optical and infrared line ratios, comparison of radio and emission line fluxes, stellar photometry, etc. In particular the intensity ratios of the strong and spectroscopically easily accessible Balmer lines H_α, H_β are frequently used to derive A_V via their decrement. Since these lines originate from different upper levels, the interpretation of the observed line ratios requires recombination line model calculations (cf. Osterbrock 1974) which in many extragalactic cases have failed to give consistent results (Ward et al. 1987, Malkan 1983, Rieke and Lebofsky 1981). This difficulty can be avoided by using multiplet line ratios originating from the same upper level so that the theoretical line ratios depend primarily on their relative transition probabilities.

There are only few candidates of multiplet lines of abundant atomic species with sufficient wavelength spacings to derive accurately the differential extinction, viz. the corresponding Paschen and Balmer lines P_γ (10939 Å) – H_δ (4102 Å), P_δ (10049 Å) – H_ε (3970 Å) (Aller and Minkowski 1956), and lines of [S II] at 10287, 10330, 10336, 10370 Å in the IR and at 4069, 4076 Å in the blue (Miller 1968). However, these line ratios have seldom been used (Wampler 1968, Miller 1973) because of the low efficiency in the IR wavelength region of electron multiplier photocathodes and because of the severe contamination with many atmospheric emission lines of OH (Osterbrock 1974).

The situation has changed with the availability of CCD detectors. Although also CCD detectors have low efficiencies in the IR region, they provide a significant advantage over the earlier spectrophotometry by allowing a correct elimination of the atmospheric emission lines from sky background exposures in two-dimensional long-slit spectrophotometry.

As with the INT/IDS CCD spectrograph combination at the La Palma Observatory (Greve et al. 1989), we have used the ESO 1.52-m telescope and BC spectrograph equipped with the GEC # 14 CCD detector and the grating # 28 which in 1st and 2nd order allows the detection of the IR and blue components.

Figure 1a shows the flat-field corrected IR image (30 min. exposure time) of a section of the 30 Doradus nebula in the Large Magellanic Cloud. The many strong atmospheric lines, particularly located at the short wavelength end, confuse the image. The sky-corrected, flux calibrated spectrum is displayed in Figure 1b showing the detection of P_γ (10939 Å), He I (10830 Å) and P_γ (10049 Å). The [S II] 10300 Å lines are absent, or very weak, because of the low metallicity of the LMC. The corresponding lines H_δ (4102 Å) and H_ε (3970 Å) of the blue wavelength region are displayed in Figure 2. Using the observed P_γ/H_δ and P_δ/H_ε line ratios and adopting a standard reddening curve we derive A_V = 2.0–2.5 mag. for this particular region of 30 Doradus.

Similar spectra with exposure times of ~10 minutes for the IR wavelength region have been obtained for the Orion nebula.

Despite the low efficiency of the CCD detector in the IR wavelength region ($0.91 < \lambda < 1.1$ μm), we conclude from our observations that significant research on galactic and extragalactic H II regions can be carried out with the available telescope-spectrograph-CCD detector combination. The observations open up the possibility of deriving ex-

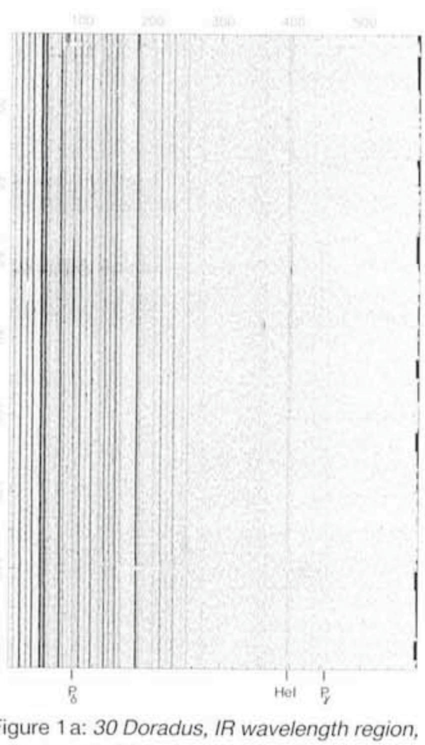

Figure 1a: *30 Doradus, IR wavelength region, not corrected for sky emission.*

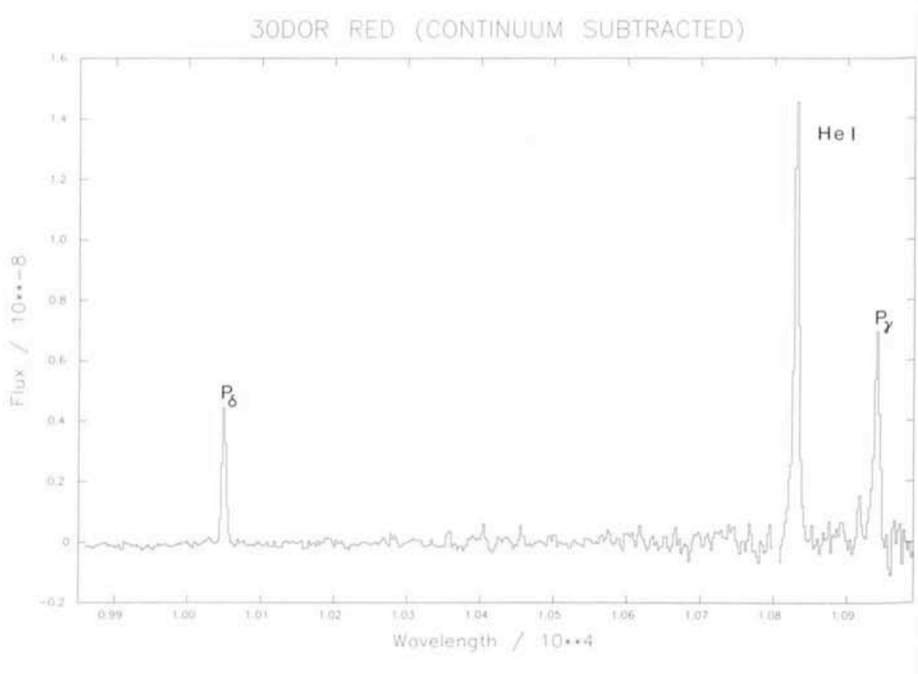

Figure 1b: *30 Doradus, IR wavelength region, sky-corrected and flux calibrated.*

tinction values without heavy reliance on recombination line model calculations. It is our intention in this context to investigate in proposed follow-up observations of galactic H II regions whether this observing technique gives consistent results when compared with data derived from the Balmer line decrement method.

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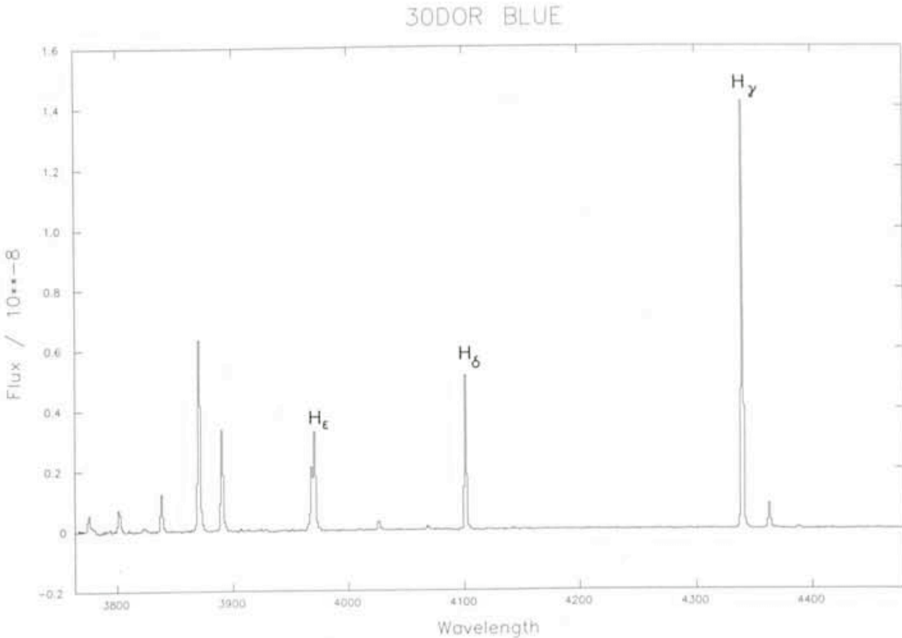

Figure 2: *30 Doradus, blue wavelength region, sky-corrected and flux calibrated. The Hε line is blended with the [Ne III] 3967 Å line.*

Star Formation in Dwarf Irregular Galaxies

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1. Introduction

Contrary to the more spectacular and appealing Spiral and Elliptical Galaxies, for a long time Irregular Galaxies have not been considered to deserve detailed studies. Only in the last decade, the difficulty found in the interpretation of the major evolutionary processes taking place in bigger, more complicated galaxies, has led to new interest in Irregulars, which should be easier to understand, for a number of circumstances. The structures of Irregular Galaxies appear, in fact, to be simple, with no combination of halo and disk phases and no special evidence of dynamical phenomena playing an important role. They contain a large amount of gas, easily detected by radio telescopes, which means that they are in a relatively early stage of the evolution. Besides this, their visible stellar content is young enough to indicate that Star Formation is active in these galaxies, several H II regions are present and allow the derivation of the metallicity, even at large distances. For all these reasons, Irregular Galaxies seem to offer a suitable ground for studying the basic phenomena controlling the evolution of galaxies.

Extensive studies by several authors have confirmed the above general features (see Viallefond, 1988, for a recent review), suggesting that Irregular Galaxies are presently the best candidates for the identification of the properties of primordial galaxies, which makes them particularly interesting from the cosmological point of view. On the other hand, the detailed study of the stellar content of Irregulars has opened some important questions on how the Star Formation processes have been operating in these systems. The Initial Mass Function (IMF) has been suggested to be considerably flatter than in our own Galaxy (Terlevich and Melnick 1983), but Matteucci and Tosi (1985) argued that a normal Salpeter function is more appropriate. As for the Star Formation Rate (SFR), according to Gallagher, Hunter and Tutukov (1984), Dwarf Irregulars are likely to have undergone a continuous, maybe even constant Star Formation, as seems the case for giant Irregulars and late type Spirals, while Matteucci and Chiosi (1983), on theoretical grounds, have rather suggested a bursting Star Formation Rate.

To try to answer these questions and to better understand the evolution of these galaxies, we have undertaken a project of CCD photometry of some Dwarf Irregulars in the Local Group. Our aim is to derive as deep as possible Colour-Magnitude (CM) diagrams to be compared with theoretical simulations performed with different prescriptions for the SFR and the IMF. In this respect, it is worth noting that the stellar content in these galaxies is not so crowded as to prevent a good resolution with optical telescopes, when adequate techniques for the data reduction are used. The relatively small distances ($m - M \lesssim 26$ mag) of Dwarf Irregulars in the Local Group allow to resolve their stellar content down to $M_v \simeq -1$ to 0, which corresponds to Main-Sequence stars of approximately 2 $M_\odot$. We will then be able to derive information on the SF which occurred over the last ~1 Gyr.

2. Data Acquisition and Reduction

Besides DDO 221 (WLM), for which results have already been published (Ferraro et al., 1989), the programme galaxies are DDO 70 (Sextans B), DDO 209 (NGC 6822), DDO 210 and DDO 236

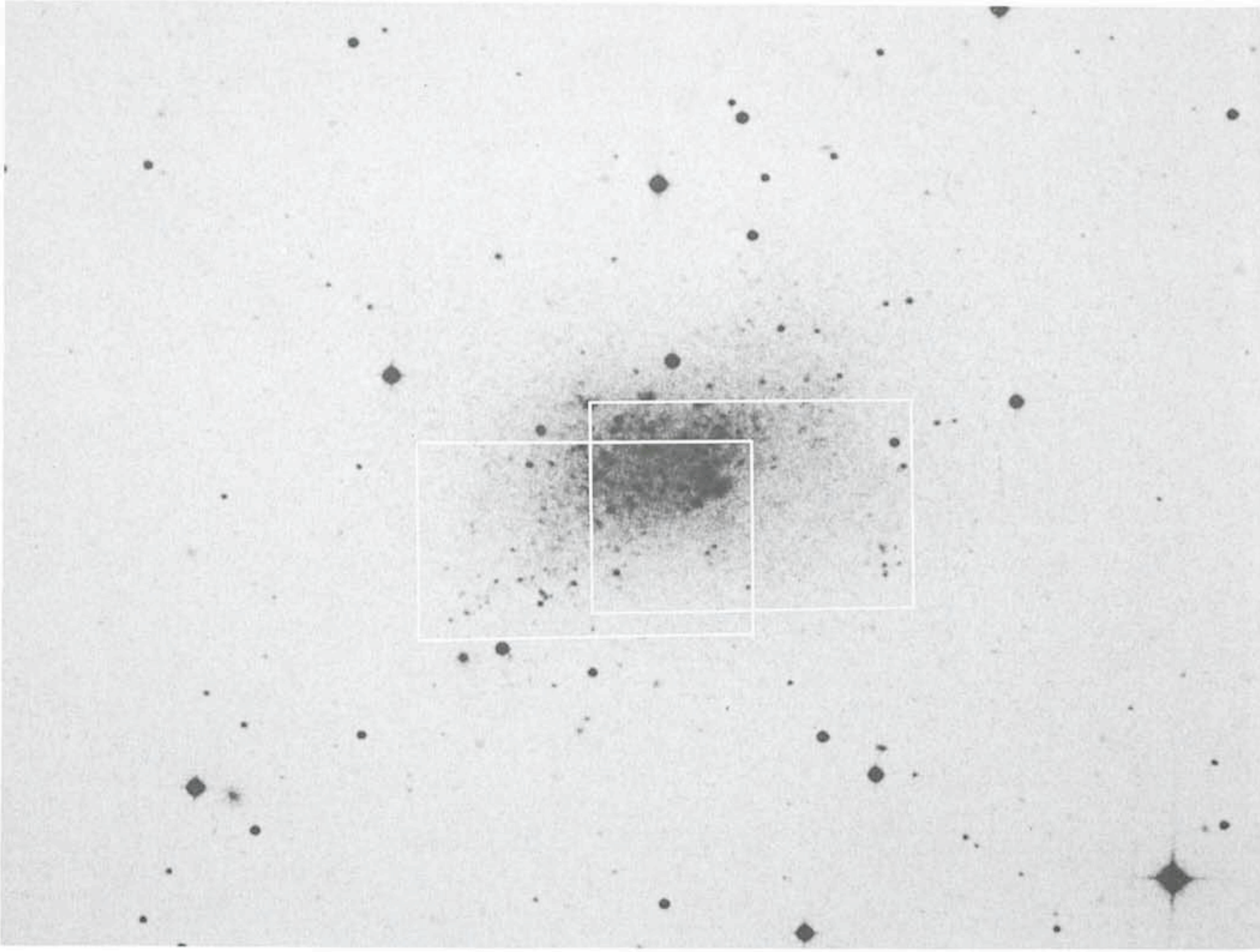


Figure 1: *Optical photograph of Sextans B from a 2-hr IIIa-J ESO Schmidt plate with our observed CCD fields superimposed.*

(NGC 3109). For each galaxy, at least one external and two internal fields are being studied, to analyse the possible differences among various regions and to properly treat background and foreground contamination. All the observing runs have been allocated at the ESO-MPI 2.2-m telescope in Chile. Sextans B has been observed in Johnson B, V and R filters and in the Gunn I filter in March 1988 and 1989. DDO 209 and DDO 210 are being observed at the end of July 1989 and DDO 236 in February 1990. Therefore, here we will only present some results relative to Sextans B (Fig. 1).

Preliminary data reduction has been performed using DAOPHOT (Stetson 1987) and, as a further check of the accuracy of our results, we are re-reducing them with ROMAFOT (Buonanno 1989). These packages are the most suitable for the data analysis in crowded fields, and from the results obtained so far, it seems that they give similar magnitudes and photometric errors in each filter down to V ~ 25. The different approach in the stellar detection and fitting, though, seem to imply a larger completeness factor in the samples reduced with ROMAFOT.

In order to derive an accurate CM Diagram, out of all the detected stars we retain only those with photometric error smaller than 0.1 mag. A further selection has been done on the basis of the location of the stars in the two-colour, (B−V) vs (V−R), diagram (see Fig. 2 for Region 2 of Sextans B). The resulting CM diagrams are shown in Figure 3 for the two observed regions, and, due to the applied selection criteria, they should be accurate enough to allow a meaningful comparison with theoretical predictions.

3. Interpretation of the Data

For a better understanding of the CM diagrams in terms of a combination of the various effects due to stellar evolution, Star Formation and IMF, we have developed a numerical code which generates synthetic, theoretical HR diagrams, by Monte Carlo simulations. The computations are based on a homogeneous set of stellar evolutionary tracks, assume different IMFs and SFRs, and take into account the observational photometric errors and completeness factor at each magnitude level. Different choices for the tracks in the data base are possible, with or without overshooting from convective cores, and the conversion from the theoretical

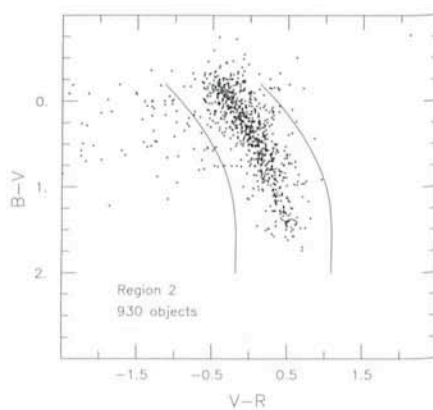
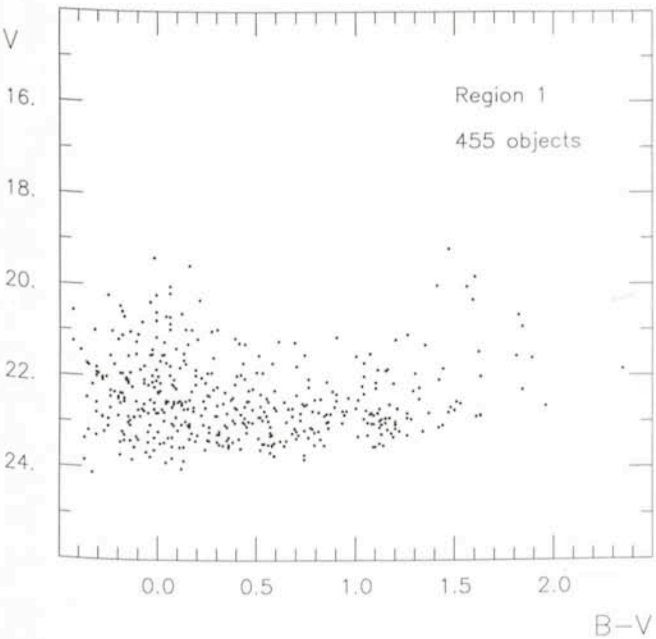


Figure 2: *Two-colour diagram for Region 2 of Sextans B. Only stars with photometric errors smaller than 0.1 mag are shown. The curves are located at 2σ from the mode of the stellar distribution and the objects outside this region are rejected.*



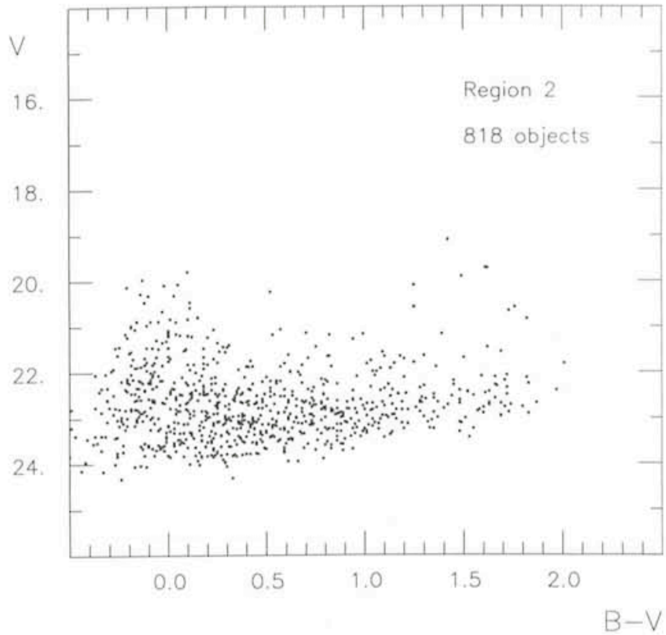


Figure 3: *CM diagrams of the stars selected from the observations of Regions 1 and 2 of Sextans B.*

Log L vs Log T_e plane to the observational M_v vs (B−V) plane are performed by means of linear interpolation in tables kindly provided by C. Chiosi (private comm.). The comparison between the theoretical HR diagrams derived with different prescriptions and the observed CM diagrams is performed in terms of the object distribution in different cells on the M_v vs (B−V) plane, and allows to choose the combination of SFR and IMF which is most consistent with the data. Notice that this procedure represents a significative improvement with respect to the classical Isochrone fitting method, as it is able to account for the stochastic nature of the Star Formation process, the effect of small number statistics, and the spread introduced by the photometric errors.

Figure 4 shows one of the simulated diagrams which is in better agreement with the observational data for Region 2 of Sextans B. The adopted distance modulus is m − M = 26.1 mag, as derived from Sandage and Carlson's (1985) Cepheids, using, however, the revised period-luminosity-colour relation by Feast and Walker (1987). Evolutionary sequences with Z = 0.001 and convective overshooting (Bertelli et al., 1986) have been used to produce this diagram. Standard tracks do not seem to populate consistently the blue supergiant region, due to the short extension of the loops during the core Helium burning stage. In this respect we notice, however, that the very occurrence and extension of the loops in the HR diagram is fairly sensitive to details in the input physics used in computing the stellar models (cf. Renzini, 1984). The B−V distribution of the red supergiant stars, instead, turns out to be too extended, with respect to the simulations, regardless of the underlying evolutionary scenario. This cannot be easily attributed to observational errors, since special care has been taken in the data handling, as described above. We rather suggest that the adopted conversions from the theoretical Log L vs Log T_e to the observational M_v vs (B−V) plane are inadequate to describe the extremely low gravities and temperatures of the red supergiants. The conclusions that we are going to derive for the history of Star Formation will not, however, be sensitive to this uncertainty.

The diagram in Figure 4 displays the results for a SFR which has been constant over the last billion years, but has ceased to act 2.5×10^7 yr ago: had it

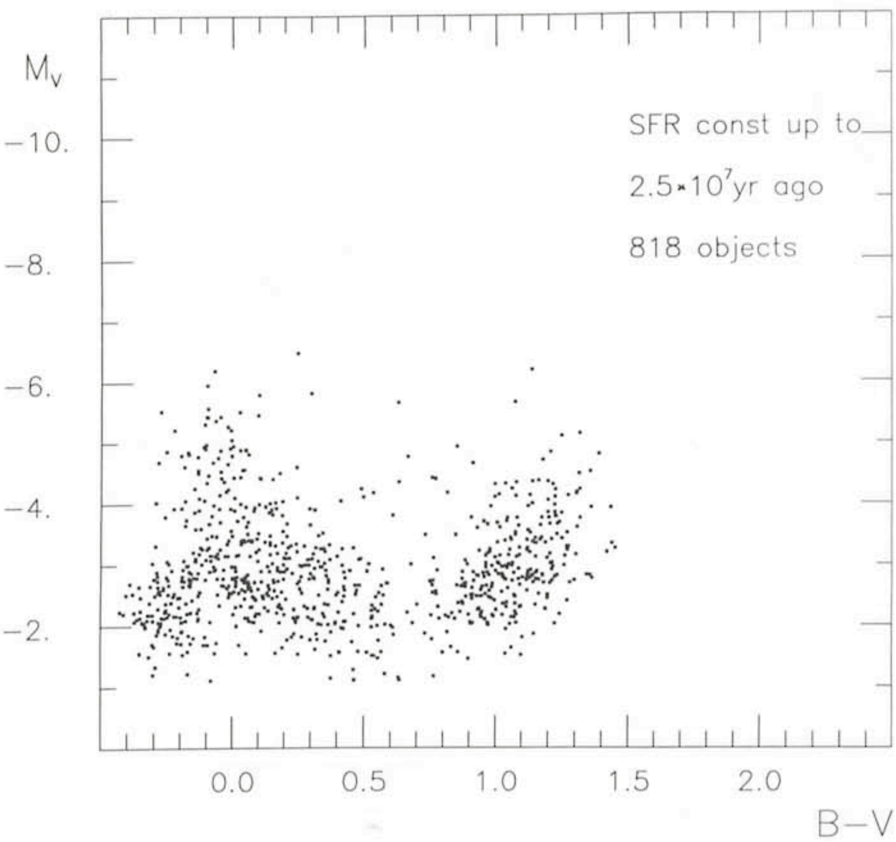


Figure 4: *Simulated CM diagram for Region 2 of Sextans B for an adopted distance modulus of m-M = 26.1 mag and a constant star formation which stopped 2.5×10^7 yr ago.*

continued up to now, a blue plume corresponding to massive Main Sequence stars would be present in the CM diagram, contrary to the observational evidence. Similar results can be obtained with two long and distinct episodes of Star Formation, but short and separated bursts do not give a satisfactory agreement with the data, since the distribution of objects happens to be too clumpy around the corresponding isochrones.

Three types of IMF have been tested: the relatively steep IMF by Tinsley (1980), which is in good agreement with the solar neighbourhood data; the IMF suggested by Melnick (1987), which is very flat for the low metallicity appropriate for Sextans B; and Salpeter's IMF, which is intermediate between the other two. This latter, which turned out to be the only IMF consistent with the data on WLM (Ferraro et al. 1989), leads to a satisfactory agreement also in the case of Sextans B, although a further check has to be done, comparing the theoretically predicted with the observed luminosity function.

From Figure 3 it can be noticed that the two examined regions of Sextans B, and therefore all the galaxy, have undergone a similar history of Star Formation, as the distribution of stars in the CM diagram is virtually the same. This is not a trivial consequence of the small size (R $\lesssim$ 2 Kpc) of this galaxy, though. Indeed WLM has a similar size, but one region shows the effect of a recent burst of star formation, unlike the rest of the galaxy. In both galaxies, however, an underlying population of stars up to 1 Gyr old is present in every examined region, and the differences appear to concern only the very recent SF activity. From the data relative to these two galaxies, it seems therefore that Star Formation in Dwarf Irregulars is generally a rather continuous process, a result which will be checked against the observations of the other galaxies in our sample. If this conclusion will be confirmed, we anticipate an impact on the current theoretical interpretation of the chemical evolution of Dwarf Irregular galaxies. A continuous SF, in fact, provides a large heavy element production, which would be incompatible with the observed low metallicities typical of these systems.

As a possible solution, strong galactic winds triggered by Supernovae explosion (Matteucci and Chiosi 1983) can be invoked to remove most of the enriched gas. Yet, from the results of model computations, a bursting mode of SF is preferable, even when the action of galactic winds is taken into account (cf. Matteucci and Tosi 1985).

4. Conclusions

The history of Star Formation in Dwarf Irregular galaxies can be studied in a very efficient way through the analysis of their Colour-Magnitude diagrams, yielding significant results for the general understanding of the evolution of galaxies, when data are collected for a number of cases. Unfortunately, the number of Dwarf Irregulars which can be studied in detail with ground-based telescopes is relatively small. We believe, however, that our sample of about ten regions in five galaxies will be significant enough to draw some general conclusion and will provide a useful base for further studies with the Hubble Space Telescope.

Acknowledgements

We warmly thank Cesare Chiosi for providing the photometric conversion tables, and Francesco Ferraro for his fundamental help in data acquisition and reduction.

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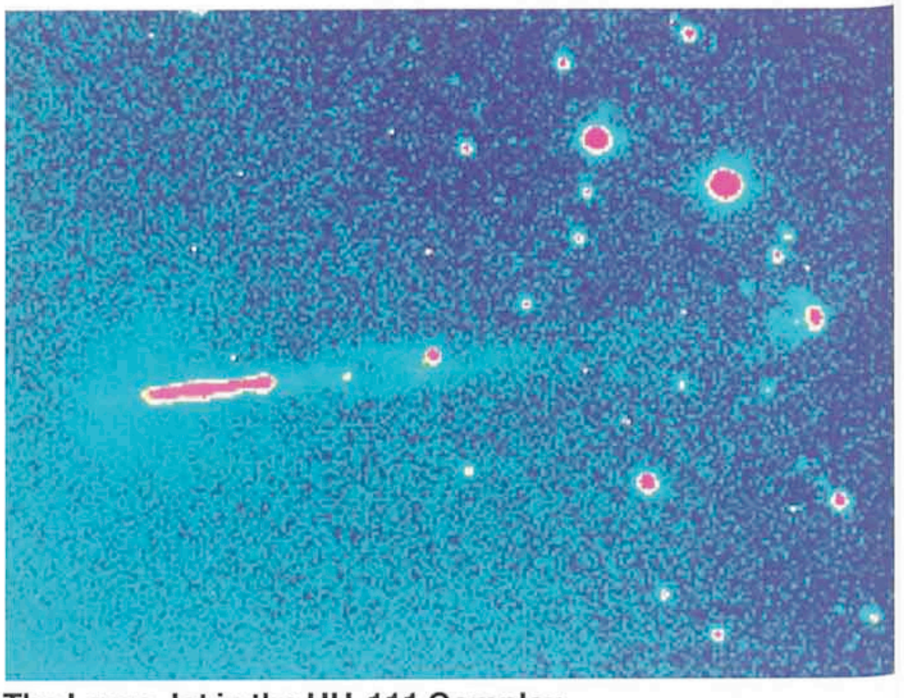

The Large Jet in the HH-111 Complex

This false-colour picture shows a newly discovered large jet in the HH-111 complex, just north of the celestial equator in Orion.

The straight jet emerges from the surrounding interstellar cloud in the left part of the picture. The outline of the cloud is vaguely visible by the brighter background near the lower edge of the picture. Also seen is a diffuse reflection nebula where the jet emerges. This nebula is illuminated by the light from a newborn star, hidden deep within the cloud. Because of the heavy obscuration, the star itself is not visible on this photo. The jet produces a "bow-shock" nebula; this is the bright, mushroom-shaped nebula in the right part of the picture. The round points are background stars in the Milky Way.

The picture was produced as a composite of four 1-hour CCD exposures, obtained with the Danish 1.5-m telescope at La Silla through a narrow optical filter. The light seen here from the jet is emitted by singly ionized sulphur atoms.

This new object was discussed in detail at the recent ESO Workshop on "Low mass star formation and pre-main sequence objects".

Optical Observations of X-ray Binaries

TH. AUGUSTEIJN, ESO

As part of my PhD study, and in the framework of a student-fellowship at La Silla as outlined by Prof. H. van der Laan in the March issue of the *Messenger*, I have been working on a research programme on accretion-driven stellar X-ray sources. Another part of my work at this moment is a long-term investigation of pulsation light curves in intermediate polars (a subtype of the cataclysmic variables), which will be concluded during this year. This research is done under the guidance of my thesis research advisor Prof. Jan van Paradijs of the University of Amsterdam, and Dr. Hugo Schwarz at La Silla. A brief outline of the background, and a short description of the research programme on accretion driven stellar X-ray sources is given below. To finish, some observational results on a particular object are presented.

Introduction

Luminous stellar X-ray sources are interacting binaries that contain an accreting neutron star or a black hole. Over one hundred X-ray binaries have been found since Sco X-1 was discovered nearly 27 years ago [1]. With the launch of the UHURU X-ray satellite in 1970, the binary nature of these objects was established through the detection of X-ray pulsations from Cen X-3 which showed regular Doppler variations of the pulsation period induced by the orbital motion [2] and the discovery of eclipses of the X-ray source. The subsequent launch of a great number of X-ray observatories in the 70's and 80's, of which GINGA and the MIR station are the only ones presently operating, greatly enlarged our knowledge of these objects.

Optical observations including identification, orbital light curves, and measurement of the orbital velocities of the optical counterpart of these sources also contributed considerably to our understanding of the basic properties of these systems.

X-ray Binaries

In X-ray binaries (see for reviews e.g. [3] and [4]), a neutron star or black hole accretes matter from a companion star. The X-rays are produced by the conversion of the gravitational energy of the infalling matter into radiation. This process generates energy ten times more efficient than nuclear fusion.

The X-ray binaries can roughly be divided into two groups on the basis of the spectral type of the mass donor (see e.g. [4]); massive X-ray binaries (MXRB) with O or B type companions and low mass X-ray binaries (LMXB) with a late type, or sometimes white dwarf, companion. The known orbital periods for these sources are in the range 1.4 to 41 days for MXRB and from 11 minutes up to 9 days for the LMXB.

The MXRB can be easily studied in the optical because the optical companions are intrinsically bright. Their structure and evolution is therefore relatively well understood. By contrast, much less is known about the optical properties of the more numerous (~100) detected LMXB. The companion stars in LMXB are intrinsically faint and most of the optical light emitted by a LMXB comes from an X-ray heated accretion disk. This, together with a mean distance of ~10 kpc, causes most of them to be fainter than 18th magnitude. Combined with the, in some cases, extremely short periods, this makes especially time-resolved observations difficult, and requires at least 4-m class telescopes.

LMXB

Better detectors on optical telescopes have made spectroscopic observations of the faint LMXB much more practical in recent years. Consequently, one of the three parts of my research programme is a spectroscopic study of these sources.

The optical spectra of LMXB generally show a few emission lines (mainly Hβ, He II 4686, and the Bowen 4640 lines) superposed on a blue continuum. The latter lines indicate reprocessing of X-rays [5]; their relative strengths may be an indicator of the metallicity of the source [6].

The aim of my project is to study orbital variations of the wavelength and strength of the emission lines which could give us an insight into the line forming region and the mass of the companion star.

Black Holes

A very interesting aspect of X-ray binaries is that some of them may contain black holes as the accreting X-ray source.

The main problem for black hole candidates is that it is sometimes difficult to prove that the compact object is not a neutron star. For instance, the detection of coherent pulsations (the signature of a rotating magnetized neutron star), or bursts (see below) from a system are clear indications of the presence of a neutron star. The crucial evidence for the presence of a black hole (beyond the lack of these X-ray time signatures) is a measurement of the mass of the compact object which should be in excess of ~3 $M_\odot$, the upper theoretical limit to the mass of a neutron star [7].

Currently there are three strong candidates, LMC X-3 [8], Cyg X-1 [9], and A0620-00 [10], and one possible, LMC X-1 [11].

The mass of the compact object in these sources is derived, by optical spectroscopy, from the radial velocity curves of the absorption lines of the companion. From the radial velocity amplitude one can determine the mass function;

$$f(M) = \frac{M_x^3 \sin^3 i}{(M_{opt} + M_x)^2}$$

where M_x, M_{opt} are the mass of the compact object and the optical companion respectively, and i the inclination of the system with respect to the plane of the sky, By inserting $M_{opt} = 0$ and $i = 90$ (i.e. the system is seen edge-on), one gets a lower limit for M_x.

For the black hole candidate LMC X-3, Kuiper et al. [12] have, on the basis of the value of the mass function and modelling of the optical lightcurve, derived a mass of the compact object in the range (4.5–6.5) (d/50 kpc) $M_\odot$ with d the distance to the source. Taking a 2σ lower limit for f(M), a source distance of 40 kpc, and assuming a flat (instead of spherical) X-ray emitting region situated in the orbital plane, the authors find a lower limit to M_x of 2.8 $M_\odot$.

It is clear that a good determination of the radial velocity amplitude is essential for the conclusion that LMC X-3 contains a black hole (or not).

A major problem with the determination of the radial velocity curve is the possible contamination of the stellar absorption lines. This can be due, for example, to the deviation of the companion from spherical symmetry as a result of the tidal forces exerted by the massive compact object, or to some extra emission or absorption by either the disk or the X-ray heated side of the companion. These effects could distort the symmetry of the absorption lines and produce spuriously large values of the radial velocity amplitude. As the

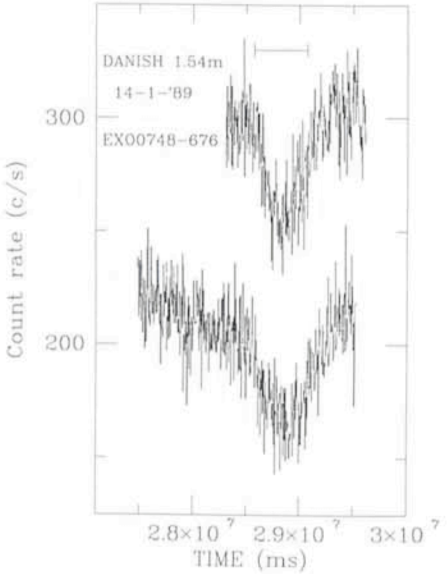

Figure 1: *The light curves of two consecutive eclipses observed on January 14, 1989. Each point is the average of four one-second integrations. The time-axis gives the time in milliseconds after UT = 0 h. The count rate is in counts per second. The upper curve is shifted upward by 70 c/s. The lower curve is shifted forward in time by 13,766,786 ms, or one orbital period.*

spectra used by [8] to determine f(M) had a resolution of ~150 km/s, the possibility of the effects described above, playing a role, cannot be excluded.

Part of my research programme is to determine, from high resolution, high signal-to-noise spectra of the optical counterpart of LMC X-3, an improved radial velocity curve. This will then be used to constrain the mass function and hopefully settle the question whether LMC X-3 contains a black hole or not.

Bursting, Dipping, and Transient Sources

LMXB show a variety of time variable characteristics.

A subgroup of the LMXB are the transient sources. Most of the time these transient sources are not detectable in either X-rays or optical emission – they turn on with typical rise times of a few days and then drop back below the level of detectability.

This phenomenon is the result of accretion instabilities which may be similar to dwarf-novae outbursts seen in some cataclysmic variables (interacting binaries containing a white dwarf and a low mass companion).

Another characteristic of a number of LMXB is the presence of X-ray (and optical) bursts. These bursts arise from a thermonuclear flash of the accumulated accreted matter on the surface of a neutron star.

A third phenomenon, observed in some LMXB, is the existence of intensity dips occurring at regular intervals. Generally, this is explained as periodic obscuration of the X-ray source caused by a turbulent thickening of the disk at the point where the gas stream from the companion hits the accretion disk surrounding the compact object (see [13] for a very clear depiction of such a system).

EXO 0748-676, the Source That Has It All!

The X-ray source EXO 0748-676 is a transient source that has remained detectable since its discovery in 1985 [14]. This source is unique in that it shows dips and bursts, and in addition it is one of the only two known LMXB to exhibit eclipses of the X-ray source, and of course also parts of the disk, by the secondary. The eclipses of the X-ray source make it possible to determine unambiguously the orbital period and phase, and to put constraints on the orbital inclination, as well as size and mass of the companion.

The third part of my research programme is to make detailed photometric observations, with a high time resolution, of the optical eclipse light curve of UY Vol, the optical counterpart of EXO 0748-676.

The aim of this project is to investigate the radial distribution of optical continuum and line emission, and the radius of the disk by studying the shape of the eclipse light curve. A comparison with cataclysmic variables, for which similar observations have been made, in which the accretion disk predominantly radiates by internal conversion of gravitational energy, can give some insight into the role of X-ray heating of the accretion disks in LMXB.

Observations

During 5 nights in January, observations with a time resolution of 1 sec were made of EXO 0748-676 using a two-channel photometer attached to the Danish 1.54-m telescope. One channel measured the source whilst the other constantly monitored the sky. Flux standards were measured with both channels to calibrate the system.

Due to some instrumental problems during the first night, little data were collected. The following nights gave much better results, though a part of the last night was affected by cirrus clouds.

Two examples of eclipse light curves, both observed on the third night, are shown in Figure 1. The data are background corrected. Each point is the average of four one-second integrations. The lower curve is shifted forwards in time by one orbital period [15], the upper curve is shifted upwards by 70 c/s.

The horizontal line near the top of the Figure indicates the predicted time interval of the X-ray eclipse of the neutron star [15]. The uncertainty in this value is only +/− 2 sec. The optical eclipse, including the partial eclipse of the disk, takes about three times longer [16].

The coincidence between the predicted times of the X-ray eclipse and the observed eclipse-like feature in the optical light curves suggests the presence of a region of enhanced optical emission closely associated with the X-ray emitting region.

Figure 1 further shows that the shape of the eclipse is highly variable, and can change from one orbital period to the next. Also, short time variability of the source is seen in all parts of the light curves.

An unexpected result of the observations was the detection of six optical bursts. Of the six bursts, five were observed in the second night and one in the beginning of the third night.

One of the bursts is shown in Figure 2. An interesting aspect of this burst is the possible detection of a second burst, at around $1.82 \cdot 10^7$ ms in Figure 2, which occurs only ~8 minutes after the first burst. Of course it is clear that a full and careful statistical analysis of the data is needed to determine if this feature is really significant.

However, the light curve shown in Figure 2 is remarkably similar to the one optical "double" burst detected in another burster, MXB 1636-53 (see [17]), in which the bursts are separated by ~6 minutes. The separation of ~8 minutes would also be comparable to that of the four double bursts detected during X-ray observations of EXO 0748-676 [18], which had separations of between 10 and 20 minutes.

In their paper, Gottwald et al. [18] show that as the persistent X-ray flux of the source decreases, the number of bursts increases. They also noted that double bursts are only observed when the persistent X-ray flux is low.

Extending this picture by taking into account that the main source of light in a LMXB is the X-ray reprocessing disk, this would mean that as the source showed many bursts (and possibly including a double burst), the X-ray source was in a low state, and consequently the optical counterpart should be faint.

Indeed, during the two nights that bursts were observed, the count rates of the optical counterpart ranged from ~200 to ~400 c/s, whilst during the

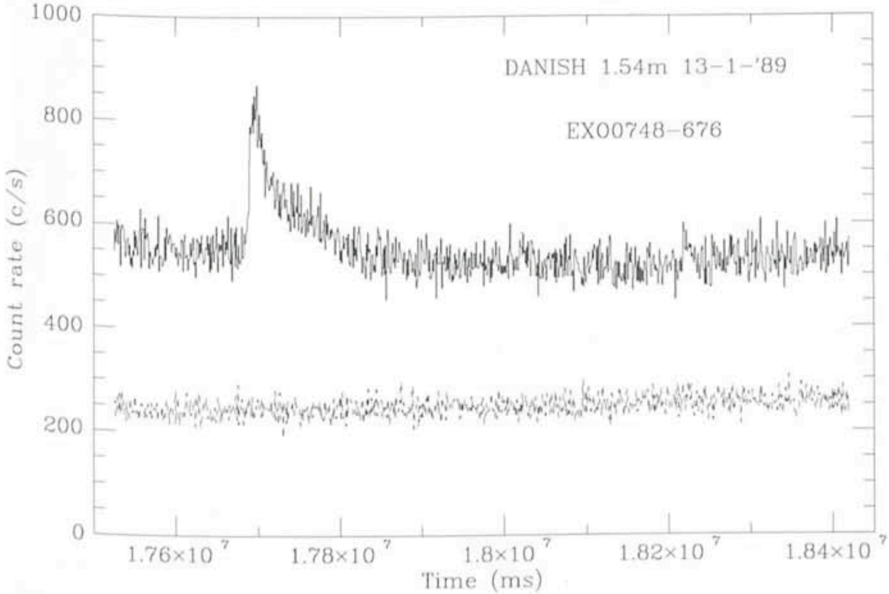

Figure 2: *The light curve of a burst from UY Vol, observed on January 13, 1989. The axes have the same definition as in Figure 1. Each point is a one-second integration. The sky counts are corrected for the difference in sensitivity of the two detectors.*

two following nights the count rates had risen to between ~400 and ~600 c/s. In this respect it is interesting to note that the shape of the "first" burst in Figure 2 is very simular to the "slow" X-ray burst profile seen in the low X-ray state.

Also, the source intensity during the second part of the third night was higher than during the first part. This can be seen by comparing the lower curve of Figure 1, which was observed during the first part of that night, and the upper curve, observed in the second part of that night, which is higher by more than the upward shift of +70 c/s. This would then also indicate an increase in the persistent X-ray flux and naturally explains the detection of only one burst at the beginning of that night and the lack of any further detection for the rest of the night.

In Figure 1 it can be seen that also during the X-ray eclipse the optical intensity of the source is significantly increased in the second part (upper curve in the Figure) of the night. Following the picture given above, this is in turn fully consistent with the idea that the disk radiates through reprocessing of X-rays, giving a rise in the optical emission with a rise in the X-ray flux also when only the side of the companion turned away from the X-ray source and (part) of the disk are visible. The depth of the eclipse also shows that the disk is a major source of optical light in the system.

To look further into the relation between optical and X-ray behaviour of this source, a separate night of observations, simultaneous with the X-ray satellite GINGA, was made on March 25 this year. Unfortunately, only three hours of data could be collected and a first quick look at the data did not show any special activity of the source, though a closer look, also at the X-ray data, will be necessary.

However, it still would be very interesting to follow this source closely in the future, if possible simultaneously in X-ray and optical, to further study this very unusual object.

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NEWS ON ESO INSTRUMENTATION

The VLT Adaptive Optics Prototype System: Status July 1989

F. MERKLE, ESO

In June 1986 the conceptual design of the VLT Adaptive Optics Prototype system was started, based on the collaboration between the Observatoire de Paris (Meudon), ONERA, the Laboratoires de Marcoussis, and ESO after funding was assured by ESO and supporting French authorities.

In August 1987 began the construction of the major components. It was completed at the facilities of the various partners in May 1988. The major components are the 19-actuator deformable mirror (LdM), the Shack-Hartmann wavefront sensor (ESO), the wavefront computer and control electronics (ONERA, LdM), the tip/tilt mirror (OdM), the opto-mechanical support structure

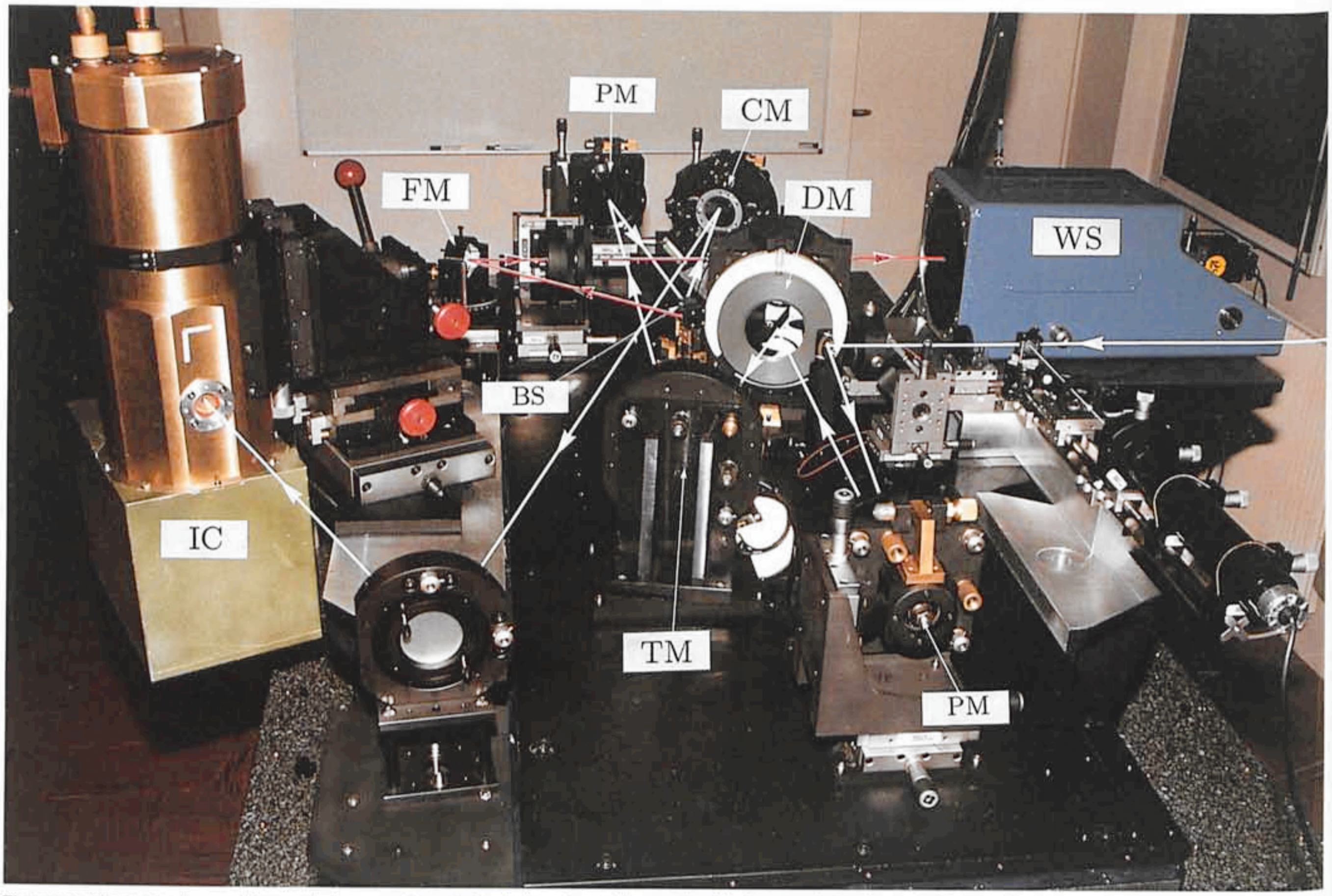

Figure 1: *The adaptive optics prototype system in the laboratory. The optical light pass is indicated. The major components are the deformable mirror (DM), the tip/tilt mirror (TM), the off-axis parabola (PM), the dichroic beamsplitter (BS), the field selection mirror for the wavefront sensor (FM), the wavefront sensor (WS), the chopping mirror (CM), and the infrared camera (IC). The electronics, including computers, occupy two standard racks and are not shown. The light path from the dichroic beam splitter to the wavefront sensor is indicated in red.*

(OdM, CNRS), and the IR array camera (OdM).

Meanwhile the system has been completely integrated at Observatoire de Meudon. First successful static tests have been performed in the laboratory and dynamic operation is under preparation. Figure 1 shows the prototype system at Meudon in June 1989. It is planned that the alignment and tuning of the system will be finished by mid-September. The major characteristics are summarized in the Table.

The first, closed-loop operation is scheduled for October 12 to 23, 1989, followed by a second observing run in November. These observations will take place at the Observatoire de Haute-Provence at the coudé focus of the 1.52-metre telescope. Currently the OHP is preparing the installation of the adaptive system in October.

Early 1990 the system will go from Garching to La Silla, after the necessary modifications for adaptation to the 3.6-metre telescope, and a series of final laboratory tests and improvements, if required. During the observations, a whole set of technical programmes will be carried out, like seeing and isoplanicity measurements in the IR and visible, partial adaptive correction at shorter wavelengths and the visible, to mention only a few of them.

This prototype system is ESO's first major step towards the adaptive optics systems required for the VLT. As a test-bench it allows to investigate the performance of all components and in particular of the control strategy. Already during the design and construction it became obvious that the computing power necessary in order to achieve the real-time control with the required bandwidth is the major constraint. A possible upgrade of the system with a mirror of approximately 64 actuators will be an important intermediate step for the specification of the VLT systems. For the VLT the current plans envisage approximately 250 actuators.

Acknowledgements

The author's thanks are due to many colleagues contributing to ESO's activities in the field of adaptive optics, particularly J.C. Fontanella (ONERA),

Table: *Major parameters of the adaptive optics prototype system*

Wavelength range:	3 to 5 micrometre (3.6-m telescope) partial correction for $\lambda < 3$ micrometre
Deformable mirror:	19 piezoelectric actuators +/– 7.5 micrometre stroke
Tip/tilt mirror:	gimbal mount piezoelectric actuators
Wavefront sensor:	Shack-Hartmann principle 5 × 5 and 10 × 10 subapertures 100 × 100 intensified Reticon detector built-in reference source additional field selection mirror
Wavefront computer:	dedicated electronics host computer based on Motorola 68020
Control algorithm:	modal correction scheme mirror eigenmodes
Camera:	32 × 32 InSb array camera (SAT detector) additional chopping mirror

J.P. Gaffard (CGE), P. Kern (Obs. de Meudon), P. Léna (Obs. de Meudon), J.C. de Miscault (CGE), G. Rousset (ONERA), and to many colleagues at ESO for stimulating discussions.

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For additional references the following papers are recommended:
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LATEST NEWS

IR Observers at the 3.6-m telescope are inormed that the new F/35 chopping secondary mirror is now available.

The F/35 chopping secondary mirror was reinstalled in August 1989 and tested with the IR Photometer/Spectrophotometer. The performance of the system proved at least identical to the one quoted in *Messenger* 39, 1, 1985. ESO's IR Specklegraph (see *Messenger* 45, 29, 1986) was also successfully used in its F/35 configuration.

A. van Dijsseldonk (ESO)

Telescope Alignment Procedures: Improved Technique in the Optical Identification of Mechanical Axes

P. GIORDANO, ESO

Introduction

In the article concerning "First Light" in the NTT in the *Messenger* No. 56, a brief description was given on page 2 of the basic steps of the alignment procedure. As was stated there, the procedure used in the NTT was essentially only a somewhat more refined form of a standard procedure which had been successfully used on a number of La Silla telescopes. The first – and most fundamental – step is the optical identification of the altitude axis (alt-az telescopes) or declination axis (equatorial telescopes).

The set-up for this step in the NTT is shown in Figure 1. ST1 and ST2 are two sighting telescopes mounted at the two Nasmyth foci. Target mirrors tM1C1 and tM2C2 were mounted on the fixed parts of the fork. The observation of a central cross on these target mirrors and the observation of the ST graticule in autocollimation against the plane faces of the target mirrors enables the two ST to be placed on the mechanical altitude axis, thereby establishing a basic reference for the whole operation. However, space reasons dictated in this case that one had to "look through" tM2C2 to observe tM1C1 with ST1 and conversely with ST2. The conventional solution using "half-coated" mirrors leads to loss of ¾ of the light and ghost images with higher intensity than the required images.

The selected solution was based on the combination of narrow band dielectric mirrors and illumination of the sighting telescope with the corresponding light using narrow band interference filters. We get in ST1, for example, a maximum of reflectivity from M2C2, in spite of 2 passages through M1C1 (see Fig. 1).

The wavelengths chosen in the realization of the 2 beams were in accordance with the laser light currently used in our laboratory:

Red beam λc = 632,8 nm HeNe laser
Green beam λc = 543,5 nm HeNe laser

Realization

The dielectric mirrors were realized and delivered on time by MELLES GRIOT (France), who, after a first study and a computer simulation, achieved in practice an excellent confirmation of the theoretical values. The front surface, with the cross-hair, is coated with the dielectric layer, while the back surface is coated with a broad band antireflective coating.

The interference filters were selected carefully from the ESO La Silla catalogue, in order to optimize the total efficiency of the delivered version of the dielectric mirrors.

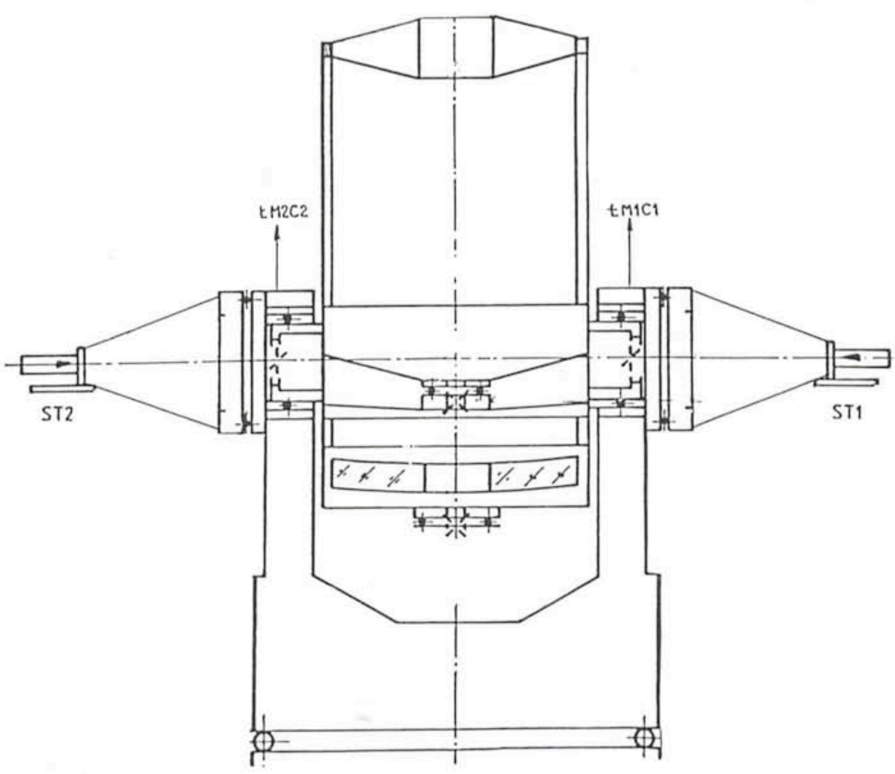


Figure 1.

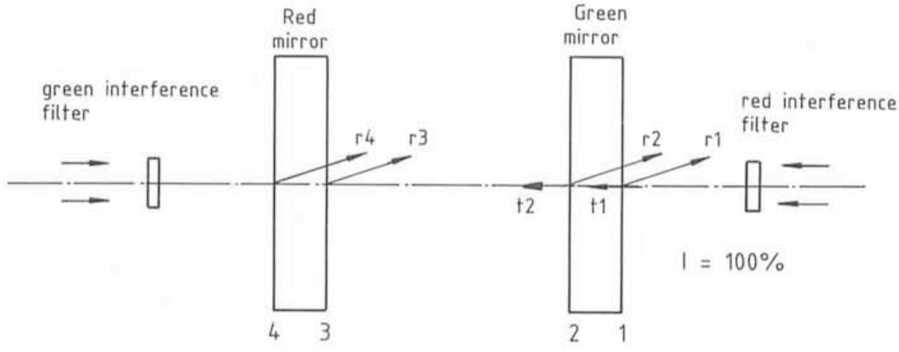


Figure 2: *Schematic diagram. Please note that the numbering is in accordance with the direction of the light. In this example, the light enters from the right-hand side.*

Figure 2 shows how the system functions. Surfaces 2 and 3 are coated. In a non-absorbing material the energy conservation formula is r + t = 1 and the transmitted amplitude is given by t = 1-r.

The main objective of this design was to obtain the highest ratio of image intensities reflected by surface 3 with respect to surface 2. In the "classic" case of half coated mirrors, this ratio has a very low value of 0.25. Our new arrangement (red dielectric mirror used at 646.6 mm) achieves a ratio of 37.2, about 150 times higher! In the second case (green dielectric mirror), using an appropriate narrow filter, we could achieve a value of 2.4, a gain of about 10 times. However, with a filter operating at a slightly shorter wavelength, which was not available at that time, a value of 10.5 would be achieved, a gain of about 40 times. A small harmonic leak was the reason why the green case was somewhat less efficient than the red.

EFOSC 2

W. ECKERT, D. HOFSTADT, J. MELNICK, ESO

Late in 1987 it became clear that, before the implementation of the ESO Multi Mode Instrument (EMMI), the NTT would require an optical instrument with imaging and spectroscopic capabilities.

To build a second EFOSC was a logical choice in view of its moderate size and above all, the possibility of retrofitting the instrument later on at the 2.2-m telescope. EFOSC is in high demand at the 3.6-m telescope where it caters for nearly one-third of the observations and a similar potential use exists at the 2.2-m.

The initial idea was to build a copy of the present version but it soon became evident that a new mechanical design was required to adapt different optical scales and to allow for a larger detector format. It was also clear from our experience with the 3.6-m version that a number of improvements were desirable, particularly for the setting and handling of the optical components.

While the basic configuration layout was maintained (see Fig. 1), the intention was to acquire optical components with an improved blue transmission. Early in 1988 a contract was placed with the Swiss firm FISBA Optik for the delivery of the camera, collimator and field lens units within 6 months. Figure 2 shows the overall response curves for the three components combined. It compares favourably with the optical transmission of EFOSC. Since the final

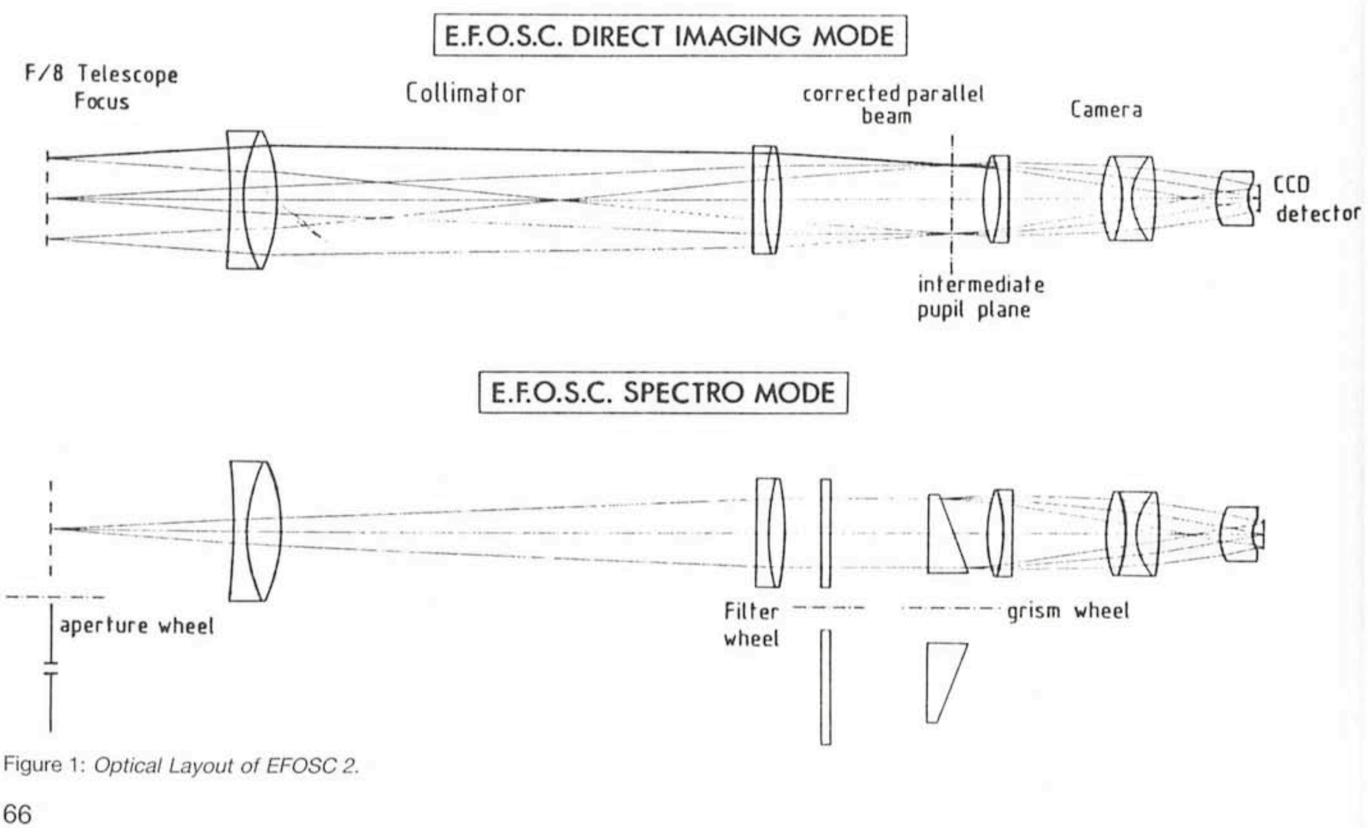


Figure 1: *Optical Layout of EFOSC 2.*

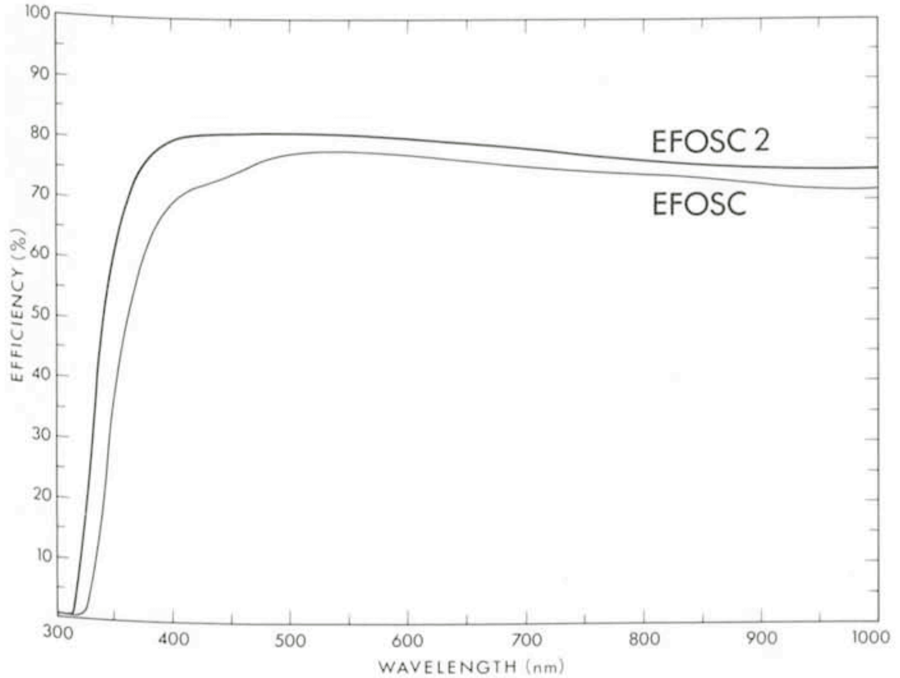


Figure 2: *Overall optical transmission of EFOSC 2 compared with EFOSC (see also note by H. Dekker, on page 64 of the March 89 issue of the* Messenger*).*

destination of the instrument was the 2.2-m, we decided to optimize the design for this telescope. The focal plane scale at the NTT is 187 μm/″ while the 2.2-m rates 85 μm/″. Table 1 shows the pixel-size matching at both telescopes for different detector formats. Obviously, oversampling is unavoidable in the case of the NTT. A photograph of EFOSC2 mounted on one of the Nasmyth foci (the "EMMI arm") of the NTT is shown in Figure 3.

For spectroscopy, a set of six grisms with 100 g/mm and 300–400 g/mm gratings have been purchased (Table 2). The long focal length of the EFOSC 2 camera combined with the 10 × 15 mm RCA CCD formats does not warrant the use of higher dispersions at present. Once the larger format CCDs become available, higher-dispersion gratings in the 600 g/mm range will be introduced. It is possible to interchange these components between the two EFOSCs. The same applies for the filter and the slit units. In general, a large degree of compatibility has been maintained in order to reduce the maintenance and operational burden at La Silla which is why we also plan to make use of the calibration units available inside the adapter/rotator of the NTT. At the 2.2-m telescope the housing of the DISCO unit, which contains the necessary calibration sources, will be adapted to interface EFOSC 2 to the telescope.

The instrument controls are CAMAC and NIM based to be fully compatible with the 3.6-m arrangement. During the first tests an HP1000 computer system identical to the standard instrumentation setups was installed at the NTT and

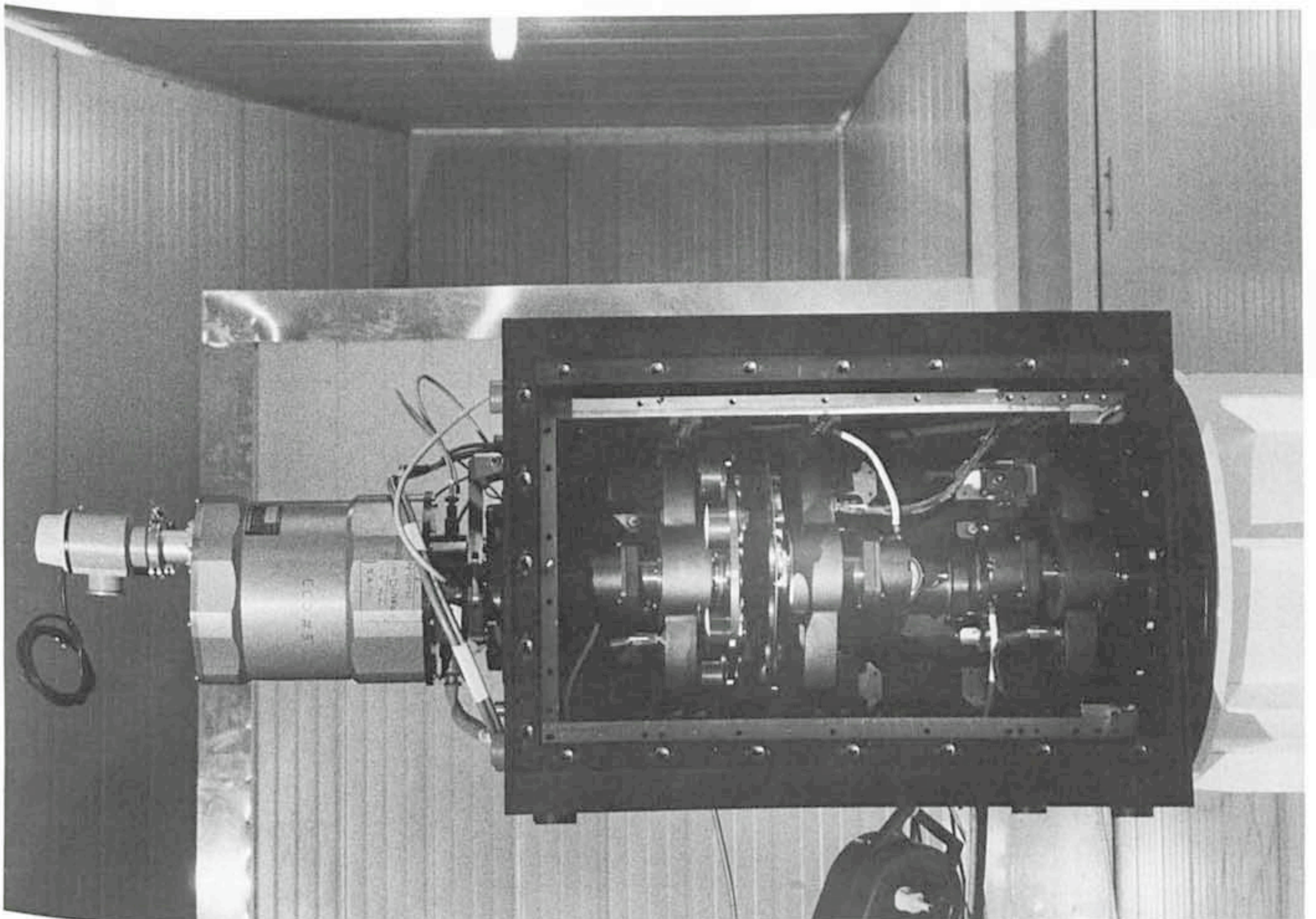


Figure 3: *Photograph of EFOSC 2 fitted with an RCA CCD.*

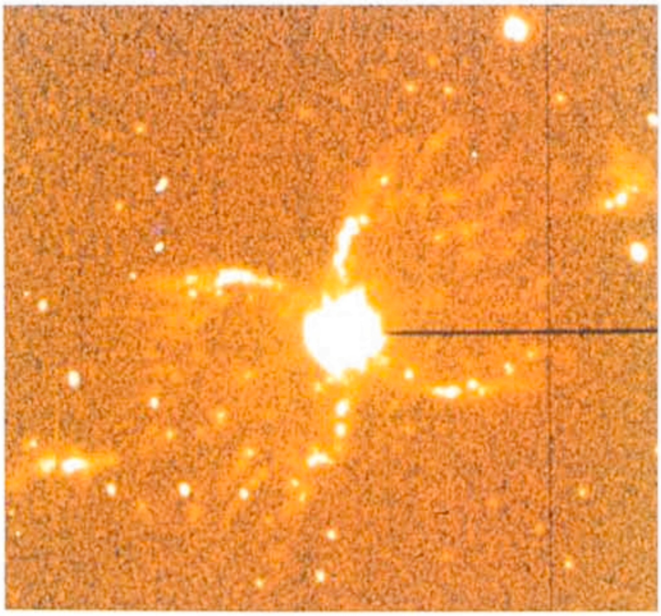


Figure 4: H_α *image of the Southern Crab (He 2-104) obtained with EFOSC 2 at the NTT. Notice the features visible in this image that are not visible or not resolved in the images published in the March 89 issue of the* Messenger.

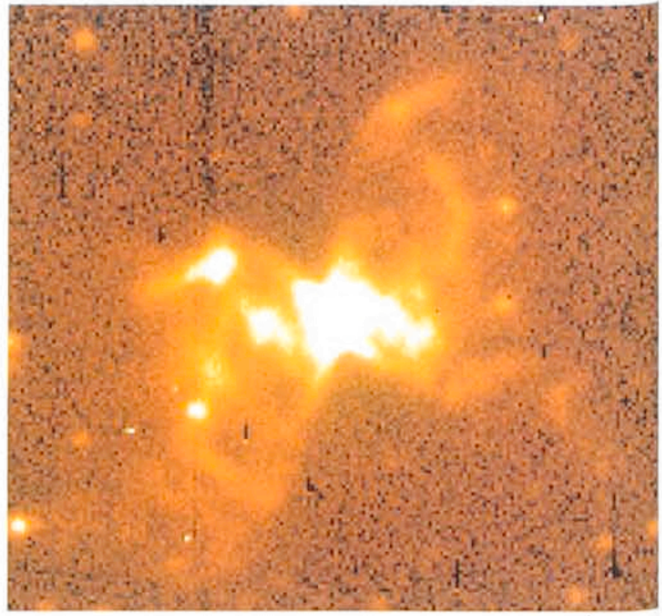


Figure 5: H_α *image of the planetary nebula He 2-84 for which very little information exists in the literature.*

Table 1: *Pixel matching EFOSC 2*

2.2-m telescope		
Detector	10 × 15 mm	25 × 25 mm
Pixel Field of view Scale	15 μm 3.2 × 4.7 arc min 1 pixel = 0.29 arc sec	25 μm 7.9 × 7.9 arc min 1 pixel = 0.48 arc sec
NTT		
Detector	10 × 15 mm	25 × 25 mm
Pixel Field of view Scale	23 μm 1.5 × 2.2 arc min 1 pixel = 0.20 arc sec	25 μm 3.7 × 3.7 arc sec 1 pixel = 0.22 arc sec

Table 2: *EFOSC 2 grism*

	g/mm	blaze λ
B1000	100	4500
R1000	100	6500
UV300	400	3800
B300	360	4500
R300	300	6000
new grating	300	4900

only minor software modifications were required to handle the data acquisition.

EFOSC 2 saw the first astronomical light on May 11 at the NTT. The first scientific programme of EFOSC 2 was to make a pictorial atlas of compact southern planetary nebulae. About 200 nebulae were imaged through narrow-band Hα and [O III] filters, many for the first time. But many previously well studied nebulae were imaged with unprecedented detail thanks to the superb seeing conditions which prevailed during the first EFOSC 2 run and to the outstanding quality of the NTT. Figures 4 and 5 show Hα images of two planetary nebulae observed with EFOSC 2. The elongated shapes of stellar images are due to field rotation, unavoidable during exposures lasting a few minutes until the installation of the adapter later this year.

EFOSC 2 has been largely a background task adventure for the La Silla mechanical, electronic and optical workshops. W. Eckert was responsible for the mechanical design and supervision of the assembling while A. Macchino and J. Santana built and integrated the electronic part. L. Baudet aligned the optical path. We are grateful to B. Delabre for the layout calculations, to H. Dekker for handling the FISBA contract and to B. Buzzoni for the optics commissioning at Garching.

At La Silla we were happy to see a new instrument emerging from our workshops. A change in our activity scope where patching, mending and grumbling around equipment delivered from other horizons is our usual fate.

Improved Shutter Timing at La Silla

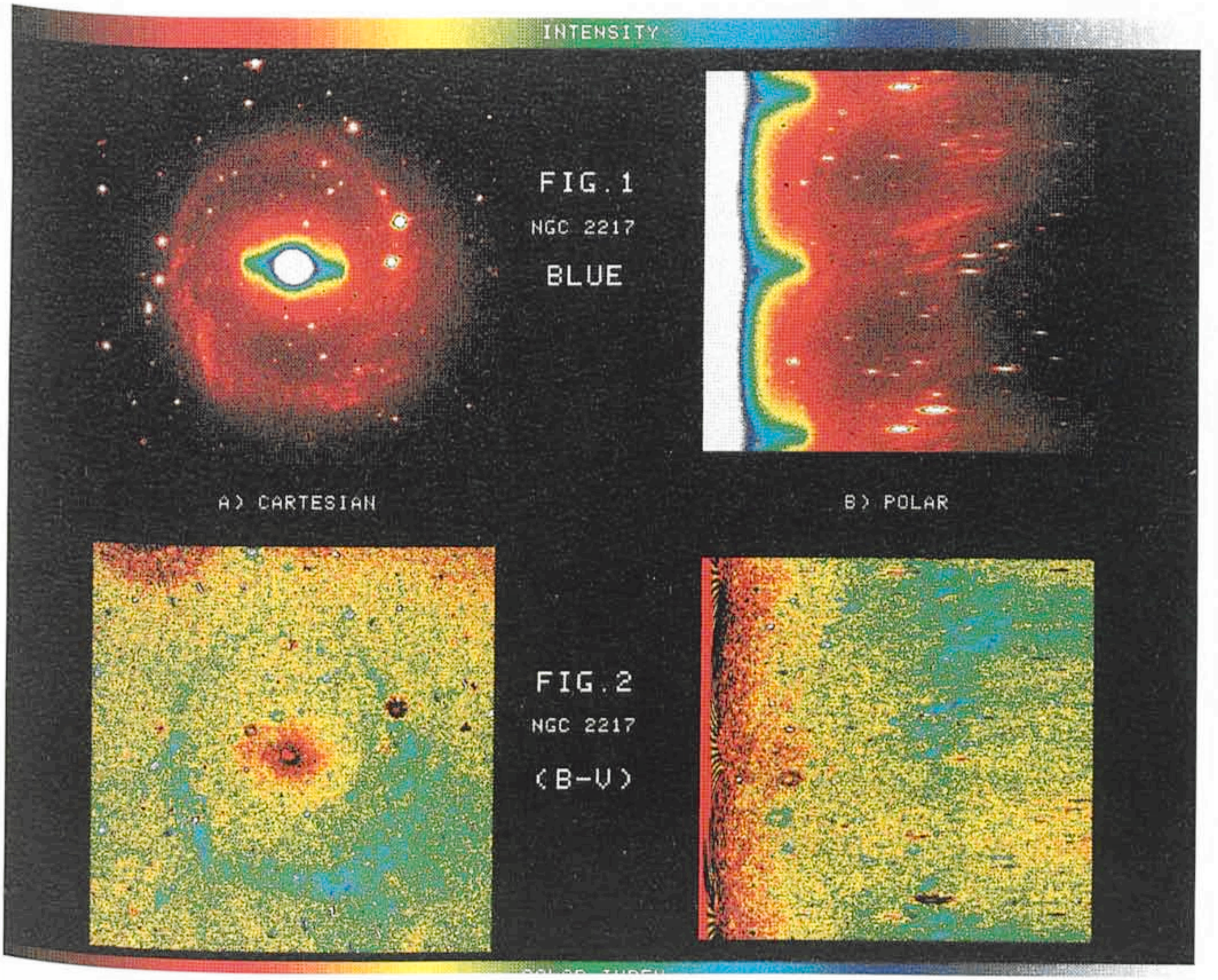
The shutter timing accuracy of most instruments using shutters at La Silla are to be considerably improved. By the time that you read this, new CAMAC module cards will have been installed which control exposure times independent of the acquisition computers. These new cards allow an on-card timing resolution of 1 mS between 1 mS and 32,000 mS. From 32 S to 32,000 S, the timing resolution is 1 S but the internal counting accuracy remains at 1 mS in all cases. Some exposure definition forms are being updated to allow a 0.1 S resolution between 0 S to 32 S. For exposures longer than 32 S, the resolution will remain at the present value of 1 S.

Tests have been done with the new shutter timing cards using the CCD cameras on the 2.2-m and Danish 1.5-m telescopes. For the 2.2-m telescope, the shutter error has decreased by a factor of nearly 16 from about 190 mS to 12 ± 3 mS. For the 1.5-m Danish telescope, the improvement is about a factor of seven to 27 ± 3 mS, both in the sense that the resultant exposures are greater than those requested by the above amounts. It is expected that these delays will be reduced even further with the installation of a system of detecting a feedback signal from the actual shutters. Observers should find that they can now do accurate photometry (one per cent or better) using bright stars with exposures as short as two or three seconds. *B. Jarvis, ESO*

A New IHAP Feature: Images in Polar Coordinates

J.A. STÜWE, Astronomisches Institut der Ruhr-Universität Bochum, F.R. Germany

Many astronomical objects show special symmetries, which generally need special techniques for image enhancement. At our institute, for example, investigations on structures in Cyan coma images of comet Halley and in electronographic images of several S0 galaxies are at work. In the course of these analyses it showed up that for morphological studies it is useful to represent the images in a way which already takes the (circular) symmetry of the objects into account. For this purpose I developed an algorithm which performs the transformation of images between cartesian and polar coordinates. In polar coordinates the images still have two dimensions with the abscissa representing the radial distance r from the centre of the object and where the ordinate shows the azimutal angle φ. $\varphi = 0°$ represents the direction of the x-axis in the original cartesian image and then φ runs positive anticlockwise. Because the transformation is not isometric the resulting r,φ-image does no longer contain e.g. counts per pixel, but nevertheless gives the information that at a position defined by radial distance r and azimutal angle φ the counts per area of the cartesian pixel have a certain value. This means: if you already calibrated the cartesian image in physical units like erg/cm^{2}s or mag/(″)^2, the resulting polar image shows the correct flux or surface brightness distribution.



This algorithm has been incorporated into the IHAP-system running at an HP 1000 F computer at our institute as two new IHAP commands. XYRP transforms cartesian to polar coordinates and RPXY transforms backwards from polar to cartesian coordinates. The transformation equations are defined in the usual way,

$X = r * \cos \varphi$ and
$Y = r * \sin \varphi$

where X, Y as well as r,φ represent the "world coordinates" of the images. In this way all other IHAP features then are applicable to the polar images as well.

Figures 1 a and b show the application of the XYRP command on an electronographic B-image of the SB0 galaxy NGC 2217. The cartesian image (Fig. 1 a) shows a barred nucleus and weak spiral arms whereas in the polar image (Fig. 1 b) these "spiral arms" appear as an almost perfect circular ring, that has no connection to the "bar" and exhibits spike like structures. This impression is even enhanced in the (B–V)-polar image in Figure 2. Here the "spikes" show up as blue features, what indicates that they are places of recent or ongoing star formation, whereas the bar is almost invisible in this picture. These images show an example of one possible application of the newly developed IHAP commands facilitating morphological studies. Several more of such investigations are in progress at the Astronomisches Institut der Ruhr-Universität Bochum, undertaken by my colleagues, who already applied this feature with great success. The two new commands will be implemented at the ESO IHAP sites.

MIDAS Memo

ESO Image Processing Group

1. Application Developments

A set of applications for reduction and calibration of photographic plates has been implemented by A. Lauberts. These procedures are based on his experience with the analysis of the ESO/Uppsala survey. Although they are optimized for the treatment of Schmidt plates, they will also be useful for other types of photographic material.

The table file system has been significantly upgraded both in performance and functionality. It now provides full support of integer types (I*1, I*2, and I*4). This is of special interest for X-ray astronomy which often deals with small numbers of events.

2. Support of DEC Windows Under VAX/VMS

MIDAS has been successfully implemented on a VAX station 3100 under VAX/VMS 5.1 with DEC windows. Working with our standard X11-based IDI routines and a VMS specific interface for the client-server communication, it required only a minor upgrade of the display software to use the VAX station as an image display station for MIDAS. The initial version of the communication interfaces was kindly provided by M. Pucillo and P. Santin from Trieste Observatory whom we thank for their significant help.

The full graphics facilities in MIDAS are being tested. Thus, full MIDAS support of VAX/VMS work stations will be available in the 89NOV release of MIDAS.

The VAX- and DEC stations based on Ultrix with DEC windows are already fully supported, so that MIDAS now covers the whole range of work stations from DEC.

3. MIDAS on New Systems

After requests from several institutes, we have successfully implemented MIDAS on an IBM PS/2 system under AIX. These systems are also offered with X11 window systems which make them interesting as low end work stations. *Please note that the mention or testing of specific computer systems is not in any way an endorsement.*

4. MIDAS Hot-Line Service

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

- EARN: MIDAS @ DGAESO51
- SPAN: ESOMC1::MIDAS
- Tlx.: 528 282 22 eo 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 or telex.

KURT WALTERS (1912–1989)

Dr. Kurt Walters died.

Dr. Walters has been ESO's legal advisor in Europe and also for Chile.

Living in Hamburg and closely associated with Prof. Heckmann, ESO's first Director General, he had in the early days of our Organization a major role in the development of ESO's relations to its member states and to Chile, where he contributed, in particular, to the successful negotiation of the ESO Convention with the Chilean government.

His calm, reflective personality, combined with an excellent judgement, was widely appreciated.

Dr. Walters terminated his work for ESO in 1976 with the beginning of ESO's relocation to Garching.

He died at the age of 77 years.

G. Bachmann (ESO)

TEX in Astronomical Publishing

S. J. HOGEVEEN, Astronomical Institute "Anton Pannekoek", Amsterdam, the Netherlands

Introduction

The use of the computer typesetting system TEX in astronomical publishing has become inevitable.

In the *Messenger* No. 52, "Astronomy and Astrophysics" first announced the availability of a TEX macro package, which may be used to submit papers intended for publication in the Main Journal. In *Messenger* 56 a repeated call to use the TEX macro package was made, and a TEX package for the A&A Supplement Series was announced. Experiments with TEX for astronomical publishing are also going on in the United States, as abstract No. 32.02 in the *Bulletin of the American Astronomical Society*, Vol. 21, No. 2, shows.

Manuscripts, prepared with the TEX macros, can be fed straight into a type-setting machine at the publisher's, thus eliminating the costly and time consuming steps of having the manuscript typeset and sent back and forth for proofreading. Shifting the burden of typesetting from the publishers to the authors affects the work of authors, editors and publishers to a lesser or greater extent. This is recognized by Dr. H.-U. Daniel as he states in the *Messenger* No. 56, in his renewed call to use the TEX macro packages: "... continuing, patient cooperation will be necessary until the usual smooth processing of manuscripts (...) has been extended to 'electronic' manuscripts."

This paper is intended as a contribution of an author to this continuing cooperation, and I hope it will be read by other authors, editors and publishers. In it, I will raise some matters which did not seem to get much attention in the developments so far, but which may be decisive as to the success or failure of the introduction of TEX for astronomical publishing.

TEX

TEX actually is a programming language, like any other programming language, except that it is not intended for numerical calculations, but for the processing of text. With TEX the data to be processed are the text, and the programme that processes the data formats the text into a desired layout.

The basic idea of TEX in (astronomical) publishing is that the author provides the text and that the publisher provides the TEX programme. Thus the author determines the contents of a paper, and the publisher is in control of the actual appearance of the paper in his journal.

However, since TEX is a programming language, there are many solutions to formatting problems, and there is no end to the features with which a programme could be equipped ("dynamic" numbering of sections, equations, etc.; semi-automatic generation of lists of references). This means that when publishers go about the development of TEX programmes – or macros, as they are actually called – independently, the macros for different journals may also be (very) different. Authors publishing in several journals would have to learn the different macros used by these journals.

Astronomy and Astrophysics

Sadly, we are already confronted with this problem, and not from two entirely different journals, but from different parts of the same journal.

The TEX macro packages for the Main Journal of A&A and of the Supplement Series were independently developed by their respective publishers: Springer in Germany and Les Editions de Physique in France.

For an author this is a most deplorable situation, especially when he is asked by the Editors to agree to the transfer of his paper from the Main Journal to the Supplement Series, or vice versa.

A Call for Standardization

Astronomical journals all have their own typical appearance and layout. Thus it seems almost unavoidable that different TEX macro packages are needed to meet the typographical requirements of each journal. However, when we look at the underlying structure of the papers in the journals, then they turn out not to be all that different.

The papers in our astronomical journals are characterized by a heading, with the title of the paper and the names and addresses of the authors, a summary or abstract, sections, equations, figures, tables, and a list of references.

It is possible to define TEX commands that deal with this structure of a paper, rather than with its layout. In fact, good typography supports the structure of a text, and the actual layout for any specific journal could be derived from the structuring commands, which really should be the same for all journals. This would alleviate authors from having to learn many different TEX macro packages.

LATEX

There already exists a macro package for TEX which may serve as an example of the above-mentioned concept.

LATEX is a general-purpose macro package for TEX, developed by Leslie Lamport. It provides authors with the tools to produce typographically sound articles, books, reports, and letters, without the need to learn the entire, complex language of TEX.

LATEX commands mainly deal with the structure of a document, while the actual layout of the document is determined by a so-called style file. LATEX thus allows the author to fully concentrate on the writing, and not to be concerned about where and how things are to be put on paper.

The LATEX style files may be adapted to produce the same source text in any desired layout, in a virtually endless choice of fonts. This means that a paper prepared with LATEX can be adapted to the typographical requirements of any specific journal, simply by making the right adjustments to the style files.

LATEX has many other interesting facilities. These have been recognized by (astronomical) authors, which is illustrated by the fact that many already use LATEX for their own purposes. One of the interesting facilities of LATEX is the semi-automatic compilation of lists of references from a bibliographic database, when it is used together with a programme called BIBTEX.

Fortunately, the advantages of LATEX have been recognized by the publisher of the Main Journal of A&A, Springer in Germany, and we may look forward to a first release of an A&A LATEX style file before the end of this year.

TEX and WYSIWYG word processors

Not every author is happy about the concept of TEX, where one has to prepare a source text, compile it with TEX and then print it to, at long last, see the final result.

Many prefer a WYSIWYG (What You See Is What You Get) word processor, and this preference is perfectly legitimate, because there are some very powerful interactive word processors around, capable of handling mathematical texts.

For astronomical publishing those word processors which are capable of producing TEX output are interesting, because for some time to come TEX will be the only thing the typesetting machines at the publishers' are able to handle.

Examples of WYSIWYG word processors with a TEX interface are Mathor for the IBM PC and compatibles, and MathType for the Apple Macintosh. The publisher of the Supplement Series of A&A, Les Editions de Physique in France, provide a Mathor-TEX interface to prepare papers for publication in their journal.

Concluding Remarks

The introduction of TEX in astronomical publishing is intended to increase the efficiency with which the astronomical journals can be run. With the above, I hope to have made clear that this can only be achieved if the authors are provided with tools that allow them to efficiently produce manuscripts in TEX.

Efficiency on the part of authors can be achieved in two ways, through standardization of TEX macros for the various astronomical journals, and by providing TEX interfaces for preferred mathematical word processors.

Standardization of TEX macros can be realized through the joint development of a standard macro, or by adopting the general purpose macro package LATEX, which to a great extent could serve as a standard.

In the end, publishers will also benefit from a form of standardization as advocated here, because when the output of a "standard" word processor is widely accepted, more authors will be apt to learn and use that word processor (or T_EX macro package, for that matter).

It is a great pity that Astronomy and Astrophysics appears thus far not to have recognized these aspects about T_EX in astronomical publishing, a fact which is indicated by the two widely different macro packages for their Main Journal and their Supplement Series. However, the experiments of Springer with LAT$_E$X, and those of Les Editions de Physique with Mathor, hold promises for the future.

It is a pleasure to report that the matter of standardization has been recognized early in the developments with T_EX for The Astrophysical Journal and for The Astronomical Journal.

Many aspects mentioned in this paper have also been put forward in a poster presented at a meeting of the American Astronomical Society, by C.D. Biemesderfer of the National Radio Astronomy Observatory and R.J. Hanisch of the Space Telescope Science Institute.

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Contents

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: 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 thirteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. A 3.5-m New Technology Telescope (NTT) will become operational soon 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.

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