No. 56 – June 1989

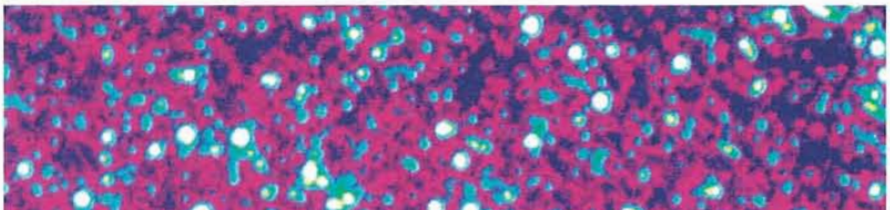
"First Light" in the NTT

R. WILSON, ESO

On the night 22–23 March 1989, "First Light" was achieved in the NTT in the sense that the first direct images of astronomical objects were produced with the optics in an optimized state near the zenith position.

The fact that the quality of these images turned out to be the best ever recorded in ground-based astronomy certainly made it the most memorable event in the ESO career of the author and his colleagues whose work on the NTT had led to this remarkable success.

But this result did not drop out of the sky! Many years of hard work by a small group of dedicated colleagues were necessary to achieve it. The principal new technology feature of the NTT was its Active Optics control system, the background and principles of which were described in *The Messenger* No. 53 (September 1988), page 1. The other new technology feature of fundamental importance for the optical quality was the design of the building. Although its basic concept is the same as that of the MMT (a building rotating with the alt-az mounted telescope), the new features were crucial, particularly the opening of the telescope area on both sides to allow maximum natural ventilation. These two new technology features, together with the excellent work of Carl Zeiss in figuring the optics, were the key to the image quality achieved at First Light.



This false-colour photo shows one of the best CCD frames obtained with the ESO NTT during the night of "first light" on March 23, 1989. The field is near the centre of the bright southern globular cluster Omega Centauri and the frame size is ~47 × 47 arcseconds. The measured diameter of the stellar images (at half of the maximum intensity) is only 0.33 arcseconds. Exposure time: 10 seconds; North is up and East is to the left. See page 3 for more details.

The Basic ("Passive") Alignment of the Optics

The final stage for the NTT optics started in November 1988. The mechanics of the telescope had been assembled under the supervision of Gerardo Ihle. To him and his colleagues in Chile we owe, also for much help later, a deep sense of gratitude. The optical alignment procedure and the handling of all the elements involved, required the definition and procurement of a considerable number of mounting and handling devices. This was planned and defined by Francis Franza and Paul Giordano last autumn and manufactured with the help of Rainer Grote. Francis and Paul then spent 6 weeks from the beginning of November, without intermission, preparing this material for the following alignment mission. This included the mounting of the prime mirror supports and their testing with Lothar Noethe. As an example of the sort of auxiliary material involved, one can cite the temporary "bridge" over M3 which serves for its mounting but also as support for one of the sighting telescopes used in the alignment.

Then followed a second mission from 10 January, also of 6 weeks without any intermission, for the basic (passive) alignment of the optics of the NTT, carried out by Francis Franza, Paul Giordano and Ray Wilson. The procedure for this alignment was laid down by the above on the basis of a standard procedure used by them on a number of La Silla telescopes, notably the 3.6 m, the Danish 1.54 m, the CAT and, in its final stages, for the MPIA 2.2 m. The NTT alignment procedure was a more refined and complete form, taking account of its alt-az mount and double Nasmyth focus. If one considers certain inevitable problems of control of the telescope, this alignment programme, comprising 56 individual technical steps, represented the absolute maximum achievable in 6 weeks of continuous work. In fact, without the absolutely excellent support from the La Silla colleagues in electronics, mechanics and optics, it would not have been possible in the time. In particular, the continuous superb support of the mechanical workshop must be emphasized as playing a key role in the completion of the heavy work load. This general procedure included the aluminization of the three mirrors, carried out under the supervision of Paul Giordano who has many years of experience in this field. Of course, the biggest task here was the primary aluminization, above all because of the delicate handling procedure involved.

The individual steps of the alignment procedure can be grouped in the following work packages:

- Optical identification of the ALT-axis (basic reference line for the whole alignment).
- Optical identification of the AZ-axis.
- Optical identification of OPT, the line defined as the optical axis of the telescope and which is perpendicular to ALT and traverses the intersection point of ALT and AZ.
- Reduction of the angular error between OPT and AZ and the intersection (coplanarity) error in the knot point of AZ relative to ALT.
- Adjustment of M3 bearing axis to be coincident in angle and position with OPT.
- Mount M2, centre it to OPT, set it perpendicular to OPT and align the focus movement to OPT.
- Remove M1 dummy (counterweight), mount M1 cell (without M1) and centre M1 cell to OPT.
- Insert M3, adjust its tilt in both planes and place its reflecting surface on the intersection of ALT with OPT.
- Mount M1, adjust tilt of the M1 cell to eliminate decentring coma on a natural star ("*Technical* First Light").

The last step above is the final one in the *passive* alignment. In fact, it could not be completed at that stage as the image analyser (our off-line test system called "ANTARES") was not yet available at that time with a CCD detector. At that stage, therefore, no attempt was made to adjust the M1 cell but about ⅔ of the considerable coma (which was normal and expected at this stage without adjustment of the M1 cell) was corrected by a visual inspection of the defocused image and by using the full range available of the M2 x-y movement for fine coma correction. "Technical First Light" was celebrated on 15 February with an image on TV of Jupiter, with modest seeing and at a zenith distance of about 50°.

The Final Effort: Trimming the NTT Optics to the Limit

The final stage of the setting up and optimization of the optics near the zenith was accomplished by the above team and Lothar Noethe in a 16-day mission ending on 23 March. Lothar played the central role as the person responsible for the entire software and image analysis side, following up the work on the 1 m experiment and the acceptance of the optics at the manufacturers, Carl Zeiss.

The first essential step was to get the image analysis working. This was rapidly achieved with no significant problems. Gaetano Andreoni of La Silla became an invaluable member of our team and worked with us the whole time.

The image analysis confirmed immediately the amount of decentring coma we had expected from the previous mission. The Coma3 (decentring coma) coefficient was evaluated from the mean of many measurements as about 12,800 nm or *4.5 arcsec* with zero correction (central position), of the x-y movement of M2. Using the calibration value given by Bernard Delabre from the optical design of the telescope, it could be deduced that the M1 cell had to be tilted by about *2 arcmin* to correct this large coma. This is a measure of the extreme sensitivity of passive telescopes to decentring coma, since this is a quite small angle and well within the mechanical tolerances of the telescope. A maximum of 2,5 mm had to be machined off the flexion bar feet holding the M1 cell in order to achieve this tilt. The biggest problem was to interpret the physical orientation of the coma in the telescope: an error here would have meant the whole operation of lowering the cell and machining the flexion bars would have to be repeated! It was therefore with a feeling of great relief that we saw the confirmation of the orientation when the first image analysis showed that the coma had been reduced to less than one tenth of its original value.

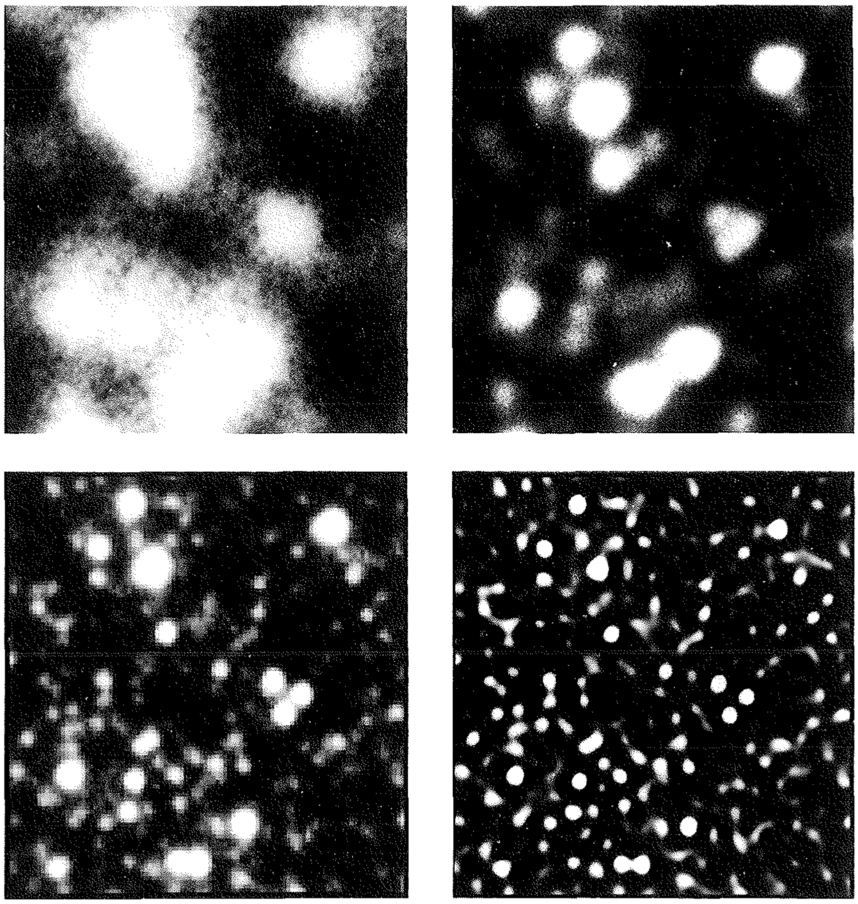
This formally completed the *passive* adjustment of the telescope. It remained to optimize its performance in the zenith by the dc active optics correction, i.e. the correction of residual fixed errors.

The Night of "First Light"

Apart from one effect, the image analysis had brought no surprises. This one effect was a residual of axi-symmetric (spherical) aberration which was some five times larger than the maximum we had expected. Variations of this value could be explained by a hot-air bubble effect on the primary, but a fixed residual of about 0.5 arcsec remained. This exceeded the passive specification. Because its correction absorbed a much larger part of our total active dynamic range than we expected, it proved most convenient to correct using the "natural mode", a system of modal formulation suggested by Noethe and Schneermann for the VLT. In this way, this aberration as well as the other fairly small residuals *were all reduced to values within one tenth of an arcsec, including the residue of coma.* This required the averaging of ten or more measurements. We were helped by the fact that, during the nights leading up to "First Light" on 22–23 March, the external seeing was extremely good.

On 20 March we could already announce that *the "INTRINSIC QUALITY" of the telescope optics (80 % of the light of a star concentrated in about 0.15 arcsec) had already been reached.* This dc modulation of the M1 active support was then introduced into the springs provided and remains now as a fixed

A Revolution in Ground-based Direct-imaging Resolution



These four images illustrate the importance of improving the resolution of astronomical images. They demonstrate the great potential of the ESO New Technology Telescope (NTT), in terms of finer details and fainter limiting magnitude, as compared to other telescopes.

The field shown is near the centre of the bright southern globular cluster ω Centauri. It measures 12 × 12 arcseconds and covers about 1/16 of the area of a CCD frame, obtained with the NTT on the night of "First Light", see the picture on page 1.

The first (upper left) picture is an enlargement of a photographic plate obtained in 1984 with the ESO Schmidt telescope under seeing conditions mediocre by La Silla standards (~ 2 arcsec). The exposure time was 10 min on unsensitized, blue-sensitive IIIa-J emulsion behind a GG 495 filter (spectral range 500 – 540 nm). The original image scale is 67.5 arcsec/mm; i.e. the field shown corresponds to 0.18 × 0.18 mm on the original 30 × 30 cm plate. In other words, about 2.6 million fields of this size are contained on the Schmidt plate.

Next (upper right) follows an excellent photographic plate obtained at the Cassegrain focus of the ESO 3.6 m telescope in 1977. The exposure lasted 6 min 15 sec and the seeing was ~ 1 arcsecond. The emulsion was IIIa-J and no filter was used (spectral range 300–540 nm). The image scale is 7.2 arcsec/mm; on the original 6 × 6 cm plate this field measures 1.7 × 1.7 mm.

A 10 sec unfiltered CCD exposure was made with the NTT at the moment of "First Light" on March 23, 1989; a small part of it is shown here in two versions. The first (lower left) is the "raw" 100 × 100 pixel image (pixel size 0.123 arcseconds). The Full Width at Half Maximum (FWHM), as measured directly on the stellar images in the frame is 0.33 arcseconds. To this value, the NTT optics contributed perhaps 0.15 arcseconds, so that the actual, atmospherically induced seeing may have been better than 0.3 arcseconds, a spectacular value, even by La Silla standards.

At the lower right, the same frame is shown after "sharpening" by advanced image processing. For this, the frame was subjected to deconvolution with a point spread function, which was empirically constructed from 50 profiles of uncontaminated stellar images and at the same time resampled at 1/5 of the pixel size in both directions. The FWHM is now improved to 0.18 arcseconds; the stellar images are noticeably sharper and faint stars are much better visible. To facilitate the comparison, the intensity scale is the same in both NTT frames.

The image processing was made by Dietrich Baade at the ESO MIDAS facility in Garching with an algorithm developed by Leon Lucy. About 3 hours VAX 8600 CPU time was needed to perform 20 iterations; this time can of course be significantly reduced with other computers, optimized for "number-crunching".

The improvement in resolution is dramatic, as illustrated for instance by the triple star, just right of the field centre. The distance between the two components which are closest to each other, is only 0.79 arcseconds. The Schmidt picture does not indicate any multiplicity, the 3.6 m barely resolves the system, while the NTT shows the three components, well detached from each other. Note also the resolution of the double system near the lower border, here the distance is 0.59 arcseconds.

Since the light is better concentrated on the detector, the higher resolution also leads to fainter limiting magnitudes. The 10 second NTT exposure reaches about magnitude 20. A simple extrapolation then predicts that a limiting magnitude well beyond 27 mag may be reached with the NTT within a reasonable exposure time. The actually achievable value will of course also depend on other factors, like the sky background and the accuracy of the tracking.

correction. The *passive* correction of coma had been so accurate that the final *active* correction established only required x, y movements of 0.176 mm and 0.031 mm respectively, only tiny fractions of the nominal range available of ± 5 mm. Although the relatively large value of spherical aberration originally found has been actively fully corrected and therefore does not finally worry us, it is still important to understand its origin. This will be investigated further.

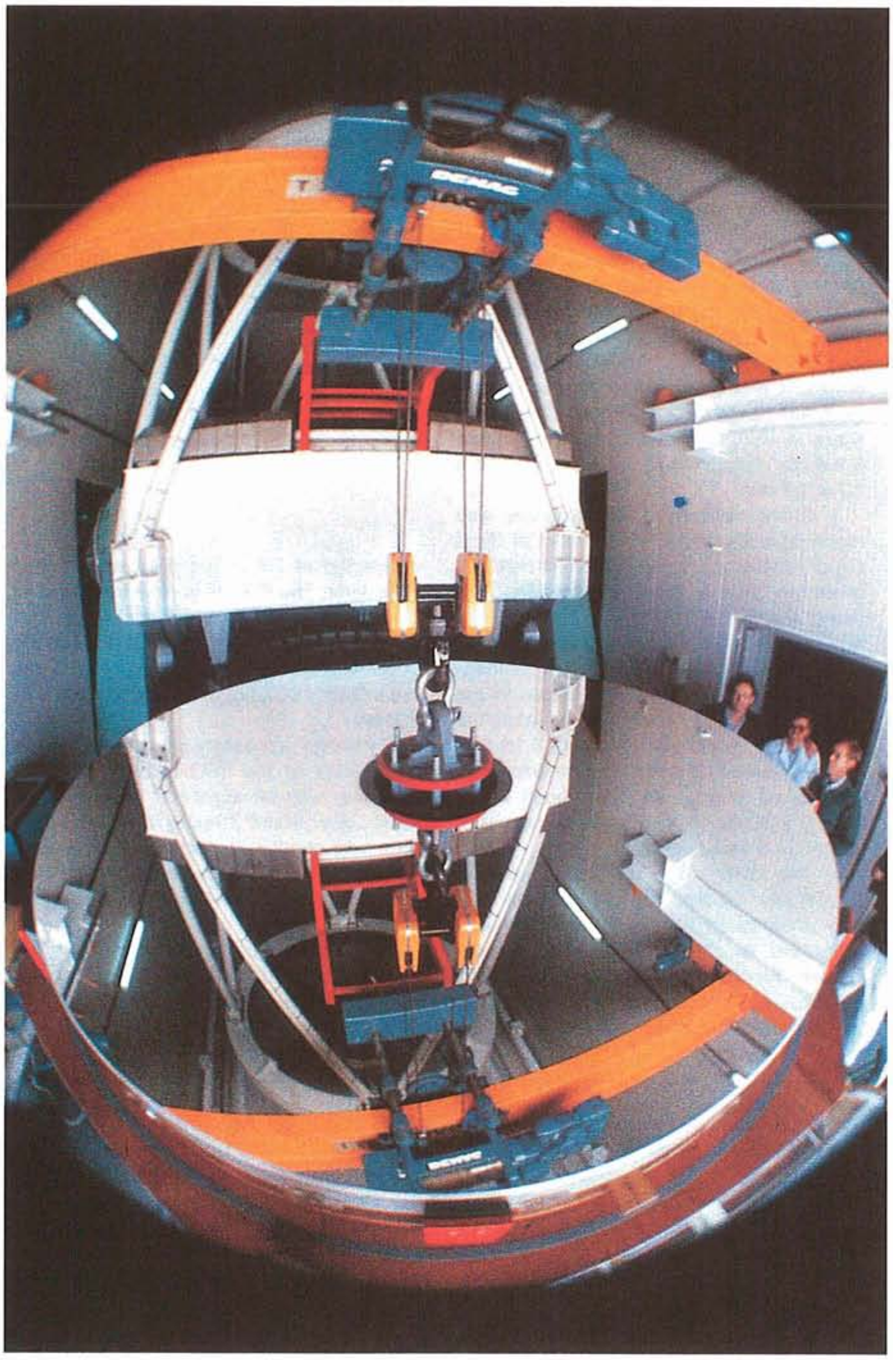
The CCD of the image analyser was dismounted and set up via a 45° mirror directly in the telescope focus. On the evening of 22 March we were ready for "First Light" in the true sense of the first astronomical images with the optimized optical system. The field available with direct imaging on the CCD was only *47 arcsec,* so account had to be taken of this in selecting objects. A further important parameter was the exposure time. A true judgement of the quality of the telescope image always requires an exposure time which integrates out the external seeing. With very good seeing,

ANTARES at the NTT Nasmyth focus; F. Franza and P. Giordano (right) (Photo Ph. Dierickx).

In the NTT control room at the moment of "First Light": R. Wilson (right), L. Noethe (at terminal) and R. Gaetano (foreground).

15 seconds may be sufficient, normally 30 seconds is required as a minimum. On the other hand, the telescope tracking was – inevitably – not yet optimized. Krister Wirenstrand had provided us with excellent support in getting the tracking to a level which was quite sufficient for our image analyses (about 1 arcsec drift in 60 s) but the requirements for direct imaging with very good seeing are far more stringent. Of course, at 21.00 hours we did not know what seeing we would have that night, but the very good seeing of previous nights, as measured by the seeing monitor at Vizcachas, 5 km away, had raised our expectations: it had often given values of 0.7 arcsec, sometimes lower.

Globular clusters were agreed to be the most favourable objects, both from their density of stars and ease of identification, as the pointing model was still in a relatively early stage of development (e.g. no precession correction working). Philippe Dierickx, who had joined us a few days before from Garching, and the author made up a list of possible objects fairly near the zenith from the amateur catalogues of Norton and Burnham. It should be emphasized that the telescope optics had only been optimized *near the zenith* at this stage. The performance at zenith distances of 60° had also been investigated and the quality measured was still 80% energy within about 0.5 arcsec at that inclination, without any supplementary correction. This is a better quality than any other telescope on La Silla at this zenith distance, even after optimum adjustment, but we are certain we can achieve effectively the same quality with the NTT at 60° as near the zenith, i.e. 80% energy within 0.2 arcsec. However, this will require a minor modification of the axial fixed points of the M1 support, so the optimization for the inclined telescope will only take place in July-August. For this reason, it was desirable to limit the



The newly aluminized 3.58 m NTT mirror arrives at the telescope. Photo: H.-M. Hahn.

zenith distance to a maximum of 30°, preferably less. However, *field rotation errors* were worse near the zenith. So it was clear that, at this stage of technical progress on the telescope, there were severe constraints on the position and brightness of suitable objects.

Excellent Seeing!

It soon became clear we were going to have a night of excellent external seeing. By 22.00 hours 0.7 arcsec was reported by Vizcachas (see the article by M. Sarazin on page 8). A number of excellent pictures of various objects were taken. Towards 23.00 hours Vizcachas reported the extraordinary seeing value of *about 0.4 arcsec!* It was already clear that we were privileged to have a night for our First Light of quite exceptional seeing. We were greatly assisted and encouraged by the presence and active help of two astronomers, Jorge Melnick and Sandro D'Odorico, to whom we extend our thanks. The author suggested that we go to the globular cluster *ω Centauri* to get a rich field of stars in a well-known object. The first exposure of 10 s without filter with zenith distance 23° was analysed by Jorge and found to give a FWHM of an arbitrarily chosen star of 0.44 arcsec! An atmosphere of great excitement prevailed: Jorge queried whether the pixel size (23 μm) and telescope scale (187 μm/arcsec) could really be correct? They were! An exposure of the same field in ω Centauri of 60 s was made, using a filter. Jorge deduced FWHM values for 5 stars between 0.42 and 0.36 arcsec! Field rotation effects (slight ellipticity at the upper left, less at the lower right on the screen) were apparent. So it was decided to reduce the exposure for the next picture to *30 s* with a zenith distance of about 18° (the minimum). The seeing was given by Vizcachas as 0.5 arcsec. Jorge measured one image of *0.35 arcsec,* others of 0.39 and 0.42 and expressed his amazement. Clearly, the dome seeing was negligible: a gentle and steady wind blew across the telescope, through the building fully open on both sides.

Shortly afterwards, the pictures taken were transferred to Garching via the satellite link, blocking the computer. There was telephone communication and mutual jubilation at the astonishing results. Our colleagues in Garching were working intensively to process the images, confirming our results. A wonderful spirit of a total team prevailed, separated by 12,000 km in two groups, all rejoicing at the remarkable proof of success of the NTT right from the start at first light.

Some final comments about the quality of these images should be made. With our image analyser and the force sensors on the M1 support, we had complete proof two nights before that the quality of the telescope optics themselves was better than 80% energy in 0.2 arcsec. On the night of first light we knew also from the force measurements that the quality was slightly inferior due to excess loads on the fixed points. This gives a slight triangular effect in the images which can be detected in the deconvolution of the images by Dietrich Baade. Nevertheless, it is unlikely that the quality of the optics was worse than 80% in 0.20 arcsec. *The slight ellipticity of the star images is entirely due to tracking errors (constant over the field) or associated field rotation errors (variable over the field).* It will require a lot more work on the tracking before it is within its specification of 0.1 arcsec rms with 15 min or more integration time. Until this is achieved, tracking errors will be the limitation of the optical quality achievable near the zenith. Also, we repeat, the inclined optical performance has still to be optimized. So, much technical work has still to be done to get the NTT fully within its extremely stringent specification.

A New Era

The real surprise of the First Light pictures was the extraordinary external seeing and the proof that, without optimization of the thermal conditions in the building and telescope, the dome seeing was effectively zero. This finally proved the point we have always made: that it is worth pursuing the goal of virtually diffraction limited quality of the optics (now readily achievable and *maintainable* with active optics) and optimized conditions for dome seeing because the real limits of external seeing have hardly been known or explorable in the past. A new era can start with the NTT and other telescopes using its principles, in which an image quality can be obtained which penetrates into the domain of space optics – but at costs of only a fraction of 1% of those of space optics!

Finally, our grateful thanks again to all those colleagues on La Silla and Garching who helped us achieve these results.

. . . and the View from Garching

During the early weeks of 1989, news about progress with the NTT at La Silla kept circulating through the ESO Headquarters in Garching. Whenever a staff member arrived from La Silla, he was immediately and persistently questioned by colleagues about the latest status. How happy we were to learn in February about the fine results reported by the optical group during the final trimming of the NTT optics!

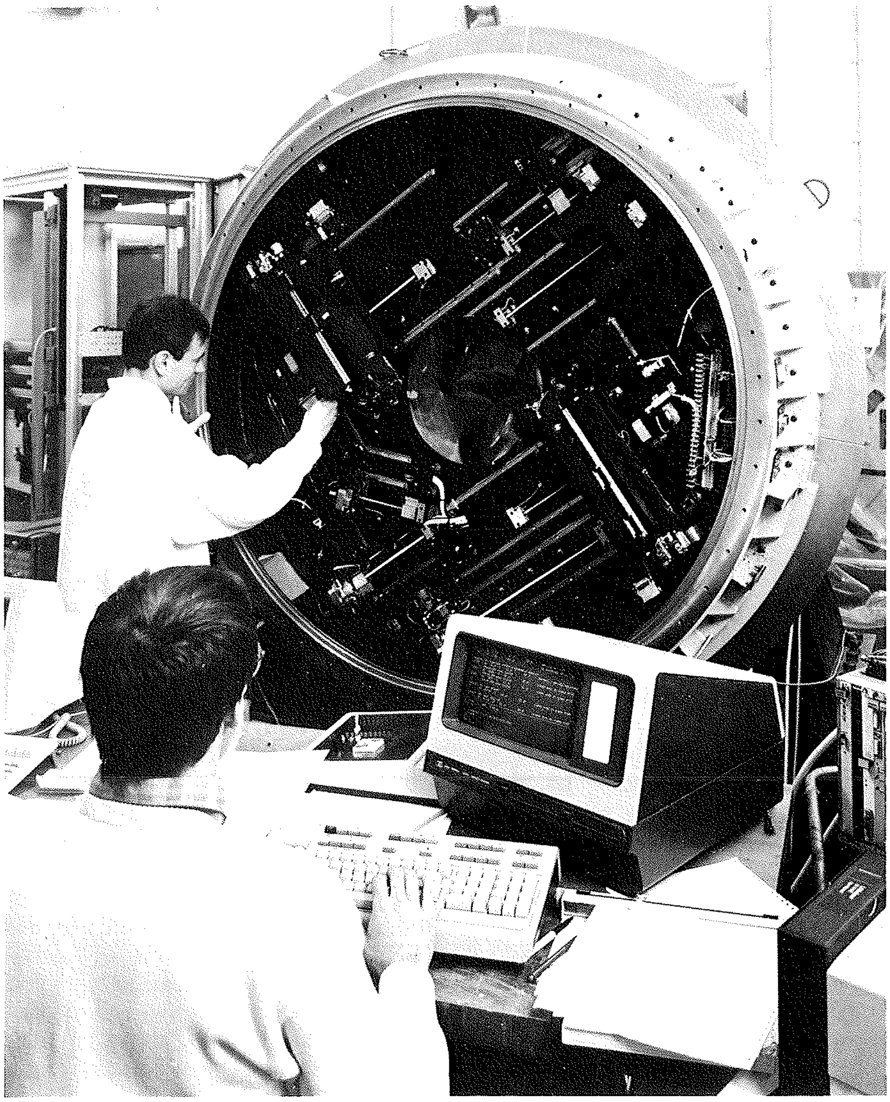
By mid-March we knew that the great moment was rapidly approaching. A Telefax from Ray Wilson informed us that the predicted optical quality was being achieved and that the night of "First Light" was imminent. We talked about the first astronomical pictures and how they would look, and we tried to forget that, even above La Silla, clouds might eventually spoil our hopes.

A Memorable Morning

On March 22, two days before Good Friday, we received the details about the NTT performance, which Ray Wilson has described above. We also learned that during the coming night the first attempt would be made to have "First Light". Would it be possible to obtain reasonably good images and would it perhaps also be possible to transmit them in near-real time to Garching via the permanent satellite link? And quite apart from the astronomical/technological significance of these first images, should we try to inform the world immediately about this important event or should we rather plan a Press Release for the week after?

In the evening that day, we decided to proceed as optimists and to prepare ourselves for the best. Some of the staff members agreed to be on call in the early morning hours. Massimo Tarenghi, Manager of the NTT project, said that he would already be in the Remote Observing Room at 2 o'clock in the morning, i.e. when the night fell at La Silla; the time difference was 5 hours.

Sure enough, there he was, speaking on the telephone with Lothar Noethe in the NTT control room on La Silla, when I arrived just after 3 o'clock. I sensed something unusual in the way they excitedly spoke to each other and then I



One of the two NTT adapter-rotators during integration at Garching in May 1989. Intensive tests on mechanics, electronics and software are going on and the optical integration will be started immediately after reception of the optics. The most optimistic planning foresees the start of the installation on the telescope at the beginning of October.

learned about the exceptional seeing, enabling the NTT optics to be tested to the limit, even at the moment of "'First Light"! It was just too good to be true! When would we get the first images? After some discussion, we agreed over the line that the most important thing would be to secure several good images in Chile, before attempting to transmit any of them to Garching. In this way, the images would be there, even if the complicated transmission process should lead to a crash of the NTT control system. And there we were, sitting, hearing the "Ah's" and "Oh's" 12,000 kilometres away, wishing as never before that we would soon be able to see those fantastic images.

The Images Arrive

Finally, shortly before 6 o'clock in the morning of March 23, Anders Wallander, one of the remote observing operators in Garching, took over the control of the NTT computer via the satellite link and requested it to transmit the first CCD image. At first something did not work, and Massimo later said that I went rather pale. (He never saw himself.) But then it came, and it took us a few minutes to measure the size of the stellar images with the IHAP system. We could not believe our eyes! More frames followed and were immediately written to tape. Preben Grosbøl rushed to the Terminal Room and read them into the MIDAS system on the VAX computer. David Chittim nursed the connected photographic Dicomed facility to incredible performance heights and soon Claus Madsen came with the first negatives from the darkroom. But then Massimo told us that the seeing was improving and even better images were on their way! We threw away an hour's effort and started all over again.

By 8 o'clock that memorable morning, we knew that we had in our hands the sharpest images ever obtained with a large ground-based telescope. Clearly, we should attempt to share them with the rest of the world as soon as possible. There was no longer any question of waiting until after Easter, and all available resources were switched into high gear. Two hours later, Hermann Heyer was ready with most of the 650 photographic copies of the ω Centauri field; equally many photocopies of the rapidly compiled Press Release and figure captions soon came back from Harry Neumann's Xerox machines; Elisabeth Völk was busy with the address labels and the envelopes that had been stamped in record time by Herbert Zodet and Marianne Fischer. And just before 12 o'clock, Hans-Jürgen Kraus delivered the entire lot to the Garching Post Office, less than six hours after the image was first recorded by the NTT at La Silla. Early the following week, European newspapers began reporting about the event, quite a few of them reproduced that famous picture.

The Future

The moment of "First Light" for the ESO NTT signals a new era in observational astronomy and none of those who participated in that exhilarating experience will ever forget the team spirit which permeated the staff on both sides of the link. For the time being, further adjustments are being made by the engineers. And soon it will be time for the astronomers to think seriously about how they can best exploit the exciting new capabilities of the ESO NTT, so dramatically demonstrated that Thursday morning. No doubt they will know how to take full advantage of this beautiful new tool. *R. M. WEST, ESO*

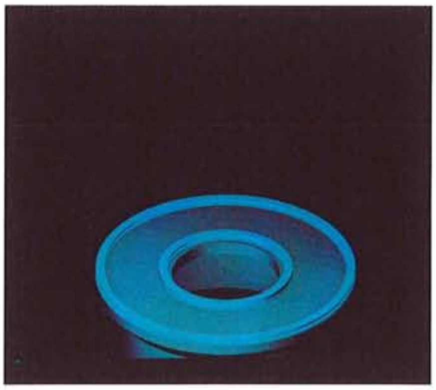
Operating Manuals Now Available

The following updated Operating Manuals have recently become available:

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

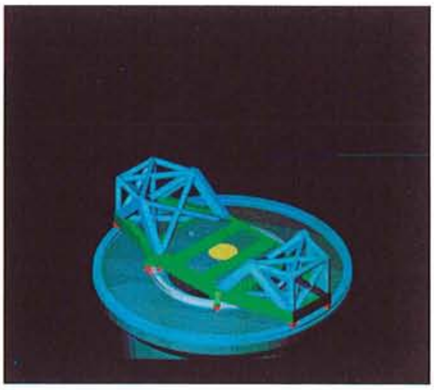
Copies of these manuals can be obtained from Visiting Astronomers' Service, ESO Headquarters, Karl-Schwarzschild-Str. 2, D-8046 Garching bei München, F.R. Germany.

Building the VLT with CAD

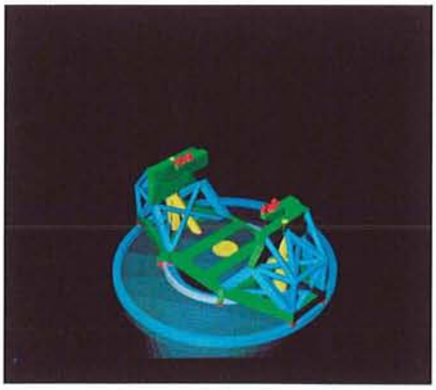


1

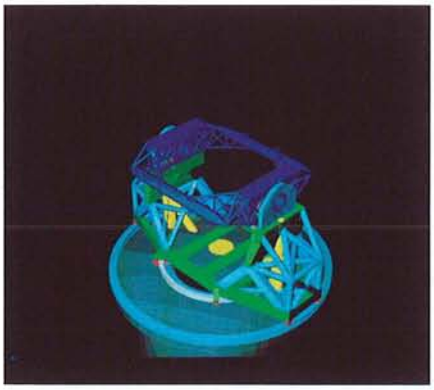
2



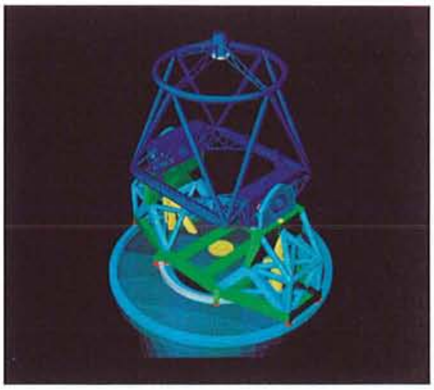
3



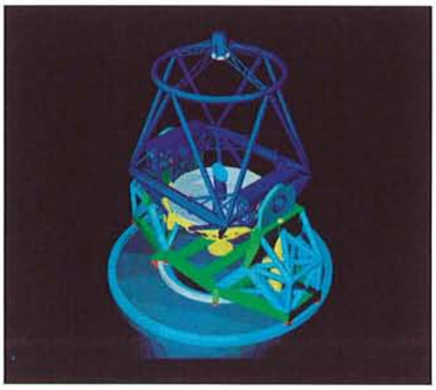
4



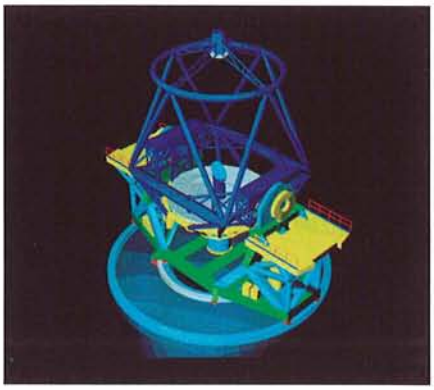
5



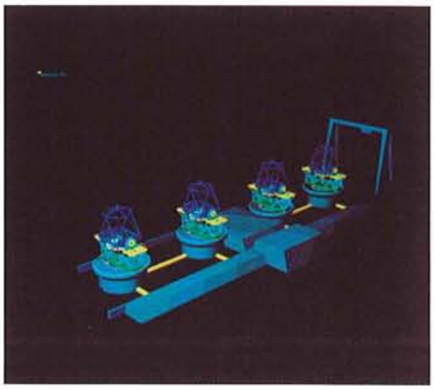
6



7



8



9

The Euclid Computer Aided Design (CAD) system from MATRA-Data, installed at ESO Headquarters, is an indispensable tool for VLT design studies. It also allows to "build" the VLT mechanical structure, as shown on these pictures, of an 8 m unit telescope.

In the first picture, the tracks of the azimuth hydrostatic bearings are shown integrated in the concrete structure of the telescope pillar. The inner track has a main diameter of 9 m and will also be used as a centring device for the telescope structure. The stator of the azimuth linear drive will also be mounted on it. The outer track only provides an axial support to the structure on a mean diameter of 18 m.

In the second picture the base frame of the fork lies on the two tracks, incorporating the azimuth drives and the azimuth hydrostatic pads.

In pictures 3 and 4, the fork is completed with the pedestal tubular structure, the girder box construction – on which the altitude bearings are fixed – and the coudé beam tube.

Picture 5 shows the centrepiece of the telescope tube on its altitude bearings, together with the motors of the altitude direct drives.

In picture 6 the Serurier structure, which holds the top ring with the M2 unit, is mounted on the centrepiece.

In picture 7 the tube is completed with the addition of the M1–M3 unit (cell structure, 8 m primary mirror and Nasmyth mirror).

Picture 8 shows the auxiliary equipment (electronic racks, tanks, banisters), the Nasmyth platforms supporting the instruments, and the Cassegrain facility.

The last picture shows how the VLT 16 m telescope array will look after completion of assembly of the mechanical structures of all four telescopes.

M. QUATTRI and E. BRUNETTO, ESO

Site Evaluation for the VLT: DIMM 3 in Operation

M. SARAZIN, ESO

There has been a lot of activity within the VLT sites' study since our last *Messenger* report [1]. The VLT site group in Chile welcomed new members to face the increasing workload due to the simultaneous operation of three seeing monitoring stations in addition to the measurements of precipitable water vapour and cloud cover survey initiated in 1983.

The main instrument on each site is the Differential Image Motion Monitor (DIMM) described in [2] which delivers the image quality of an equivalent one-minute exposure made at the focus of a large telescope of perfect optical quality. In addition to the DIMM, the altitude distribution of the turbulent layers is estimated using a set of three instruments: a scintillometer, more sensitive to turbulent activity occurring at high altitude, an acoustic sounder (SODAR) for the 30 m to 800 m range, and microthermal sensors for monitoring local effects.

The current study focuses on three candidates and is now entering its ultimate year before the final choice of the VLT site. Here is some miscellaneous information:

DIMM 1, installed in April 1987, is consistently providing confirmation that **Cerro Paranal,** 2664 m, is definitely a sub-arcsecond site, with a yearly 50 percentile FWHM of 0.9 arcsec at 0.5 μm in 1988. The minimum 1-min record was 0.27 arcsec, the seeing was lower than 0.5 arcsec during 5 % of the observing time, while 95 % of the measurements were under 1.6 arcsec.

On **Cerro Vizcachas,** since October 1988, at 2400 m altitude, 6 km south-east of La Silla, DIMM 2 has already earned itself a reputation among visiting astronomers. Thanks to the very good correlation between observing conditions on the two sites, La Silla has become the first astronomical observatory to provide seeing information on line: dial the 4128 from your control room and the Vizcachas operator will give you the current situation and trend. Sorry, no forecast available yet, since seeing meteorology is a brand new science, but there are good hopes that specific numerical models can be developed in the future to adapt the VLT operation to the local observing conditions on the basis of forecasts delivered a few hours in advance.

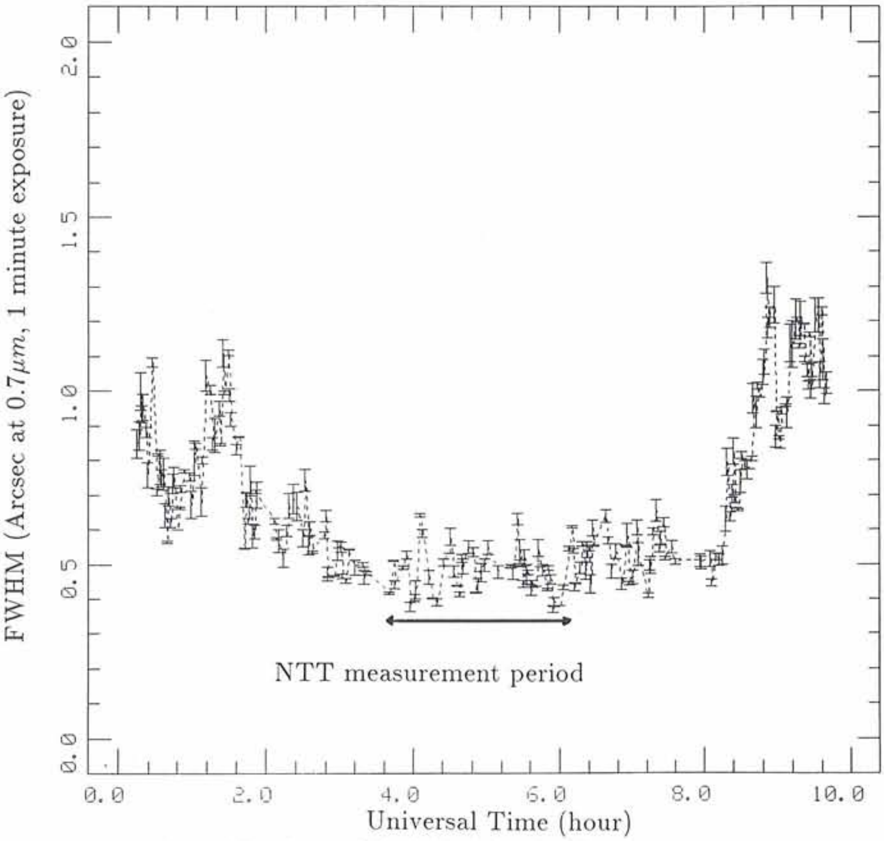


Figure 1: *The seeing at Vizcachas on March 23, during the NTT active optics installation.*

Recent seeing measurements made at the NTT during the installation of active optics confirmed again the excellent correlation of the observing conditions at La Silla and Vizcachas. Figure 1 shows of the DIMM 2 seeing record on March 23, when a 10-second CCD exposure recorded at the NTT showed an impressive full width half maximum of 0.33 arcsec. During the same period, the best 1-minute average seeing measured 5 metre above ground at Vizcachas was 0.37 arcsec at 0.7 μm. For such a low value the DIMM, with a signal-to-noise ratio greater than 5, was still far from its limit. The oscillations seen on the graph correspond to real

IMPORTANT NEWS ON VLT INSTRUMENTATION

A document "ESO VLT Instrumentation Plan: Preliminary Proposal and Call for Responses" will be distributed in June to Institute Directors, libraries and ESO Committee members. It presents a preliminary instrumentation plan for the VLT and outlines possibilities and requirements for the participation of ESO Member State Institutes in its implementation. Responses from the community are invited by November 1989, after which it is intended to finalize this plan and prepare the first Call for Instrument Proposals. A limited number of additional copies will be available from the Project Division (VLT Instrumentation Plan) at ESO.

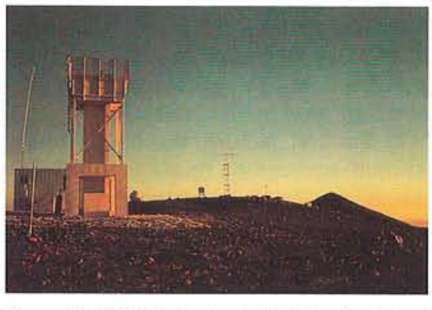


Figure 2: *DIMM 3 tower and control room on Cerro La Montura. The sharp summit of Paranal can be seen in the background.*

atmospheric short-term instability. These are much larger than the DIMM uncertainty given by the vertical error bars (statistical error $< \pm 5\,\%$).

DIMM3 was first used to check the comparability of its two predecessors before being transported to the newly equipped summit of **Cerro la Montura,** 2509 m, 4 km north-east of Paranal, shown on Figure 2. Contrary to Vizcachas and La Silla, those two northern summits present very different wind patterns. This has raised some concern that the lower wind velocity found at La Montura might be traded against an increase of local seeing. Regular measurements started there on April 1 to detect possible differences with the nearby Paranal.

References

1. H. Pedersen et al.: Seeing Measurements with a Differential Image Motion Monitor; *The Messenger* No. 53; September 1988, 8–9.
2. M. Sarazin, F. Roddier: The ESO differential image motion monitor; submitted to *Astron. Astroph.*, Feb. 1989.

The VLT in the Wind Tunnel

L. ZAGO, ESO

Introduction

Increasing evidence collected over recent years has shown that the best local seeing conditions are found when the telescope is exposed to an undisturbed moderate wind flow. This recognition has contributed decisively to direct the design of new telescope buildings towards more open and, incidentally, cheaper solutions than the conventional domes.

The unit telescopes of the VLT are being designed for operation in the open air with a fully openable inflatable dome at present considered for daytime protection. With this concept the wind becomes an important loading condition in the design of the telescope and its effects must be quantified accurately. In order to provide the required data, a series of wind tunnel tests has been performed with models of the VLT unit telescope and its enclosure.

Wind Tunnel Simulation

The basic problem of tests at a reduced scale is that it is seldom possible to scale down all intervening quantities. This is also true for wind tunnel tests where, for instance, it is obviously not possible to scale down the air molecules and gravity. One has to identify the main factors which determine the amplitude of the aerodynamic force for each particular case, then try to simulate those factors as accurately as possible and estimate the corrections due to other parameters which cannot be simulated rigorously.

The aerodynamic force applied on an object is conventionally defined as:

$$F = \frac{1}{2} C_p S \varrho V^2 \qquad (1)$$

with V the flow velocity, ϱ the air density, S a reference surface (generally the exposed cross-section) and C_p an adimensional coefficient mainly dependent on the object shape, but also on the relationship of some flow characteristics to the scale of the object.

In general, the largest part of the aerodynamic force applied on an object depends on the size, number and type of the vortices generated in the wake. For low velocity flows such as atmospheric wind, this wake turbulence, hence C_p, is mainly affected by two parameters: the turbulence already present in the upstream flow and the Reynolds number, which expresses the product of geometry and velocity scales, relative to viscosity.

The first consequence is that, since the atmospheric boundary layer is turbulent, this turbulence must be reproduced in the wind tunnel upstream of the model. This requires special installations, properly called boundary layer wind tunnels, which have a rectangular cross-section and a length sufficient to build up a scaled down atmospheric turbulence upstream of the test model. Even in such wind tunnels, however, it is not possible to achieve a complete Reynolds number similarity: this would require that velocity be increased by the same factor as the geometry scale is reduced, which in many cases would make the flow supersonic. Nonetheless, the C_p of sharp-edged objects is not too dependent on the Reynolds number, so that the measurements are generally accurate enough for most purposes in building engineering, where the objective mostly concerns the determination of ultimate dimensioning loads, to which some safety margin is anyway added.

In the VLT case, the determination of wind loading is required to quantify the "normal" performance of the telescope, hence a greater accuracy is desired than the one achievable in standard tests. Furthermore, the telescope structure is made of round section members, which have a low drag but also a C_p which is quite dependent on the Reynolds number. Therefore, the wind tunnel test measurements on the VLT model had to be complemented and corrected by separate tests of telescope bar elements at both full and model scale. The measurements were then used to calibrate and validate a detailed numerical model of the telescope. In this way, not only the full scale loads on the telescope were evaluated with better accuracy than otherwise achievable, but also further possible design changes of the telescope structure will not need new tests, but just a new run of the numerical model with updated inputs.

Some Results

While it is not the purpose of this article to present all the results of the VLT wind tunnel tests, below are a few examples which illustrate some interesting aspects of this work.

The scale of the VLT model was 1 : 80. Two different enclosure configurations were tested in the wind tunnel, both of which assume an inflatable dome fully open during observations. The first enclosure surrounds the tele-

(a) (b)

Figure 1: *Some of the configurations tested in the wind tunnel: (a) Telescope imbedded in a recess platform. (b) Open platform with the telescope exposed.*

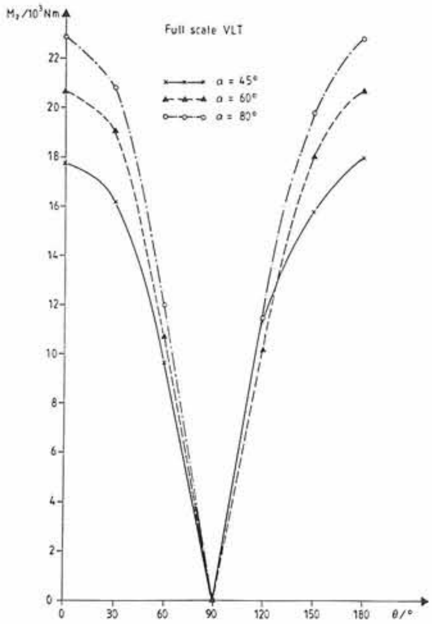


Figure 2: *Full scale altitude torque for the telescope imbedded in the recess platform as function of azimuth angle θ for elevation angles α = 45°, 60° and 80°, with a mean wind speed of 16 m/s.*

scope approximately up to the level of the altitude axis, with the lower part imbedded in a recess. This is at present the preferred solution as it allows control of the wind loading on the primary mirror. The second configuration leaves the telescope fully exposed to the wind and was previously envisaged in conjunction with a linear wind screen, which was also simulated in the wind tunnel.

Static Wind Loading

The most important result concerning static wind loading is the torque about the altitude axis (Fig. 2), which is a main parameter for the design of the drives. The torque about the azimuth axis is, in the worst case, only about half the previous one.

Flow in the Platform Recess

Some tests have provided evidence for a recirculation pattern inside the platform recess (Figs. 3 and 4). This may be very useful in order to ensure a moderate ventilation around the primary mirror. In any case, the final enclosure design will include doors and semi-permeable wind screens integrated in the recess wall which will allow alteration of the flow pattern in order to achieve anything between a very still environment and natural ventilation with ambient air.

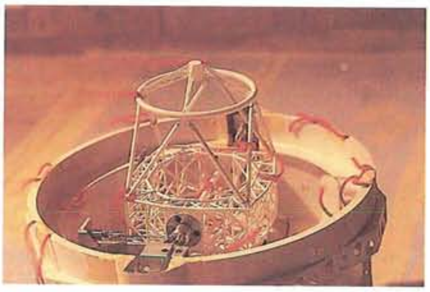


Figure 3: *Flow visualization with wool tufts showing the recirculation pattern in the recess.*

Wind Loading on the Primary Mirror

The wind loading on the primary mirror was measured by means of 32 tiny pressure tubes, which allowed accurate mapping of the distribution of pressure coefficients.

Dynamic Wind Loading

This was one of the most interesting parts of the tests for its implications on the further design of the telescope control systems. In general, the dynamic wind loading can be determined by means of expression (1), considering the wind velocity term as a function of time V(t). Thus the coefficients determined from the static loading measurements can also be used in a dynamic response analysis.

Moreover, two additional parameters are required. The first one is the actual spectral distribution of wind energy on the telescope. The objective of some wind tunnel measurements was indeed to determine the influence of the different enclosure types, since "natural" wind spectra have already been measured on the possible VLT sites. The second dynamic parameter is the

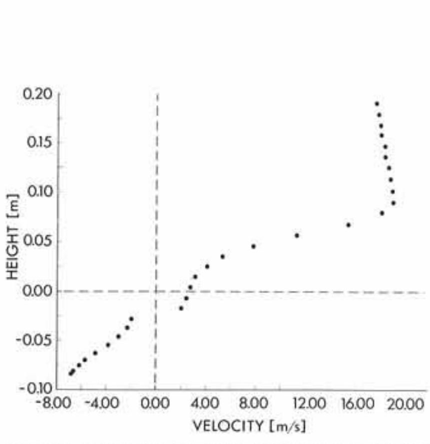


Figure 4: *Mean velocity profile measured just in front of the telescope tube (set vertical). Note that the height is given in the model 1 : 80 scale.*

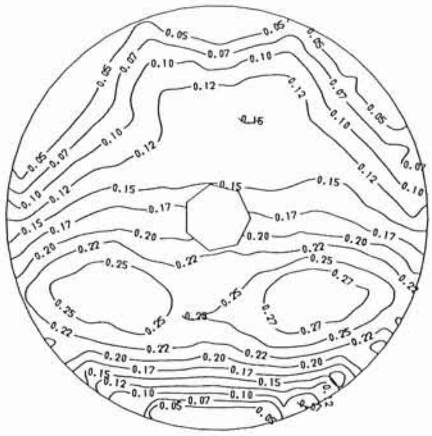


Figure 5: *Contour map of pressure coefficients on the primary mirror for 0° azimuth and 60° elevation. In this case the local pressure coefficients vary between 0.05 and 0.27.*

aerodynamic admittance of the structure, which quantifies the filtering effect of a large structure with respect to high frequency fluctuations.

Acknowledgements

The VLT wind tunnel tests were performed by the Ecole Polytechnique Fédérale of Lausanne, Switzerland, under ESO contract. Special acknowledgement is accorded to the personal contributions of J.-A. Hertig and C. Alexandrou.

References

[1] Zago L.: Latest Studies Lead to Revised Design of the VLT Enclosure, *The Messenger*, No. 52, p. 7.
[2] Hertig J.-A., Alexandrou C., and Zago L.: Wind tunnel tests for the ESO VLT, Proc. ESO Conf. on Very Large Telescopes and their Instrumentation, pp. 867–876, Garching, March 1988.

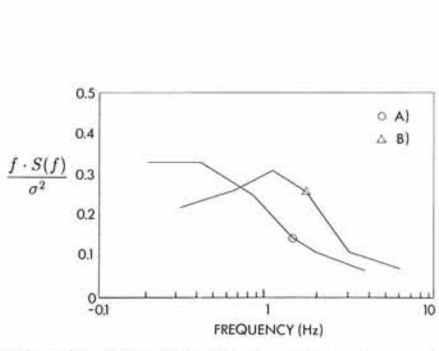
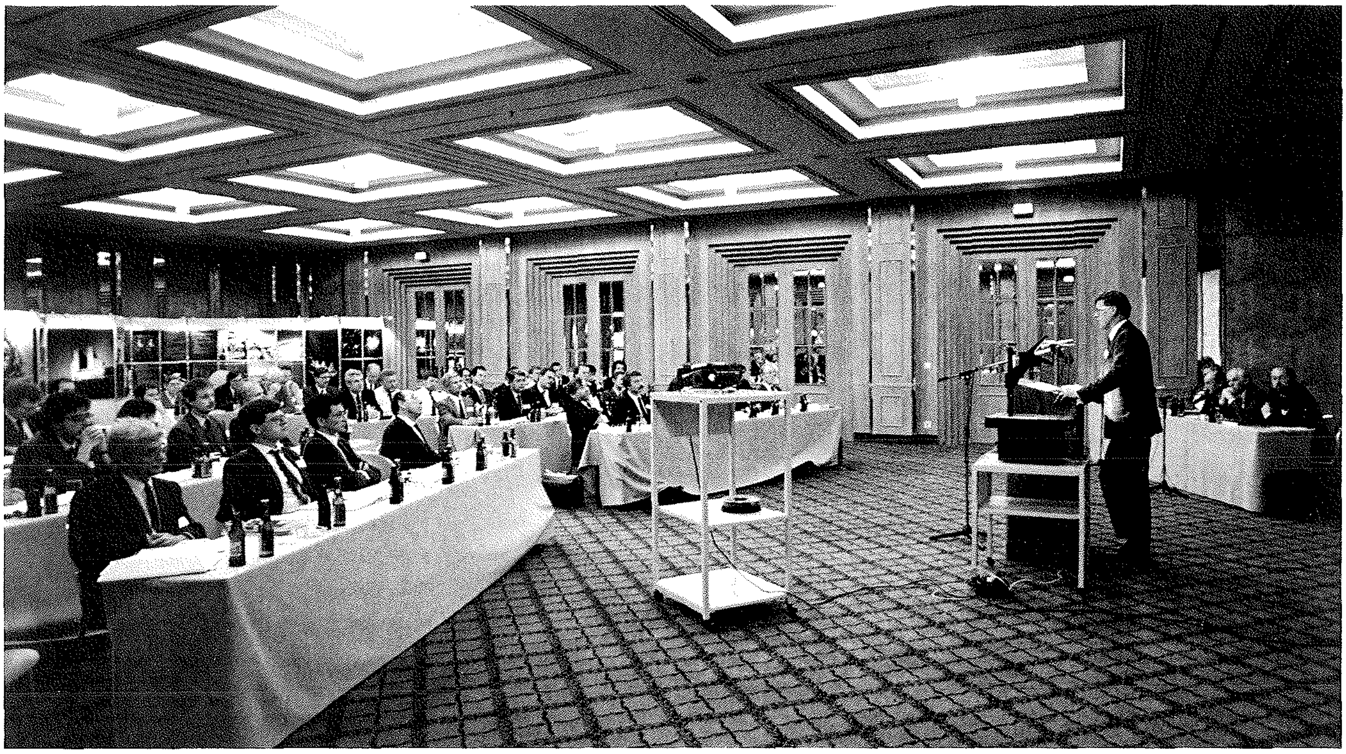


Figure 6: *Wind velocity spectrum measured just in front of the telescope tube B), compared with the one measured at the same location in the empty wind tunnel A). The difference of the two spectra quantifies the turbulence generated by the platform.*

Presentation of the VLT Project to European Industry



The ESO Director General, Professor H. van der Laan, opens the VLT Presentation on April 20, 1989, at the Munich Hilton Hotel.

With the decision by the ESO Council in December 1987 to fund the VLT Project, the Organization was faced with the greatest technological challenge in its 25-year history. All through 1988, ESO engineers and scientists worked to improve upon the initial design, often in collaboration with other academic institutions and frequently with European firms.

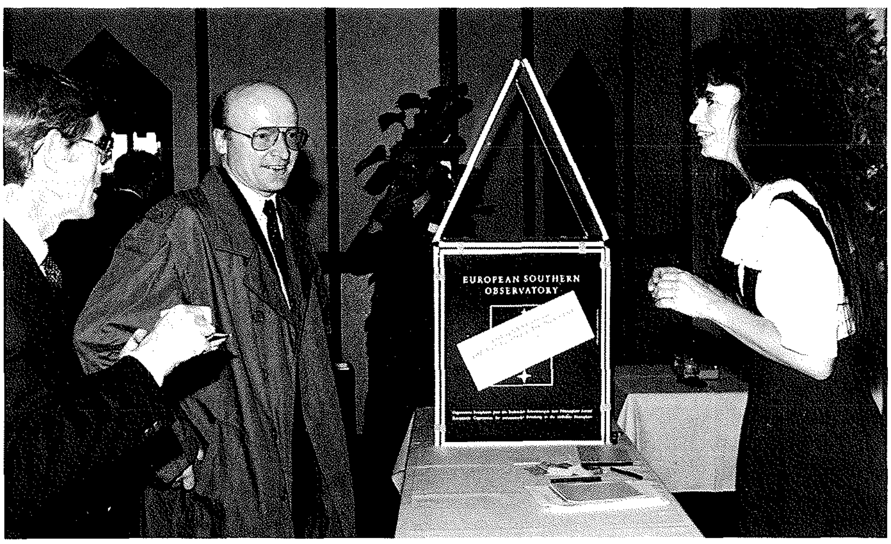
Now, the VLT Project has entered into a new phase, during which most of the industrial contracts will be concluded. In order to fully exploit the technological potential in the member countries, it was felt desirable to give a detailed presentation of the VLT project to interested firms in the ESO member countries. This would enable these firms to prepare themselves to participate in the tendering for VLT contracts. At the same time, personal encounters among their representatives might contribute to the establishment of possible international consortia for the major contract areas.

The VLT presentations to industry, organized by M. Tarenghi, Head of VLT Project Coordination and Control, took place in Munich during four days in late April 1989. They included detailed reviews about the VLT Optics and Optical Systems, the Opto-mechanical Systems, the Large Mechanical Systems, and the Infrastructure, Civil Engineering and Enclosures, respectively. Each day the presentation was opened by the Director General or by Professor Tarenghi, followed by an overall review of the VLT project by the Head of VLT Project Engineering, D. Enard. Details about commercial procedures at ESO were given by R. Fischer, Head of Contracts and Procurement. Then followed reviews of the individual calls for tenders by senior staff members.

The participation by firms from the eight ESO member states was most gratifying; up to about 100 persons were present each day. There were many questions, to which clarifying answers were given. Most of these concerned technical aspects of the VLT project, others aimed at a better understanding of ESO's mode of operation and the way the VLT contracts will be selected.

There is no doubt that these presentations were most useful to all involved. At the end of the fourth day, ESO and European industry had very successfully intensified the collaboration so crucial for the smooth completion of the VLT project.

The editor



Samantha Milligan, Secretary to the VLT Coordination and Control Group, had four busy days during the VLT Presentations. Here she is at the Reception Desk next to Dr. N. Wavre from ETEL S.A. (Switzerland) and ESO optical engineer F. Franza (left).

Complementary Astrophysical Data for Hipparcos Stars

(1) Astrophysical Fundamental Parameters of Early-type Hipparcos Stars

M. GERBALDI, Institut d'Astrophysique, Paris, France
A. GÓMEZ, S. GRENIER, C. TURON, Observatoire de Paris, Meudon, France
R. FARAGGIANA, Università di Trieste, Italy

(2) Radial Velocities of Southern Late-type Hipparcos Stars

M. MAYOR, A. DUQUENNOY, M. GRENON, Observatoire de Genève, Switzerland
C. TURON, F. CRIFO, Observatoire de Paris, Meudon, France
M. IMBERT, E. MAURICE, L. PREVOT, Observatoire de Marseille, France
J. ANDERSEN, B. NORDSTRÖM, Copenhagen University, Denmark
H. LINDGREN, ESO

The Hipparcos Mission: Accurate Astrometric Data for 120,000 Stars

Hipparcos, the satellite of the European Space Agency to be launched in July 1989, is the first satellite ever devoted to global astrometry (Fig. 1). The basic principle of observation is to scan continuously and systematically the whole sky with a telescope capable of measuring the angle between stars separated by a large angle (Fig. 2). The telescope is of Schmidt reflective type, the angles are measured by superimposing – by use of a complex mirror – in the focal plane of the telescope two fields of view separated by a "basic angle" of 58°, each field containing one of the stars in a pair. The satellite is designed to spin slowly, scanning the entire sky by means of the combination of two motions: a spinning rotation around the axis normal to the two lines of sight and a revolution of the spin axis around the satellite-Sun line. The angle between the spin axis and the Sun is 43°.

As the satellite scans the sky, the star light is modulated by a grid consisting of a large number (about 3,000) of regularly spaced opaque and transparent slits and the modulated light is sampled by a detector, an image dissector tube, IDT (Fig. 3). At any one time, about four or five of the programme stars are simultaneously visible in the telescope, but only one star is observed at a time with the small instantaneous field of view (diameter of about 30 arcsec) of the image dissector.

The observing time is distributed among the stars according to their magnitudes. From the phase difference between the modulated signals from two stars (Fig. 3) and the value of the basic angle, it is possible to determine very precisely the angle between the two stars. As the sky is scanned, each programme star will be linked to several others in different directions during the nominal lifetime (2.5 years), allowing to build a dense set of angular distances between stars covering the entire sky. After appropriate reduction of the data, the astrometric parameters: positions, parallaxes and proper motions for the programme stars can be finally obtained.

The satellite attitude is determined by two redundant "star mappers" composed by a small number of slits unequally spaced, some of them being parallel to the main grid and some others being oblique (Fig. 3).

From these considerations it is clear that the programme stars should be evenly distributed over the sky and their magnitude distribution should be compatible with the satellite observing possibilities. The list containing the 120,000 stars to be observed and all the data necessary to satisfy satellite operation is called the Input Catalogue. It has been elaborated by the INCA Consortium, constituted by 26 European Institutes from eight countries (Perryman and Turon, 1989), from the stars of about 200 proposals submitted by the astronomical community and a large stellar sample complete down to a well defined limiting magnitude called the "survey".

The Input Catalogue constitutes the best possible compromise between

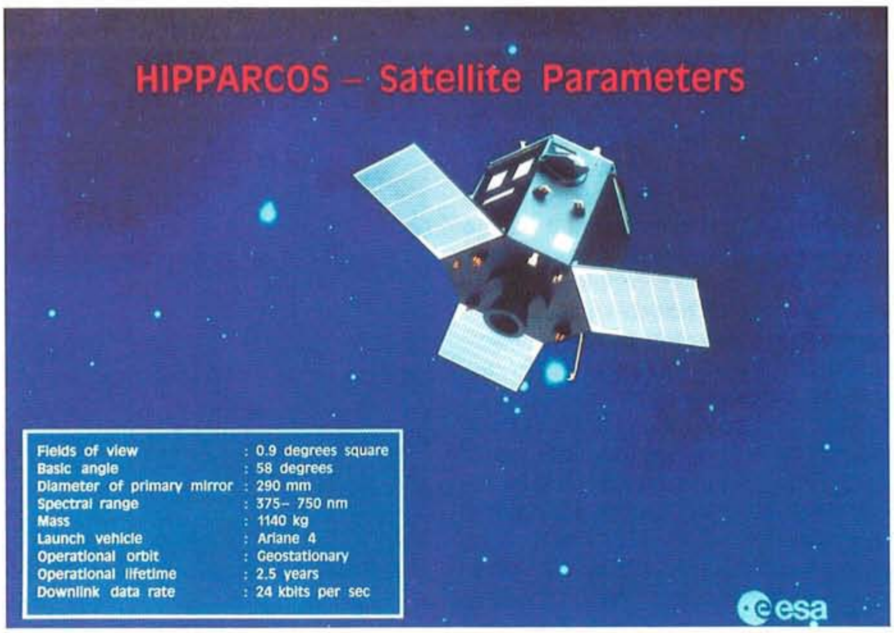


Figure 1.

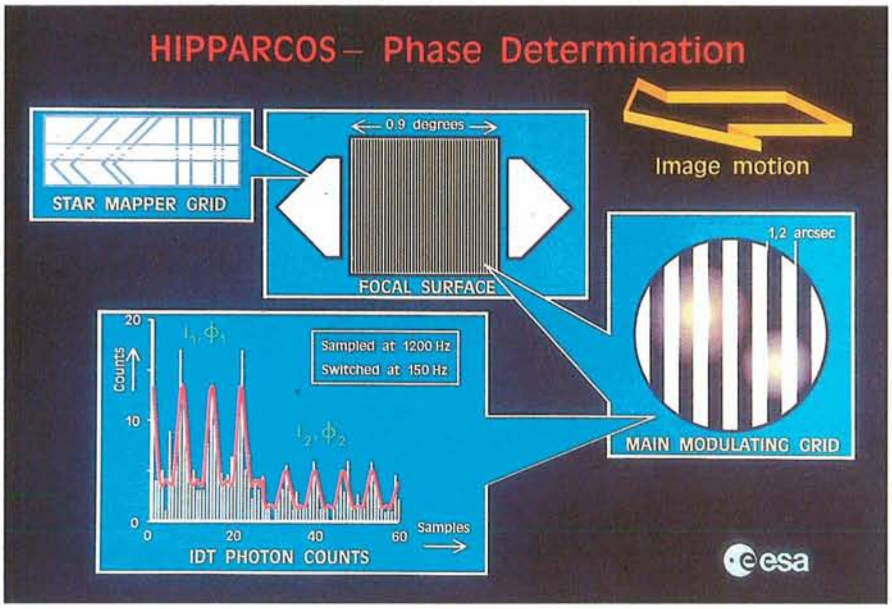


Figure 2.

satellite operation, data reduction requirements, and the scientific objectives of the mission.

The raw data produced by the satellite – consisting essentially of photon counts from the IDT and the stars mappers – will be reduced by two independent European Consortia: FAST and NDAC (Perryman et al., 1989).

Hipparcos will observe stars down to the magnitude B = 12, the accuracy of the main mission results is about 0.002 arcsec on positions and parallaxes, and 0.002 arcsec/yr on proper motions for stars brighter than B = 9 (Perryman and Schuyer, 1985). Trigonometric absolute parallaxes will be obtained up to distances of about 500 pc for a large variety of stars, the relative accuracy will be higher than 20% for about 30,000 stars within a volume of 100 pc around the Sun (Gómez, 1988) (Fig. 4).

Major Progress Expected in the Study of Galactic Stellar Populations

Stellar population studies require the knowledge of many parameters: position, velocity, metallicity, age and mass. The unprecedented quality of Hipparcos parallaxes and proper motions, five to ten times more accurate than the present ones, will lead to major revisions of our knowledge of the galactic and even extragalactic domain.

The Hipparcos programme results from the combination of 200 proposals, having specific scientific goals, with the limited-magnitude "survey" sample. The limiting magnitude of the survey is a function of the stellar colour, fainter for early-type stars, and of the galactic latitude, the aim being a uniform star density over the sky and to select a maximum number of stars for which the ages and distances may be precisely defined.

From distant luminous stars, within about 1000 pc, a precise description of the galactic velocity field, including spiral wave perturbation, will become possible since the proper motions are quasi-absolute and so accurate. The formation of clusters and associations will also be described and their subsequent evolution characterized by the observed internal motions and expansion rates. Birth places of clusters and young stellar objects will also be traced back. In addition to the tangential velocities, accurately obtained from Hipparcos measurements, the availability of radial velocities will allow to reconstruct individual stellar orbits.

Half of the programme stars are formed by the Hipparcos survey where intermediate and old populations dominate heavily. The local velocity field will therefore become extremely well defined statistically. In order to distinguish among the different stellar populations, data like effective temperature, gravity and metallicity are necessary. The relations age-metallicity-kinematics should be clarified, at least in the solar vicinity. The situation is the same for the past rate of star formation.

As the survey is deeper towards the galactic poles, an accurate determination of the velocity field perpendicular to the galactic plane is expected, leading to a new estimate of the local total mass, hidden and visible, of the Galaxy. An important improvement of the luminosity function is foreseen, mainly for the massive stars, but also for the lower main-sequence stars and in the red giant domain. The fine structure of the main-sequence will be described in relation with metallicity and helium abundance.

The possibility of obtaining parallaxes of rare and luminous objects: old stars like RR Lyrae or Mira variables, or young stars as blue or red supergiants, will allow to determine distances to old galactic objects like globular clusters or irregular and spiral galaxies, and to improve, ultimately, our knowledge on the extragalactic distance criteria.

Most astrophysical applications of Hipparcos astrometric results require that parameters like temperature, gravity, metallicity, radial velocity and stellar rotation are made available from ground-based observations with an accuracy consistent with that of Hipparcos.

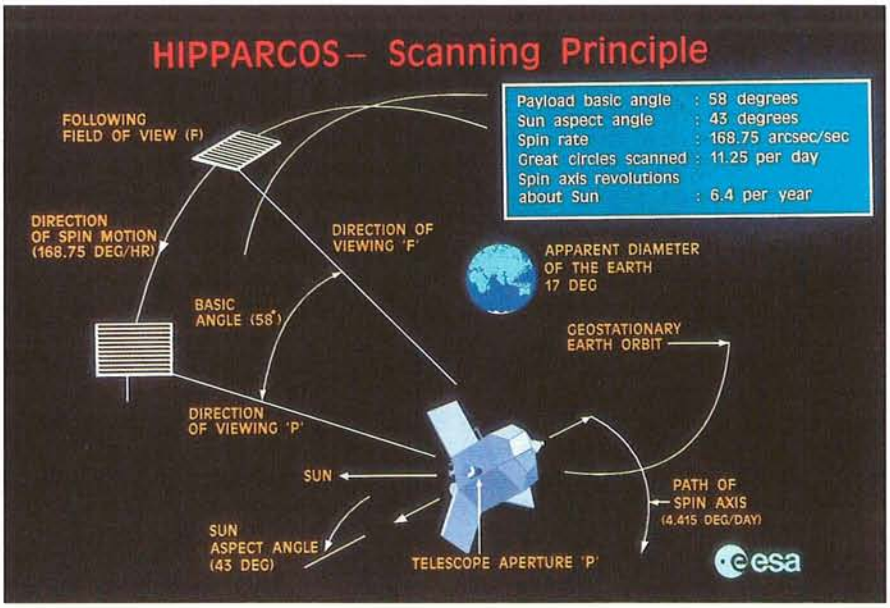


Figure 3.

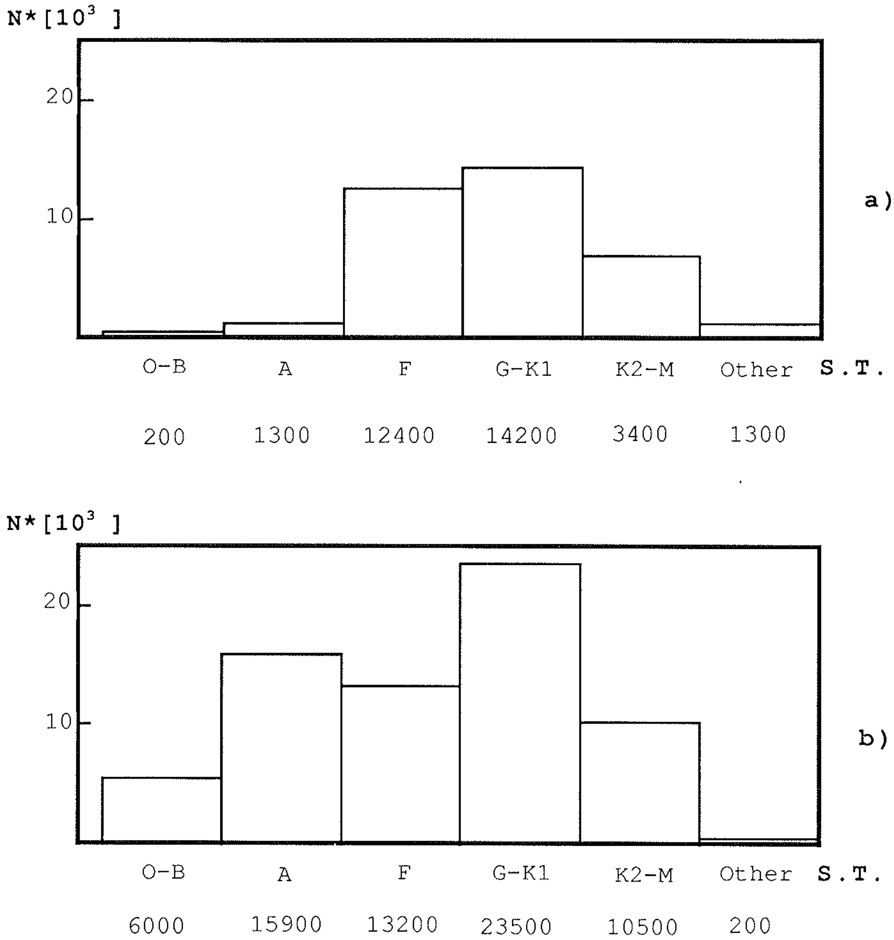


Figure 4: *Number of stars versus spectral type for different ranges of heliocentric distance (r), a) $r \leqslant 100$ pc; b) 100 pc $< r \leqslant 500$ pc.*

The two Key Programmes cover the blue and the red Hipparcos stars respectively; they will allow to obtain basic complementary astrophysical data for the stars in the solar neighbourhood.

Astrophysical Fundamental Parameters for Early-type Southern Stars

About 20,000 southern early-type stars will be observed by Hipparcos, and complementary astrophysical data for this large amount of stars cannot be reasonably obtained from ground-based observations in a five-year period. Moreover, many of these stars present abundances anomalies. In fact, in this area of the HR diagram, a large variety of spectra is found among the A-type stars.

In order to obtain a representative sample of early-type stars, well suited for galactic studies and compatible with the observational possibilities, we have focused our attention on non-chemically peculiar B-, A- and early F-type stars of the southern sky closer than 100 pc (about 1800 stars).

Spectroscopic observations will be performed with the Echelec Spectrograph and the CCD Camera at the 1.5 m ESO telescope, in the spectral range centred at 4500 Å (Hγ). This spectral region is well suited for radial velocity determinations as well as for the determination of $v \sin i$, T_{eff}, log g and metallicity.

Radial velocities will be obtained with an accuracy of the order of 2–3 km/s, the accuracy limit being mostly due to the stellar structure itself.

The sample defined above has been selected from spectral classification which permits to distinguish normal from peculiar stars, but there is a growing evidence that among the so-called normal stars mild peculiarities exist. Even Vega, the prototype of the normal dwarf A0-type star, has recently been suspected to have a non-solar abundance. Mild peculiarities will be detected with these spectroscopic data and the sample of normal stars will be refined. Effective temperatures and gravities in connection with Hipparcos parallaxes will allow to obtain better age determinations. The distribution of $v \sin i$, related to star formation mechanisms, will also be analysed (Ramella et al. 1989).

We gratefully thank ESO for the allocation time to this key programme, allowing to obtain a set of astrophysical parameters of a well-defined sample of early-type Hipparcos stars in the solar vicinity.

Radial Velocities and Rotational Velocities for About 25,000 Red Stars in the Southern Sky

Some 70,000 stars of spectral type later than F5 have been selected to be measured by the Hipparcos satellite. Due to the important percentage of spectroscopic binaries in any star sample, at least two radial velocity measurements separated by two or three years will be necessary. This leads for stars later than F5 alone to some 100,000 radial velocity measurements over the next five years! Such an undertaking would be dispairing with conventional photographic techniques. Thanks to the development by R. Griffin of the photoelectric cross-correlation technique some twenty years ago, this survey now seems possible (Fig. 5).

Different cross-correlation spectrometers are operational, but most are located in the northern hemisphere where a coordinated effort of some of them might allow the determination of radial velocities.

In the southern sky, however, the situation is notably different. There, the CORAVEL spectrometer at La Silla would have to accomplish alone a large fraction of these measurements. In fact, CORAVEL (COrrelation RAdial VELocities) realizes the optical cross-correlation of the stellar spectrum with a template of some 1500 absorption lines (Baranne, Mayor, Poncet, 1979) optimized for late-type stars. If the position of the cross-correlation function is evidently related to the radial velocity, the width at half depth of this function is a fine measurement of line broadening mechanisms. For most of the stars, the width allows a precise determination of $v \sin i$ (Benz, Mayor, 1981). The area of the cross-correlation function is essentially a function of temperature and heavy element abundance (Mayor, 1980) and a straightforward way (almost reddening free) to obtain a metallicity determination (Fig. 6).

In operation since 1981 at the 1.54 m Danish telescope at La Silla, the CORAVEL has shown that accuracies of the order of 0.2 km/s of the velocity, 1 km/s of the $v \sin i$ and 0.15 dex of the heavy element abundance can be achieved. The cross-correlation technique is so sensitive to rotational broadening that only a few stars bluer than F5 can be measured. Conversely, the same template will allow the velocity determination of the latest M stars.

Thanks to the generous allocation of

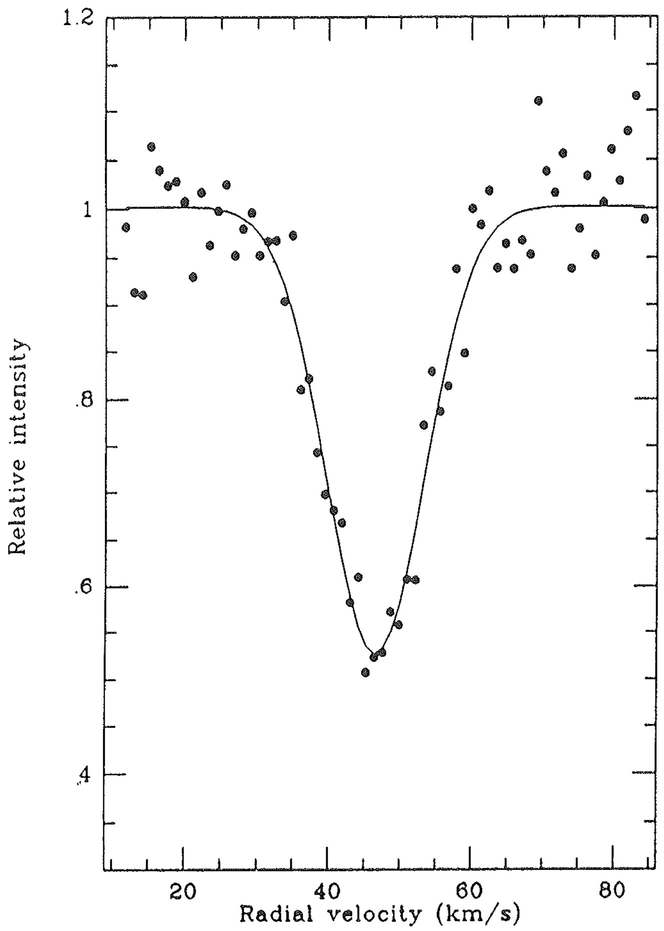


Figure 5: *The cross-correlation dip of a K2 III star of magnitude B = 10.4 after 60 sec of integration. After such a short exposure, the radial velocity uncertainty is about 0.5 km/s.*

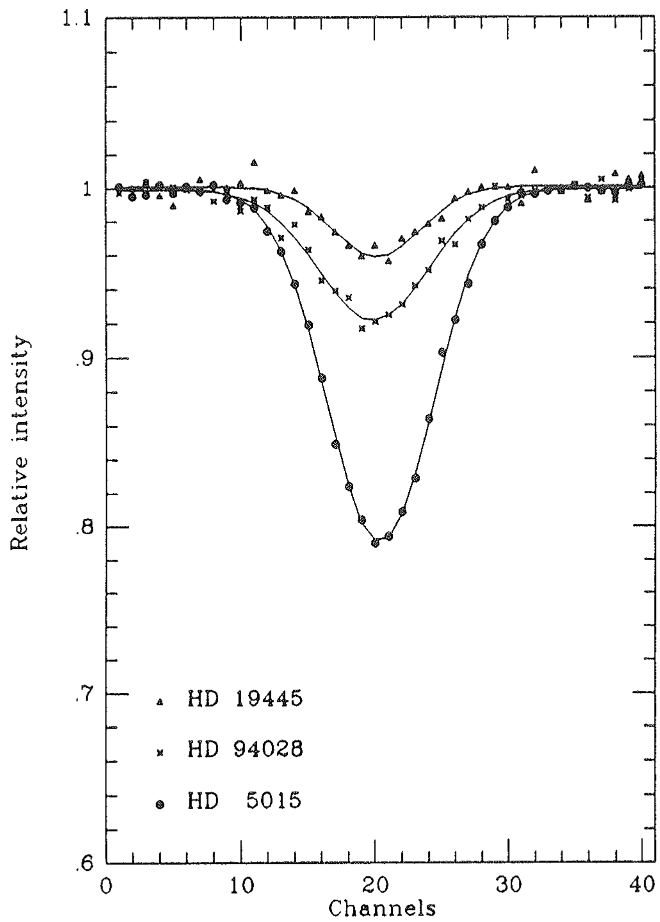


Figure 6: *The cross-correlation dips of three stars having about the same temperature, but quite different metallicities. The (Fe/H) are respectively +0.1, −1.4 and −1.8 for HD 5015, 94028 and 19445. Such a comparison shows the extreme sensitivity of the dip surface with metallicity.*

time by ESO and by the Danish Board for Astronomical Research, we are rather confident that all the red stars in the southern hemisphere of the Hipparcos mission will have known radial velocities in five or six years.

References

Baranne, A., Mayor, M., Poncet, J.L.: 1979, *Vistas in Astronomy* **23,** 279.

Benz, W., Mayor, M.: 1981, *Astron. Astrophys.* **93,** 235.

Gómez, A.: 1988, 2nd Inca Coll. "Hipparcos Scientific Aspects of the Input Catalogue Preparation – II", Sitges, Spain, J. Torra and C. Turon eds. p. 63.

Mayor, M.: 1980, *Astron. Astrophys.* **87,** L1.

Perryman, M.A.C., Lindegren, L., Murray, A.: 1989, "The Data Reductions", Hipparcos Book, vol. III, ESA publication (in press).

Perryman, M.A.C., Turon, C.: 1989, "The Input Catalogue", Hipparcos Book, vol. II, ESA publication (in press).

Perryman, M.A.C., Schuyer, M.: 1985, Coll. "Hipparcos: Scientific Aspects of the Input Catalogue Preparation", Aussois, France, M.A.C. Perryman and C. Turon, eds. p. 13.

Ramella, M., Gerbaldi, M., Faraggiana, R., Bohm, C.: 1989, *Astron. Astrophys.* **209,** 233.

PISCO Modifications

Recently, the software for PISCO has been extensively modified and improved. This has had the following effects:

- reliable on-line reduction
- possibility of hard copy of on-line data
- simplified calibration procedure
- simplified exposure definition form
- various bugs removed

During the night, the on-line results can now also be printed; this is useful for planning the next night's work. On-line reduction now works with the proper Fourier transform method and gives an accurate impression of the data quality obtained. It can be used with or without automatic sky subtraction.

The calibration menu has been simplified and is therefore more user-friendly, as is also the exposure definition form. Finally, some bugs were removed from other parts of the software.

The PISCO Observer's Manual is now available (ESO Operating Manual No. 13).

H.E. SCHWARZ, ESO

Joint ESO/CTIO Workshop in 1990

The European Southern Observatory and Cerro Tololo Interamerican Observatory will hold a joint workshop on "Bulges of Galaxies" in the period January 16–19, 1990, in La Serena, Chile.

The emphasis will be on the interaction between theory and observations of bulges of galaxies. Topics will include: dynamics and kinematics, stellar populations, chemical evolution and the bulge/disk/halo connections. The meeting will be in the form of relatively long invited reviews, shorter contributed papers and posters.

For more information, please contact: H.E. Schwarz, ESO (La Silla), via ESO Headquarters, Karl-Schwarzschild-Str. 2, D-8046 Garching near Munich, Federal Republic of Germany. The E-mail address is: schwarz@dgaeso51.bitnet.

A Study of the Most Distant Radio Galaxies

G. MILEY[1], K. CHAMBERS[2,1], R. HUNSTEAD[4], F. MACCHETTO[2,6], J. ROLAND[3,1], H. ROTTGERING[1] and R. SCHILIZZI[5]

[1] Sterrewacht, Leiden, Netherlands; [2] Space Telescope Science Institute, Baltimore, USA; [3] Institut d'Astrophysique, Paris, France; [4] University of Sydney, Australia; [5] Radiosterrenwacht, Dwingeloo, the Netherlands; [6] Astrophysics Division, Space Sciences Dept., European Space Agency

Background

Galaxies associated with powerful radio sources are amongst the most frequently used cosmological probes, because their enormous radio luminosities enable them to be easily pinpointed out to large distances. During the last thirty years, several groups, notably Hyron Spinrad and his collaborators at Berkeley, have carried out remarkably successful studies using the 3C sample to locate galaxies at high redshifts. These galaxies have been used as standard candles to study both the geometry of the universe and the evolution of stellar populations in galaxies.

Until about two years ago, most of this work was concentrated on objects from the 3C Catalogue, i.e. the strongest known radio sources in the northern sky. Optical identification of this sample is now virtually complete. To extend searches for high-redshift galaxies to a larger number of fainter (and perhaps) more distant radio sources than those in 3C, it is desirable to develop techniques for separating the most promising high-redshift candidates from the tens of thousands of catalogued weaker radio sources. We have developed a method of preselecting these few high-z "needles" from the huge "haystack" of all radio sources. This search method is the basis of our ESO Key Programme.

The technique is based on groundwork laid with the Westerbork radio telescope during the mid-seventies (Tielens, Miley and Willis 1979; Blumenthal and Miley 1979). We use the fact that ultra-steep spectrum radio sources are systematically more luminous than sources having more normal radio spectra. Back in 1960, Dave Heeschen pointed out that a weak correlation existed between the radio spectra and luminosities or redshifts of radio sources. It was found that this correlation was more striking when the fractional identification of radio sources on the sky survey was plotted as a function of radio spectral index (Fig. 1). Reasonable statistics for the steepest spectrum objects (left hand side of the plot) were obtained by measuring radio structures and positions for about fifty 4C sources, selected to be the steepest spectrum ten percentile from the 4C catalogue. Almost all of these extreme objects corresponded to blank fields on the Palomar Sky Survey, in marked contrast to the 40% identification fraction found for sources with "normal" steep radio spectra. It seemed likely that the bulk of the ultra-steep spectrum radio sources were associated with galaxies beyond the plate limits of the Survey at distances which were inaccessible with optical techniques then available.

Two years ago, study of this sample was resumed, stimulated by the revolution in detector technology that had occurred over the preceding decade. It was clear that the leaps in sensitivity in the optical (CCDs), radio (VLA) and infrared (new arrays) regions of the spectrum warranted further work on the ultrasteep spectrum 4C radio sources. The renewed attack commenced while the PI was seconded by the European Space Agency to the Space Telescope Science Institute in Baltimore and therefore was carried out primarily with U.S. telescopes. The project consisted of optical infrared and radio imaging as well as optical spectroscopy; it forms the basis of Ken Chambers' Ph.D. thesis. So far, the most important results are:

(a) Demonstration of the ultra-steep spectrum selection criterion as the most efficient method so far developed for pinpointing galaxies at high redshift. The spectroscopic survey has shown that about half the sample have emission lines and are definitely at redshifts larger than about 0.6. Eight objects in the sample are confirmed identifications with optically extended objects having more than one emission line at $z > 2$, with two galaxies at $z \sim 3.8$ (see Chambers et al. 1988a, 1989 and figures). For comparison, the largest galaxy redshift known one year ago was $z = 1.8$ for 3C 326.1 (McCarthy et al. 1987a).

(b) Establishment of the existence of a population of galaxies at epochs corresponding to $z > 3$, i.e. when the universe was less than 10% of its present age. This opens up an exciting opportunity for studying the properties of the early universe. For the first time we can measure the spatial distribution of brightness and velocity for gas in objects out to at least a redshift of 4, providing unique information about young and forming galaxies. In addition, statistics of the space density of these objects and its redshift dependence is capable of providing considerable leverage on the geometry and evolution of the universe.

(c) Discovery that powerful high-redshift radio galaxies have optical and infrared extensions which are almost exclusively aligned along the axes of their associated radio sources (Chambers et al. 1987). The optical/radio alignment effect was seen independently in a sample of high-redshift 3C radio galaxies by McCarthy et al. 1987b. In exhibiting this alignment effect, powerful high-redshift radio galaxies are unexpectedly different from radio galaxies at low redshifts. This has considerable implications for work which uses powerful radio galaxies as "standard candles" to probe the geometry of the universe.

There is not yet an accepted mechanism for producing the aligned optical/infrared flux. Some powerful constraints are provided by 2.2 micron array observations of 3C368 which suggest that the emission is produced mainly by young stars formed by an interaction of the radio jet with the interstellar medium (Chambers et al. 1988b). However, it is difficult to understand how the necessary $10^9\ M_\odot$ of stars could be formed in such a process.

The success of our search technique and the importance of distant radio galaxies in their own right and as probes of the early universe prompted us to propose a project under the ESO Key programme initiative. The direct objectives of this project are twofold. First we wish to extend the work described above to fainter radio sources and more distant galaxies, thereby increasing the number of identified ultra-high-redshift galaxies by about an order of magnitude. Secondly and more importantly, we shall study the detailed properties of the early-epoch radio galaxies that we detect.

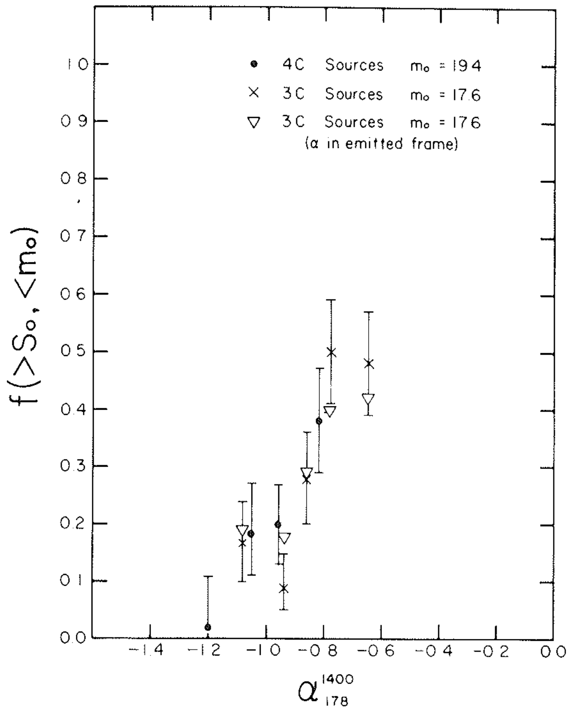


Figure 1: *The fraction of radio sources optically identified on the Palomar Sky Survey plotted against the observed metre-wave radio spectral index (from Blumenthal and Miley, 1979).*

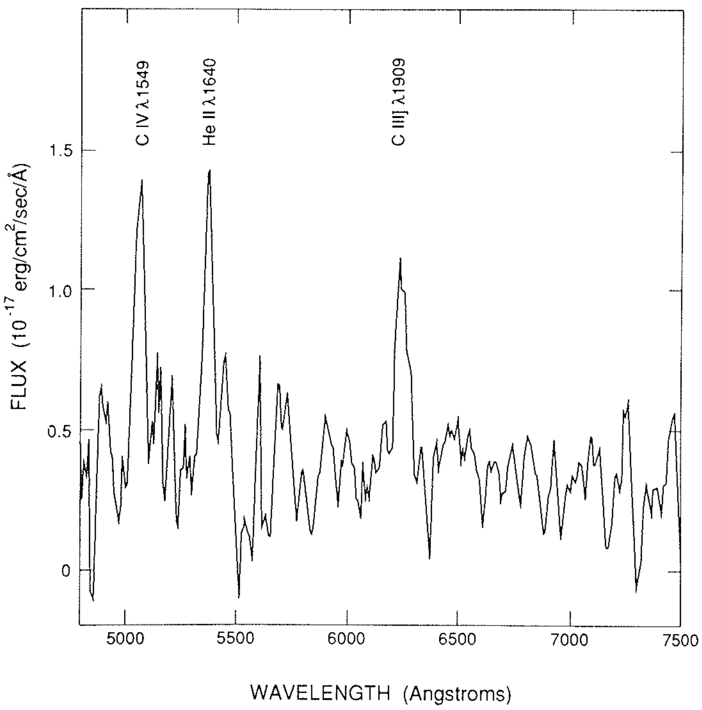


Figure 2: *The spectrum of the radio galaxy 4C 40.36 at a redshift of 2.3 (from Chambers, Miley and van Breugel 1988a).*

Finding More High-z Galaxies

The 4C sample covers less than a third of the sky and includes only the brightest radio sources. It is therefore desirable to apply our search technique to larger and fainter samples of radio sources. Both Lyman alpha emission and radio emission from 4C41.17 could easily be seen if it were at a redshift of 6, above which Lyman alpha would be shifted outside optically observable wavelengths.

To find more $z > 2$ galaxies, we have selected several samples of radio sources known to have definite or suspected ultra-steep radio spectra from the Parkes, Molonglo and Texas surveys. These comprise a total of about 400 objects. The strategy that is being followed in our search for high-z galaxies is the following:

(i) radio observations with the VLA, and Molonglo Synthesis Telescope (MOST) to find which of the suspected sources definitely have ultra-steep spectra and to provide radio structural and positional information which can be used for their optical identifications. Most of these observations have already been carried out and the radio maps have been made.

(ii) an optical and infrared imaging survey of confirmed ultra-steep spectrum objects with the 2.2 m telescope.

(iii) spectroscopic search for emission lines from the high redshift candidates with EFOSC2 on the NTT.

The Nature of the Most Distant Galaxies

Once the high-redshift galaxies have been located, there are several crucial observations which need to be made in order to study the properties and interrelationships of the stars, ionized gas and relativistic plasma in these objects.

So far, the only case for which follow-up work has been analysed is 4C41.17 (Chambers, Miley and van Breugel, 1989). The results are fascinating (see figures). The source was identified with a faint extended optical object whose spectrum showed two emission lines corresponding to Lyman alpha and CIV 1549 at a redshift of 3.8. The extended optical continuum emission (~30 kpc for H_0 = 50 km/s/Mpc and q_0 = 0.5), together with the large equivalent width of the Lyman alpha indicate that 4C41.17 is a galaxy. At z = 3.8 it is the most distant galaxy known. It has a Lyman alpha halo which is extremely bright and extends for more than 20″ (corresponding to more than 100 kpc!). The gas is clumpy and has a turbulent velocity field with a gradient of about 2000 km/s.

Using the new InSb arrays at UKIRT, we have mapped 4C41.17 and several other high-redshift galaxies at 2.2 microns (for 4C41.17 this corresponds closely to optical V-band in its emitted frame). Infrared measurements will be crucial to studying stellar populations in these objects as well as searching for the presence of dust. Moreover, Lilly and Longair (1984) have demonstrated that the infrared "Hubble diagram" for distant radio galaxies has a relatively small dispersion compared with similar plots based on optical data.

Our ESO Key Programme is one part of a multispectral project to investigate the ultrasteep spectrum radio sources and their counterparts in other regions of the spectrum. The following sorts of observations are being proposed or carried out to investigate the nature of the $z > 2$ galaxies: broad and narrow band optical and infrared imaging, low and high resolution optical and infrared slit spectroscopy, optical and infrared polarimetry, deep radio intensity and polarization imaging, VLBI, HI radio spectroscopy and X-ray imaging. Most of these have already obtained observing time allocations.

Questions to be Investigated

The proposed project will be part of a comprehensive multispectral study into the nature of distant radio galaxies. Among the several important questions about evolution and activity in galaxies and about the early universe which we hope to investigate are the following:

1. What is the space density, radio luminosity and radio size functions of high-powered radio galaxies at $z > 2$ and how do these distributions vary with redshift?

2. What are the (optical and infrared) spectral energy distributions and how do they vary across the galaxies? How do the morphologies differ from those of low-redshift radio galaxies and normal giant ellipticals? What do they tell us about the populations (and ages) of the stellar components? This aspect will benefit considerably from the complementary theoretical input to the project by the Institut d'Astrophysique, Paris.

3. How are the morphologies of gas, stars and relativistic plasma related? Are they clumpy? If so, on what scale, and are the clumps related to galaxy formation?

4. What are the dynamical properties of the gas in the $z > 2$ galaxies and what constraints can be placed on the masses of the various components? How do they differ from the dynamical properties of low-redshift radio galaxies and normal giant ellipticals?

5. What is the mechanism for the optical/radio alignment effect? Is the presence of the alignment connected more with the high redshifts of the 4C sample or with their large radio luminosities?

6. How do the properties of intermediate-redshift radio galaxies differ from the properties of nonactive galaxies in the same clusters? Are additional galaxies detectable close to our $z > 2$ galaxies? Neighbours might be expected if our objects are located in forming clusters or in regions of the universe which are preferentially conducive to galaxy formation.

This Key Programme can be expected to produce a large body of data about the epoch at which galaxies are believed to be forming. Although we can speculate about questions, these results will contribute to answering; it is the serendipitous observations that often produce the most fundamental advances in astronomy. With this in mind, we embark on this programme on the lookout for the unexpected and in the hope that our observations will pose new problems which as yet cannot be envisaged.

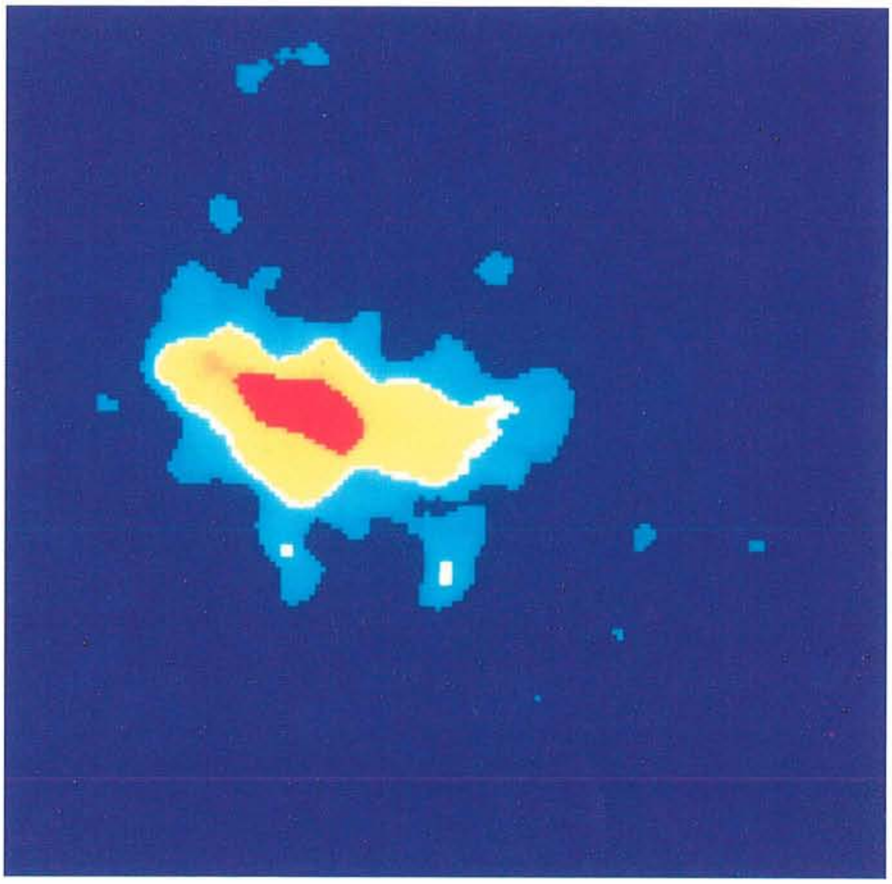


Figure 3: *Lyman alpha picture of 4C41.17 at a redshift of 3.8 (from Chambers, Miley and van Breugel 1989).*

References

Blumenthal, G., Miley, G.: 1979, *Astronomy and Astrophysics* **80,** 13.

Chambers, K.C., Miley, G.K., van Breugel, W.: 1987 *Nature* **329,** 604.

Chambers, K.C., Miley, G.K., van Breugel, W.: 1988a *Astrophys. J.* (Letters) 327, L47.

Chambers, K.C., Miley, G.K., Joyce, R.R.: 1988b, *Astrophys. J.* (Letters) **329,** L75.

Chambers, K.C., Miley, G.K., van Breugel, W.: 1989, Submitted to *Astrophys. J.*

Lilly, S.J., Longair, M.S.: 1984, *Monthly Notices Royal Astron. Soc.* **211,** 833.

McCarthy, P., et al.: 1987a, *Astrophys. J.* (Letters), **319,** L39.

McCarthy, P.J., Van Breugel, W., Spinrad, H., Djorgovski, S.: 1987, *Astrophys. J.* (Letters), **321,** L29.

Pelletier, G., Roland, J.: 1988, *Astron. Astrophys.* **196,** 71.

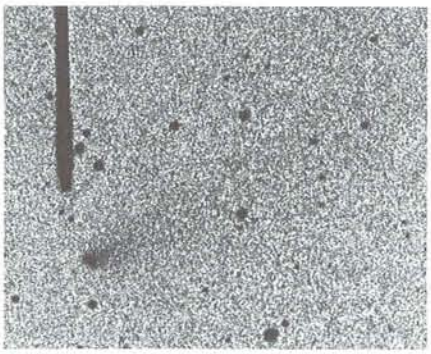
Roland, J., Véron, P., Stannard, D., Muxlow, T.: 1982, *Astron. Astrophys.* **116,** 60.

Tielens, Miley, Willis: 1979, *Astronomy and Astrophysics Suppl.* **35,** p. 153.

P/West-Hartley (1989k)

On May 11, 1989, Richard M. West at the ESO Headquarters found a new comet on a photographic plate obtained on March 14 by Guido Pizarro with the 1 m Schmidt at La Silla. This picture is a photographically enhanced reproduction from the 60 min blue-sensitive plate. The comet's head of magnitude 17.5 is seen as a short trail due to the motion during the exposure. The very faint, broad tail measures about 4 arcminutes. The dark, vertical line in the upper left part is an artificial edge mark on the plate.

Since only a single plate was available, it was not possible to determine the direction of motion with certainty. However, on May 28, Malcolm Hartley accidentally discovered a comet on a plate taken by S.M. Hughes with the U.K. Schmidt, about 15° West-South-West of the sky field shown on the photo. It was quickly realized that this object was identical with the comet seen earlier by West. A preliminary orbital computation by Brian Marsden of the IAU Central Bureau for Astronomical Telegrams indicates that it moves in an elliptical orbit with a period of about 7.5 years. It passed its perihelion in early



October 1988 at a heliocentric distance of about 318 million kilometres.

PROFILE OF A KEY PROGRAMME

A Search for Dark Matter in Elliptical Galaxies

G. BERTIN[1], F. BERTOLA[2], L. M. BUSON[3], I. J. DANZIGER[4], H. DEJONGHE[5], E. M. SADLER[6], R. P. SAGLIA[1], M. VIETRI[7], P. T. DE ZEEUW[8], W. W. ZEILINGER[2,]*

[1] Scuola Normale Superiore, Pisa, Italy; [2] Dipartimento di Astronomia, Padova, Italy; [3] Osservatorio Astronomico, Padova, Italy; [4] ESO; [5] Observatorium, R. U. G., Gent, Belgium; [6] Anglo-Australian Observatory, Epping, Australia; [7] Osservatorio Astronomico, Roma, Italy; [8] California Institute of Technology, Pasadena, USA

One of the most remarkable discoveries of recent years is that of the presence of extended dark massive halos around spiral galaxies (see e.g. Rubin 1986). For these galaxies, the overall mass distribution is inferred from rotation curves derived from both ionized gas and atomic hydrogen emission. The best evidence for dark matter comes from the fact that the rotation curves remain flat, well beyond the optical disk. This result implies that the mass-to-light ratio M/L increases outwards, indicating a substantial amount of dark matter at large radii. A well-known case is NGC 3198, where the observed H I rotation curve is flat out to 11 exponential scale lengths h; here even the conservative maximum-disk analysis requires a dark to luminous mass ratio $M_D/M_L \approx 0.8$ at R_{25} and $M_D/M_L \approx 3.9$ at the outer edge (R = 11 h) (van Albada et al. 1985). The cosmological consequences of this result have been widely discussed in the context of the problem of the "missing mass" in the universe.

To date, the evidence for dark matter in elliptical galaxies is fragmentary, and not nearly as compelling as it is for spiral galaxies. The reasons for this are twofold. Spiral galaxies are thought to be circular disks, so their intrinsic shape follows immediately from the apparent flattening on the plane of the sky. Furthermore, these galaxies contain large amounts of H I, which is an excellent kinematic tracer of the mass distribution. By contrast, elliptical galaxies are thought to be triaxial, which complicates the determination of the intrinsic shape considerably. Furthermore, only very few ellipticals with significant amounts of cold gas are known, and emission lines are generally inconspicuous. As a result, a number of studies have employed other kinematic tracers. X-ray emission has often been taken to indicate the presence of large amounts of dark matter around elliptical galaxies (e.g., Fabian et al. 1986), although this interpretation is still subject to discussion (Canizares, Fabbiano and Trinchieri 1987). Further evidence has been provided by Dressler (1979), who noted that in some cD galaxies the stellar velocity dispersion increases outwards, out to very low surface brightness levels ($\approx$24 mag arcsec^{-2} in B). The kinematics of the globular cluster system of M87 is consistent with an M/L that increases with radius (Mould, Oke and Nemec 1987). The same conclusion is reached for NGC 5128 (Cen A), on the basis of radial velocity measurements of planetary nebulae in the halo of this galaxy (Ford et al. 1989). The large intrinsic velocity dispersions of the above-mentioned kinematic tracers make it difficult to draw firm conclusions regarding the behaviour of M/L. It is therefore not surprising that perhaps the strongest indication for an increase of M/L outwards comes from the few cases where an H I disk with a flat rotation curve has been detected (e.g., Raimond et al. 1981), as well as from the recent observations of an H I ring around the elliptical galaxy IC 2006 (Schweizer, van Gorkom and Seitzer 1989).

The aim of our key project is to establish on firm grounds the mass distribution in elliptical galaxies. We plan to investigate the two-dimensional velocity fields of the gaseous disks seen in a number of ellipticals, as well as the behaviour of the stellar velocity dispersion profile out to large radii. The results are expected to have important consequences for our understanding of galactic structure and of the processes of galaxy formation. In addition, specific constraints on the distribution of dark matter are expected to bear on the problem of its composition and thus to have significant cosmological implications.

Ellipticals with Gas Disks

Disks of ionized gas have been detected in a number of elliptical galaxies. This material is thought to have been acquired from the outside (Bertola, Galletta and Zeilinger 1985; Bertola and Bettoni 1988; Bertola, Buson and Zeilinger 1988), and in many cases will have settled in one of a few possible preferred planes. If the galaxy is triaxial, and has a non-rotating figure, the gas settles in the plane perpendicular to the long axis of the system, or in the plane perpendicular to the short axis, and moves in orbits that are approximately elliptic, and are elongated along the minor or intermediate axis, respectively. If the galaxy has a rotating figure, the preferred planes generally do not coincide with the principal symmetry planes of the galaxy (Merritt and de Zeeuw, 1983; Steiman-Cameron and Durisen 1982, 1988).

In order to derive the mass distribution of the elliptical galaxy (and therefore the trend of M/L), one needs to determine the axial ratios of the galaxy and the angles θ and Φ giving its orientation with respect to the line of sight. These quantities can be evaluated by imposing the following observational constraints (de Zeeuw and Franx 1989): ellipticity ε of the stellar body (direct imaging), axial ratio of the gaseous disk (Hα imaging), angle between isophotal major axis and rotation axis of the gaseous disk (study of the two-dimensional gas velocity field) and position angle of the inner disk's major axis (Hα imaging).

Once the shape and the orientation of the galaxy has been determined it is possible to evaluate the deviations from circular motions introduced by a triaxial potential (Gerhard and Vietri 1986; de Zeeuw and Franx 1989). Bertola et al. (1989) have done this for the E3 galaxy NGC 5077, which has an emission line gas disk with measured gas velocities along 7 position angles. These authors show that the available data are consistent with a triaxial model with a constant M/L over the modest radial extent of the observations. In particular, the slow rise of the rotation curve in the inner parts of the galaxy is shown to be due to the specific orientation at which this galaxy is observed.

As part of the key project, we will apply this same analysis to a sample of elliptical galaxies, so that we cover a wide range of viewing angles θ and Φ,

* Affiliated to the Astrophysics Division of the Space Science Department of ESA

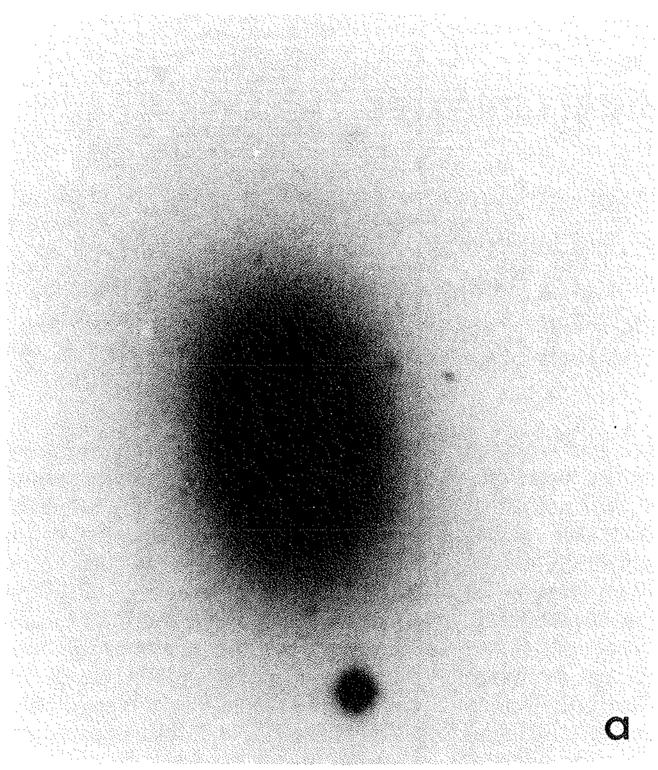


Figure 1 a: *A continuum image of the E galaxy NGC 5077, which reveals the distribution of the stellar component (N-top, E-left). A surrounding swarm of globular clusters is just visible.*

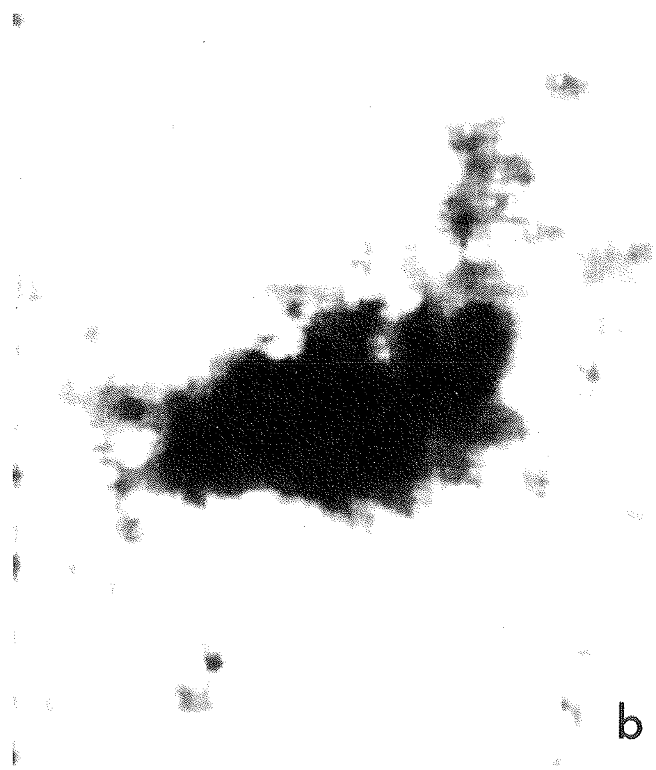


Figure 1 b: *An Hα image of NGC 5077 showing the tilted plane of the ionized gas with its apparent major axis lying almost orthogonal to the apparent major axis of the stars.*

and hence view the elliptic closed orbits at different angles.

Stellar Velocity Dispersions

Concentrated stellar dynamical models constructed under simple physical prescriptions turn out to be well fitted by an $R^{1/4}$ luminosity profile when a constant M/L ratio is assumed. One simple family of models (f_∞-models) has been tested in great detail on a survey of bright elliptical galaxies with available kinematical and photometric data (Bertin, Saglia and Stiavelli 1988a); it has been found to give excellent fits to the data and has provided (global) measurements of the M/L ratio, typically of order 10. These results tend to support the view that elliptical galaxies can effectively be described as one-component systems and that dark matter is either absent or distributed as the luminous matter. However, they rely on kinematical information that is quite restricted in radius or subject to sizeable errors. Therefore it is important to improve our knowledge of the kinematics of the stars in elliptical galaxies, and this can be done in three different ways:

(a) Measure the stellar velocity dispersion at $R \sim R_e$ with significantly reduced error bars;

(b) Extend the radial range ($R \sim 1-2\,R_e$) of the velocity dispersion profile;

(c) Extend the radial range ($R \sim 1-2\,R_e$) of the mean motion (rotation) data.

Evidently, these observations are not easy, and will require a substantial amount of telescope time.

Most likely such improved kinematical data will be in contrast with the expectations of the simple one-component models described above. If they turn out to be consistent with those expectations (i.e. low velocity dispersion and insignificant rotation) we may safely propose that in elliptical galaxies dark matter, if present, closely follows the distribution of the stars, at least out to the largest radius sampled by our kinematical data. Thus a "negative", result would actually offer the possibility to make a strong statement on the structure of ellipticals.

If rotation is found to be dynamically important in the outer parts, we would have to face the issue of constructing models that are "pressure" supported inside and "rotation" supported outside, in the presence of the ubiquitous $R^{1/4}$ profile. Very little has been done on this subject so far. These observations would stimulate interesting theoretical developments.

The second point of "failure" for the simple one-component models described above may derive from the velocity dispersion profile $\sigma(R)$ [see (a) and (b) above] which may be found to be flatter than expected. In this case we may have the best evidence of dark matter being distributed differently from the luminous matter. If we now assume that a dark component is indeed present, but with a more diffuse and extended density distribution than that of the luminous component, for a wide class of self-consistent models a relation can be obtained that gives the amount of dark matter enclosed in the sphere where kinematical information is available. This relation does not depend on the specific choice of distribution functions, provided pressure anisotropy is not unusual and mean motions of the stars are dynamically insignificant.

Since reasonable distribution functions have been found to have the $R^{1/4}$ law as a built-in property in the absence of dark matter, it would be important to show to what extent and under which conditions the presence of an "external field" due to dark matter can leave the luminosity profile *essentially unaltered;* this has been found to occur when the dark component is sufficiently diffuse (Bertin, Saglia and Stiavelli 1988b). Self-consistency is often responsible for subtle effects that go beyond the intuition provided by superposition. One thus has to develop a feeling for the mutual interactions of two spherical components by a direct (numerical) survey of a wide set of self-consistent two-component models (Saglia 1989). This study provides a valuable theoretical framework for the interpretation of the observational data that will be obtained on the basis of (a) and (b).

References

van Albada, T.S., Bahcall, J.N., Begeman, K., Sancisi, R., 1985: *Astroph. J.,* **295,** 305.
van Albada, T.S., Sancisi, R., 1986: *Phil. Trans. R. Soc.* London A **320,** 447.
Bertin, G., Saglia, R.P., Stiavelli, M., 1988a: *Astroph. J.,* **330,** 78.
Bertin, G., Saglia, R.P., Stiavelli, M., 1988b, in: *Astronomy, Cosmology and Fundamental Physics* (Proceedings of the Third ESO-CERN Symposium, Bologna, May 1988) Reidel Publ. Co., Dordrecht, Ed. G. Giacomelli.
Bertola, F., Bettoni, D., 1988: *Astrophys. J.,* **329,** 102.
Bertola, F., Bettoni, D., Danziger, I.J., Sadler, E.M., Sparke, L.S., de Zeeuw, P.T., 1989: *preprint.*
Bertola, F., Buson, L.M., Zeilinger, W.W., 1988: *Nature,* **335,** 705.
Bertola, F., Galletta, G., Zeilinger, W.W., 1985: *Astroph. J.,* **292,** L51.
Canizares, C., Fabbiano, G., Trinchieri, G., 1987: *Astroph. J.,* **312,** 503.
Dressler, A., 1979: *Astroph. J.,* **231,** 657.
Fabian, A.C., Thomas, P.A., Fall, S.M., White, R.E., 1986: *M.N.R.A.S.,* **221,** 1049.
Ford, H.C., Hui, X., Freeman, K.C., Dopita, M.A., Meatheringham, S.J., Ciardullo, R., Jacoby, G.H., 1989: *preprint.*
Gerhard, O.E., Vietri, M., 1986: *M.N.R.A.S.,* **223,** 377.
Merritt, D.R., de Zeeuw, P.T., 1983: *Astroph. J.* Letters, **267,** L23.
Mould, J.R., Oke, J.B., Nemec, J.M., 1987: *Astron. J.* **92,** 53.
Raimond, E., Faber, S.M., Gallagher III, S.J., Knapp, G.R., 1981: *Astrophys. J.,* **246,** 708.
Rubin, V.C., 1986, in: *Highlights of Astronomy* **7,** 27.
Saglia, R.P., 1989: *Ph. D. thesis,* in preparation.
Schweizer, F., van Gorkom, J.H., Seitzer, P., 1989: *Astroph. J.,* **338,** 770.
Steiman-Cameron, T.Y., Durisen, R.H., 1982: *Astrophys. J.,* **263,** L51.
Steiman-Cameron, T.Y., Durisen, R.H., 1988: *Astrophys. J.,* **325,** 26.
de Zeeuw, T., Franx, M., 1988: *Astrophys. J.,* submitted.

ESO'S EARLY HISTORY, 1953–1975

III. 26 May 1964: ESO Chooses La Silla*

A. BLAAUW, Kapteyn Laboratory, Groningen, the Netherlands

"Fehrenbach und ich haben den Eindruck, daß der Berg ein großer Glücksfall ist."
From a letter of O. Heckmann to J.H. Oort of April 21, 1964.

In the course of the year 1962, towards the end of the site testing in South Africa, ESO became actively interested in the possibilities offered by the Andes Mountains in South America. After several years of exploration from American side, the Andes had been opened up for astronomy.

Jürgen Stock's Early Explorations

Among the first who explored the Andes was G.P. Kuiper of the University of Chicago, who examined in March 1959 the area from Antofagasta southward, mostly from the air with the help of the U.S. Air Force [1]. But fully involved in the tests over the years was Jürgen Stock. Stock received his degree in astronomy with Heckmann at Hamburg, and had subsequently been associated with the Boyden Observatory in South Africa. Through his education as an astronomer, his knowledge of the Spanish language, and a sense for pioneering in the almost inaccessible Andes Mountains, Stock became the explorer par excellence for AURA's project. His remarkable reports on the early AURA activities should be read by everyone who wishes to get an idea of what it meant, to conquer the Andes for astronomy [2].

Stock organized in April 1959, as a member of the staff of the University of Texas, a site survey initiated by the Universities of Chile, Chicago and Texas [3]. This was initially meant only for finding a good site for a 150 cm telescope in the vicinity of Santiago, but the survey grew in importance when it appeared that outstanding conditions might be found farther northward. As a result of Kuiper's move to the University of Arizona in 1960, AURA, supported by NSF, took over the management of the "Chile Project" from the University of Chicago [4]. On November 23, 1962 the AURA Site Survey Team chose Cerro Tololo as the site for the Observatory, a decision ratified by the AURA Executive Committee on December 1, 1962.

For the measurement of image quality Stock used a criterion different from that applied by ESO. Instead of going by the appearance of the diffraction image as observed with the Danjon telescopes, image motion was used: the rapid, erratic displacement of the stellar image. In the earlier deliberations of ESO this method had been contemplated – Couder suggested it early in 1954 [5] – but not chosen because it required much higher stability of the telescope mounting. Stock used a double beam telescope which measured the relative motion of images in the superimposed fields of two telescopes fixed on one mounting, of 10 cm aperture and 165 cm beam separation [6].

ESO's Growing Interest in the Andes

News on the promising results of the American tests reached European astronomers, first bit by bit, then more impressively. The minutes of the May 1959 meeting of the ESO Committee, referring to the work in the Santiago area still read: *"This project will have little influence on the development of ESO."* But soon after, interest grew rapidly, and the June 1961 meeting decided to send an experienced ESO observer to Chile with one of the Danjon telescopes used in South Africa.

Naturally, the possibility of finding a site better than those considered so far in South Africa, was exciting news. But there was also something else: a certain apprehension about South Africa's future due to the growing unrest in this country. Thus, a letter of April 1960 by Danjon to Oort contains this paragraph: *"Il règne une certaine inquiétude en France au sujet de l'Afrique du Sud, mais je m'efforce de la conjurer en expliquant que le projet ESO n'est pas nécessairement lié à l'Afrique – – –",* and in his reply of May 10, 1960, Oort writes *"En vue des difficultés que vous signalez pour la France, difficultés qui existeront aussi dans d'autres pays, et en vue du fait que les Américains ont récemment obtenu des indications favorables pour les emplacements dans*

* Articles I and II appeared in *Messenger* **54** (December 1988) and **55** (March 1989).

le Chili, il faudra envisager sérieusement la possibilité d'un changement radical vis-à-vis de l'endroit de notre observatoire." Yet, a letter by Danjon to Oort of the 31st of that same month ends with: *"Je me contente de vous informer que la situation politique en Afrique du Sud n'est pas considérée ici comme une objection."* [7]. A discussion of the political aspects of the ESO enterprise at the EC meeting of July 1960 confirmed this view. Political concern, although undeniable over the years of ESO's activities in South Africa, never became the dominant element in the considerations with regard to the choice of the site; the decision eventually made was a clear-cut one, based on the superiority of the South American findings.

About the time of the above correspondence, on April 28, 1960, Oort, as Chairman of the EC, wrote to his friend C. D. Shane, Director of Lick Observatory (and serving at that time as acting Director of Kitt Peak Observatory), asking for information on the South American results. From Shane's reply, of May 6, 1960, I quote the following:

"– – – There is every indication that the climatic conditions in the neighbourhood of Vicuña are superior to those farther south. – – – I believe if the ESO Committee is interested we could cooperate in the matter of the site survey to the advantage of both groups. Also, if a suitable mountain top should be found satisfactory to all concerned and if the top area were large enough, perhaps all three observatories [Shane refers here to AURA, ESO and CARSO] could be located there with, of course, a division of the area into distinct parts for administrative purposes. If this could not be done, the next best thing would be to locate the ESO and the American observatories on mountains not too far separated so that there could be easy communications and joint meetings for the interchange of ideas. I hope you will call me for any assistance I can render to the ESO project." [8].

The November 1961 meeting of the ESO Committee pursued the idea of participating in the American site testing and also expressed the wish for one or more of the Committee members to visit Chile.

Muller and McSharry Join Stock's Group

After preparatory correspondence in June and July 1962 between Blaauw as Secretary of the ESO Committee and Stock [9], two members of the ESO site testing team joined Stock's group: the team's supervisor, A. B. Muller, and P. McSharry, both experienced observers. They arrived in Chile late November. A stay of about two months was foreseen for the purpose of establishing the correlation between observations made with the Danjon telescope and those done by AURA. It did not aim at testing other mountains than those covered by Stock.

Muller and McSharry, with the support of Stock's group, worked on two mountains: first, from December 6 to 19 on La Peineta, just over 3000 m high in the neighbourhood of Copiapo and about 300 km north of La Serena; next, on Cerro Tololo, the AURA site, from December 30 to January 13, 1963. The mountains are marked on the map on page 25. For both, meteorological observations had been made over a longer period by Stock's group, so that it was possible to arrive at some general conclusions, among which:

– Temperature fluctuations during the night were extremely small, much smaller than on the South African sites;

– Image quality was better than in South Africa: very good and constant on La Peineta and good on Tololo;

– Long spells of clear weather appeared to be a common feature of the climate in the Andes whereas they were rare in South Africa;

– Photometric quality was very good on both mountains.

Muller submitted a report on the two-month work at the February 1963 meeting of the ESO Committee [10]. Impressed by the report, it discussed in some detail the implications: living conditions, construction costs, price levels, etc. in Chile, and the possible relation to AURA. The EC decided to send a small group from among its members to Chile for further investigation.

At this point, the reader should remember that meanwhile, effective the 1st of November 1962, Otto Heckmann had become ESO's provisional Director. We shall return to this appointment in the next article dealing with the general administrative set-up of ESO after the Convention had been signed. In the present context it is important to note that from early 1963 Heckmann more and more took ESO's developments in hand.

The June 1963 AURA-ESO Summit Meeting in Chile

The mission to Chile planned in the February 1963 meeting of the EC took place in June 1963. Participants were: J. H. Oort (Chairman of the ESO Committee), O. Heckmann (ESO's Director), Ch. Fehrenbach (Chairman of the Instrumentation Committee), H. Siedentopf (Chairman of the Site Selection Committee) and A. B. Muller (Superintendent of the ESO activities in Chile). Also came to Chile F. K. Edmondson (President of AURA), N. U. Mayall (Director of Kitt Peak Observatory), and J. Stock, who by that time had become Director of Cerro Tololo Inter-American Observatory. On June 6 the two groups met in Santiago and visited the Chilean Observatory on Cerro Calan near the city, and next proceeded to the La Serena area. Heckmann had arrived in Chile earlier than the other ESO officials for contacts with government departments, the universities, ambassadors, building firms, etc.

On June 8, they undertook the trip on horseback to Tololo, where most of June 9 was spent for inspection of the AURA site. From there, both groups went on June 10 to the neighbouring mountain Morado on the AURA territory, south of Tololo; it was AURA's suggestion that this mountain, with its large surface and well tested, favourable observing conditions, might offer a suitable location for the ESO Observatory. This time, most of the trip was done per helicopter of the Chilean Air Force so that on Morado ample time was left for a summit meeting – in the double sense of the word. Principal subject of the discussion was the possible relation between the AURA and ESO projects in case ESO should decide to settle here, and a first draft for a possible agreement was prepared. Items further to be worked out were: arrangements to be made for road construction and maintenance, water supply, taking care of mining rights possibly to be claimed by third parties, co-ordination of personnel matters, etc. The remainder of Heckmann's stay in Chile served for extending his relations with Chilean authorities.

A fairly detailed report on the Chile mission, compiled by the ESO Directorate was send to the members of the ESO Committee [11]. Attached to this report are copies of letters expressing the interest of the Chilean Ministry of Foreign Affairs, the report of the visit of Heckmann and Oort to the President of the Senate of Chile, and a summary of the comparison of the climatic conditions in South Africa and Chile as discussed at the Summit Meeting on Morado on June 10. Also attached is the text of the Draft Agreement between ESO and AURA drawn up on June 6 and 9, 1963, and an excerpt of the Chilean Law in favour of international enterprises.

Follow-up on the Summit Meeting

A meeting of the EC followed right after the return of the mission in Europe, on July 23 and 24, 1963. It instructed the Director of ESO to approach the

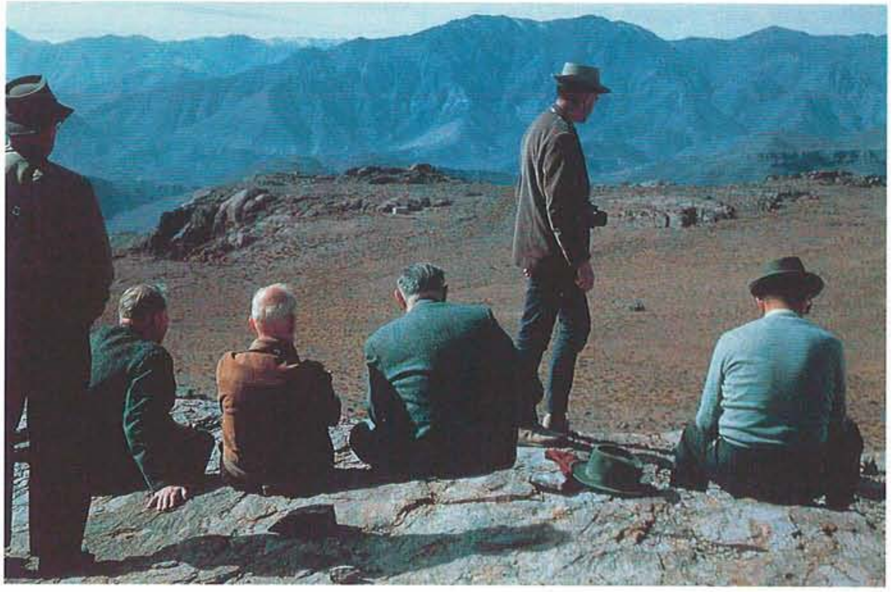
Chilean government concerning the conditions which would have to be fulfilled in order to make it possible for ESO to go to Chile, and negotiations with AURA should be pursued.

On AURA side, its President F.K. Edmondson had informed the Director of the National Science Foundation (NSF), the sponsoring organization for AURA, on the developing relation with ESO. He received approval of a resolution adopted by the Executive Committee of AURA on June 28 stating that AURA, having dedicated itself to the development of astronomy in the Southern Hemisphere, including observations made by South American astronomers and those from other countries, welcomed "the interest of the European Southern Observatory (ESO) in establishing an observatory in Chile, and in particular on the land which AURA had recently acquired. – – –", and authorized AURA's President to enter into negotiations with ESO. Edmondson communicated this to Oort in a letter of August 20, 1963, which was acknowledged by Oort per letter of August 23 [12]. Immediately following these letters, Heckmann in correspondence with Edmondson sketched a number of first measures to be taken in order that already in 1964 ESO's 1-m Photometric Telescope might be erected on Morado [13].

The talks with AURA were continued on October 11 and 12, 1963, when Heckmann visited Tucson. As in the account of this meeting we perceive divergences of concepts which would eventually lead to separate establishments, I shall report on it in some detail. Participants in the discussions on the part of AURA were its President, F.K. Edmondson; R. Wildt, Chairman of the AURA Scientific Committee; N.U. Mayall, Director of Kitt Peak Observatory; and J. Stock [14].

All present considered close relationship between AURA and ESO mutually advantageous. Central theme was ESO's strong interest in Morado, and immediately connected with this was the question whether ESO might lease or purchase the land. Heckmann rather persistently expressed ESO's strong preference for purchase, a desire that, within ESO, stemmed particularly from the side of the governments. This desire, however, met with considerable reluctance on the part of AURA, a reluctance inspired by the policy of NSF.

In addition to this, there was an element that appeared to be new to AURA: for the agreement to be concluded with Chile, ESO had in mind a contract at government level, in a way an extension of the Convention between the European governments, hence one with the



June 10, 1963: Summit Meeting on Cerro Morado.
On June 8–10, 1963, ESO officials were the guests of AURA on their property and on June 10 gathered on Morado, discussing ESO prospects in Chile.
Top photograph: *from left to right: N.U. Mayall, H. Siedentopf, Ch. Fehrenbach (in foreground), Sr Marchetti (architect, behind Ch.F.), O. Heckmann, A.B. Muller, F.K. Edmondson.*
Bottom photograph: *from left to right: A.B. Muller, O. Heckmann, J.H. Oort, H. Siedentopf, Ch. Fehrenbach, Sr Marchetti.*
These photographs were kindly made available by Dr. F.K. Edmondson.

Chilean Ministry of Foreign Affairs. Models were the agreement between CERN and Switzerland and the one between UNESCO and Chile. Exploratory steps toward such an agreement had been taken already during Heckmann's visits to Chilean authorities. For AURA, being an association of universities, the natural base for its relation with Chile was its contract with the University of Chile. Moreover, an important feature of the agreement of the kind envisaged by ESO would be a certain degree of extraterritoriality and associated diplomatic status for its establishment, like that of other international organizations in Chile. The dissymmetry implied by this status as compared to the one of AURA caused reluctance on the part of the latter: associating themselves with ESO with its extraterritorial status might, AURA feared, tend to endanger AURA's relation to Chileans. This status, moreover, would seem hard to reconcile with establishment on grounds leased from AURA. For Heckmann, however, the intended nature of the contract with Chile was virtually beyond discussion.

Still another element entered the discussions, and this one somewhat unexpectedly to ESO: the recently developped interest from the part of CARSO in possibly acquiring a share in Morado. CARSO (Carnegie Southern Observatory) aimed at erecting in the Southern Hemisphere the counterpart of the Hale Telescope and had in May 1963 been granted funds for site survey work [15]. Like ESO, it made grateful use of the findings of Stock and associates and it expressed particular interest in Morado. This tended to limit the share ESO might acquire in this site.

The lengthy discussions on October 11 and 12, 1963, left the main problems unsolved. AURA expressed willingness to reserve a temporary site on Tololo to enable ESO to start scientific work at the earliest possible date, and was prepared to recommend to the AURA Executive Committee a long-term (50 years) lease of part of Morado, but it was not prepared to recommend sale; an attitude due at least partly to apprehension with regard to ESO's intended status. In a letter of October 23 to Heckmann, Edmondson confirmed the main points mentioned here and added the offer, to allow provisional installations of ESO on Morado even if ultimately ESO would build its Observatory elsewhere [16]. Informal talks followed on Sunday, October 13, between Heckmann and Wildt who communicated his impressions in a letter to Edmondson of October 16 [17]. Wildt noted that Heckmann, perhaps over-optimistically, might not be fully aware of the amount of further negotiation still required even for reaching the suggested lease. As to the intended status with extraterritoriality, Heckmann promised to submit to AURA the draft-agreement with Chile before it would be signed by either party and he confirmed this in a letter to Edmondson of October 20 [18].

The negotiations between AURA and ESO were resumed early 1964, but at this point I should first describe developments occurring in the intervening months. By the end of October 1963 Heckmann was back in Chile for further negotiations with authorities in Chile, accompanied by Dr. K. Walters, ESO's legal advisor.

During this stay, Heckmann went as far as concluding the basic agreement with the Chilean government: the Convenio [19]. It is an agreement between ESO and the Chilean Ministry of Foreign Affairs and therefore one at the highest possible level. In this respect it is comparable to the ESO Convention. The Convenio was modelled after the agreement between Chile and the Economic Commission for Latin America, CEPAL (an affiliate of the United Nations) which has its Headquarters in Santiago, and it was adapted to ESO's legal status, immunities and exemptions, etc. as they are also recognized in the European context: the ESO Convention. The Chilean Ministry moved so fast and efficiently, that already during Heckmann's stay, on November 6, 1963, the agreement was signed in principle, to become effective upon endorsement by the ESO Council and by the Chilean parliament. (These endorsements took place from ESO's side at the first Council Meeting, February 5–6, 1964, and from Chilean side on April 17, 1964). However, for the EC these rapid developments came as a surprise, and as we shall see, not without embarrassment, for Heckmann had run a bit ahead of things . . . He was back in Europe on November 9, 1963.

Some Data from the Report of the Site Selection Committee,
on the basis of which the Andes Mountains were chosen for the site of the ESO Observatory. (Borrowed from ESO Bulletin No. 1, 1966.)

Number of Clear Night Hours per Year (A clear night defined as one with at least six successive cloudless hours.)

South Africa	*latitude*	*hours*	*Chile*	*latitude*	*hours*
Capetown	– 34°	1470	Santiago	– 33.5°	1675
Rockdale Mt.	– 32.5°	1285	Tololo	– 30°	2300
Boyden Obs.	– 29°	1750	Copiapo	– 27.5°	2760

N.B. Long spells of clear nights more frequent in Chile than in South Africa.

Image Quality

Tololo distinctly better than the South African sites, both with regard to turbulence (measured with Danjon telescope) and image motion (measured with double beam telescope).

Average temperature drop during clear night

Zeekoegat	4.2°	Tololo (Muller and McSharry)	1.3°
Flathill	5.8°	Tololo (Stock)	1.8°

Average Wind Velocity

At Tololo higher than at Rockdale Mt. and much higher than at Flathill and Zeekoegat.

Atmospheric Transparency

For both Rockdale Mt. and Tololo close to expectation for pure Rayleigh scattering; very little dust content.

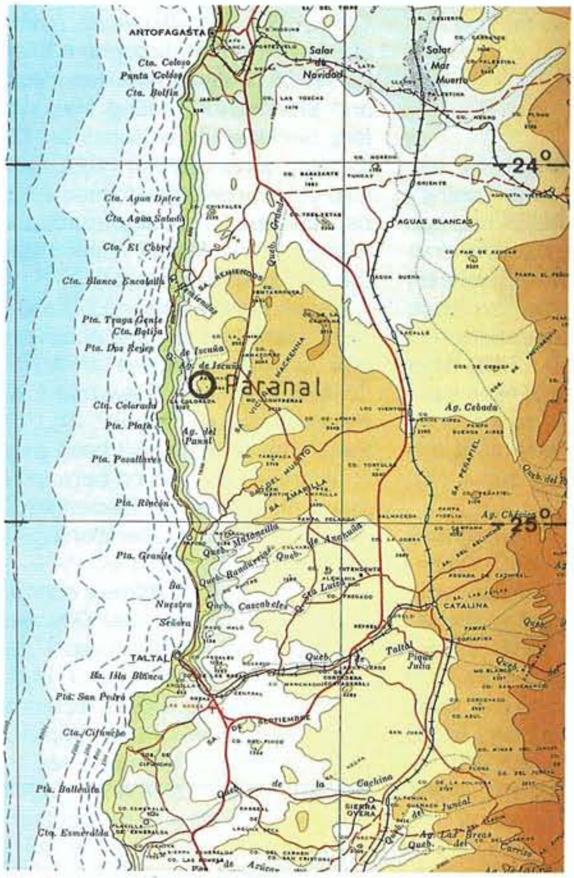
ESO Chooses the Andes Mountains for its Observatory

At its meeting on November 15, 1963, the EC first of all considered the basic question of the choice between South Africa and Chile. A report prepared by Siedentopf on behalf of the Site Selection Committee was the basis for the discussions; the Committee had convened on August 6, 1963, at Groningen, and on October 15, 1963, at Tübingen [20]. The report was published in 1966 in the first issue of the ESO Bulletin [21]. In making his comparisons Siedentopf used the data collected at Zeekoegat, Flathill and Rockdale Mt. in South Africa, and those collected for Tololo by Stock and by Muller and McSharry. In the accompanying box we summarize the principal items of Siedentopf's report. Following this presentation and a relatively brief discussion, the EC decided unanimously to choose the Andes Mountains for the site of the ESO Observatory, subject to confirmation by the later "legal" Council. The superiority of the climatic conditions was so impressive an argument, that very little discussion was devoted to financial implications, and to the interesting and challenging prospect of building up relations with a country that in respect to culture and language so far had been much more remote to most of the ESO countries than South Africa had been.

The Convenio with Chile

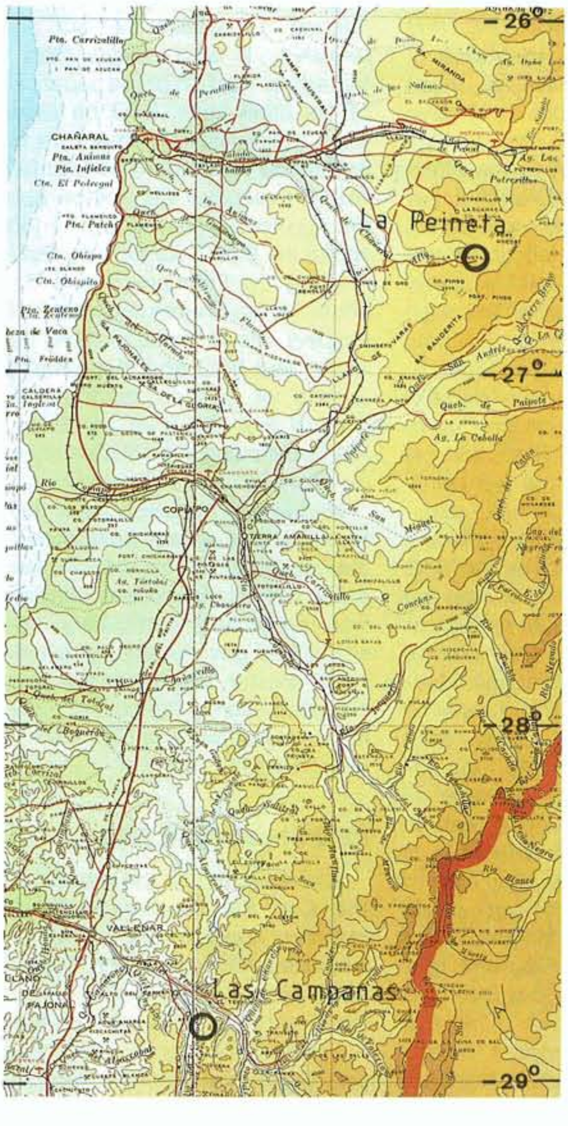
Proceeding next to Heckmann's account on his visit to Chile, the EC took note with mixed feelings. The Chairman of the provisional Finance Committee, although recommending to the EC approval of the agreement with the Chilean government, reproached Heckmann to have exceeded his authority: the text of the agreement should have been scrutinized and approved by the Provisional Finance Committee and EC prior to signing, and, moreover, the signing should have waited for the completion of the ratifications of the ESO Convention. On the other hand, the EC's Chairman expressed appreciation and admiration for the work done by Heckmann and Walters. The EC then decided to submit the agreement for endorsement at the first Council Meeting following the completion of the ratifications in Europe. (On February 5–6, 1964.)

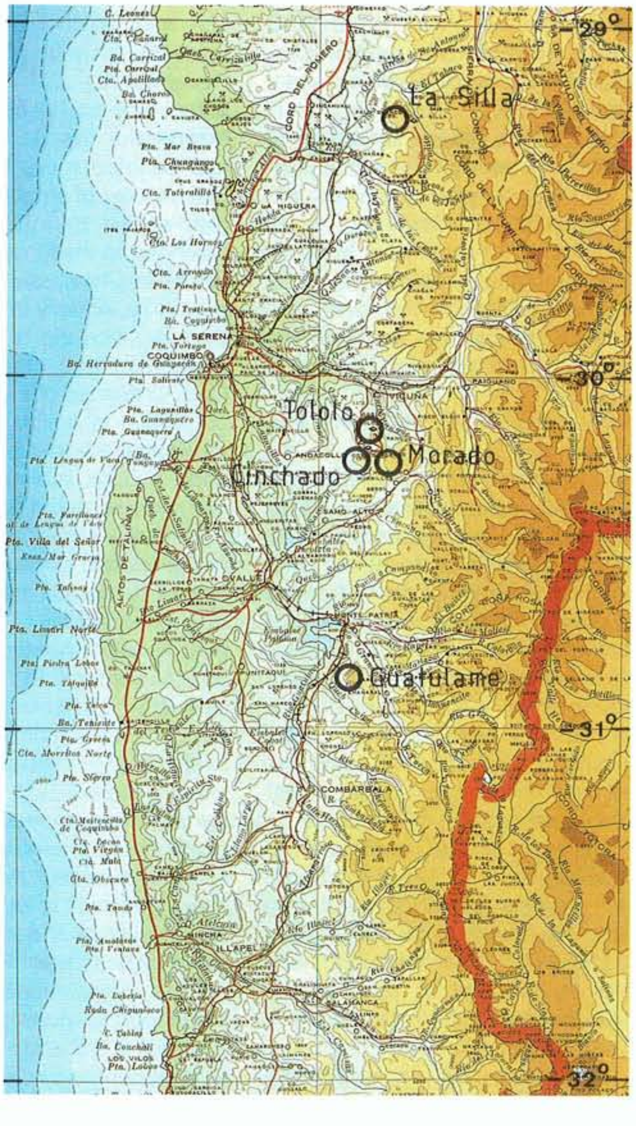
Heckmann, although showing understanding for the objections from a for-



Maps showing mountains that have played a role in ESO's search for a site. In the earliest stage, for the purpose of comparing measures with ESO's Danjon telescope with those of AURA's double beam telescope, observations were done on La Peineta and Tololo. In a later stage, Morado on the AURA territory appeared to be a likely site for ESO. In the last stage, the choice was narrowed down to Cinchado on the AURA territory, Guatulame near the town Monte Patria, and La Silla. Also marked are CARSO's site Las Campanas, and Paranal in the most northern area which is the subject of current tests.

Useful in preparing this map have been J. M. Ramberg's article in Sterne und Weltraum *of August–September 1964 (in EHA-I.A.2.2.), written right after the explorations of Heckmann et al. in March and April of that year in which La Silla appeared for the first time, as well as a map of the AURA territory in EHA-I.A.2.7., and also the maps in the ESO Annual Report for 1964 and in H. O. Voigt's article on the road construction in ESO Bulletin No. 3 of February 1968. For the maps of Chile, I used the* Atlas de la República De Chile *issued by the Instituto Geográfico Militar, 1970 edition, property of the author.*





mal point of view, must have felt wronged by the reactions in the EC. Let me quote a relevant part of the account in his book *Kosmos, Sterne, Weltmodelle,* written a decade later [22]:

"– – – Mir werden heute noch die heftigsten Bedenken wach, ob damals die Mitsprache bei der Textgestaltung von fünf europäischen Regierungen, mindestens also fünf, wahrscheinlich mehr, Ministerien, überhaupt etwas anderes als einen Zeitverlust von Monaten oder Jahren eingebracht hätte. Die europäischen Mitgliedsstaaten waren der empfangende, Chile war der gebende Teil. – – –".

Anyone who remembers the discouraging struggle within Europe for the ESO Convention, described in my first article, will have understanding for Heckmann's feelings . . .

Heckmann's book throws interesting light on what had made such unexpectedly rapid concluding of the Convenio possible. It was to a considerable extent due to influential persons in his circle of friends and colleagues. In order to appreciate this, one must remember that since long Chile had a strong German component in its population and a stronger tradition of cultural relations with Germany than with other ESO countries. Functionaries of German descent could be encountered at important governmental and cultural posts in Chile, and it was natural for these to sympathetically support the plans submitted by this energetic and highly esteemed scientist from Germany. Two of these should be mentioned here: E. Heilmeier, professor of astronomy at the Universidad Católica in Santiago, and Father Dr. B. Starischka, rector of the German High-School (Liceo Alemán) in Santiago.

It was especially Dr. Starischka who paved the way for Heckmann's approaches to government authorities. His role is not only acknowledged in Heckmann's book, but also appears from an account he recently wrote at the suggestion of Dr. E. Geyer of the Hoher List Observatory and kindly passed on by the latter to me. Several of the ministers in the government of the then President Jorge Allessandri were alumni of Starischka's School, including those of the Interior and of Cultural Affairs and the Minister of "Tierras y Colonisaciones" whose support would be invaluable for the acquisition of the ESO territory. At all these levels, including that of the President (an engineer by schooling) strong sympathy for the project was rapidly aroused. However, Chile was up for new elections by the end of 1964, and a change in the constitution of the government was expected. Heckmann was urged from many sides, including diplomatic ones, to strike while the iron was hot.

The Relation to AURA

Not only the EC was taken by surprise, so was the AURA Board. Contrary to Heckmann's promise, AURA had had no opportunity to comment on the draft text of the Convenio. Disappointment was expressed by AURA's President, Edmondson, in a letter to Heckmann of November 27, 1963 [23]. This letter crossed one of Heckmann of November 29 in which he offered explanations which – at least to the author of this article – do not sound very convincing [24].

The failure to arrive at an arrangement by which the AURA and ESO Observatories would be erected in close proximity caused disappointment at the EC meeting of November 15, 1963, particularly with its Chairman, Oort. On November 17, Oort expressed deep concern about the developments in letters to Edmondson and Mayall [23]. On November 21, the eve of the AURA Executive Committee meeting of November 22 in Tucson, he made a long telephone call to Mayall, with Edmondson and Wildt listening in [24], and followed up with letters to Mayall of November 21 and 22. However, these letters opened no fresh points of view. Meanwhile, this AURA Board meeting had adopted a resolution to the effect that, in view of established AURA policy with regard to Kitt Peak, now to be extended to their Inter-American Observatory in Chile, sale of AURA property should be virtually impossible. Although the resolution did not mention ESO, its implication was clear. In his letter to Oort, Chairman of the EC, of November 26, 1963, in which Edmondson communicates the text of the resolution, he adds *"I hope this resolution will clarify our position to the ESO Council."* [25].

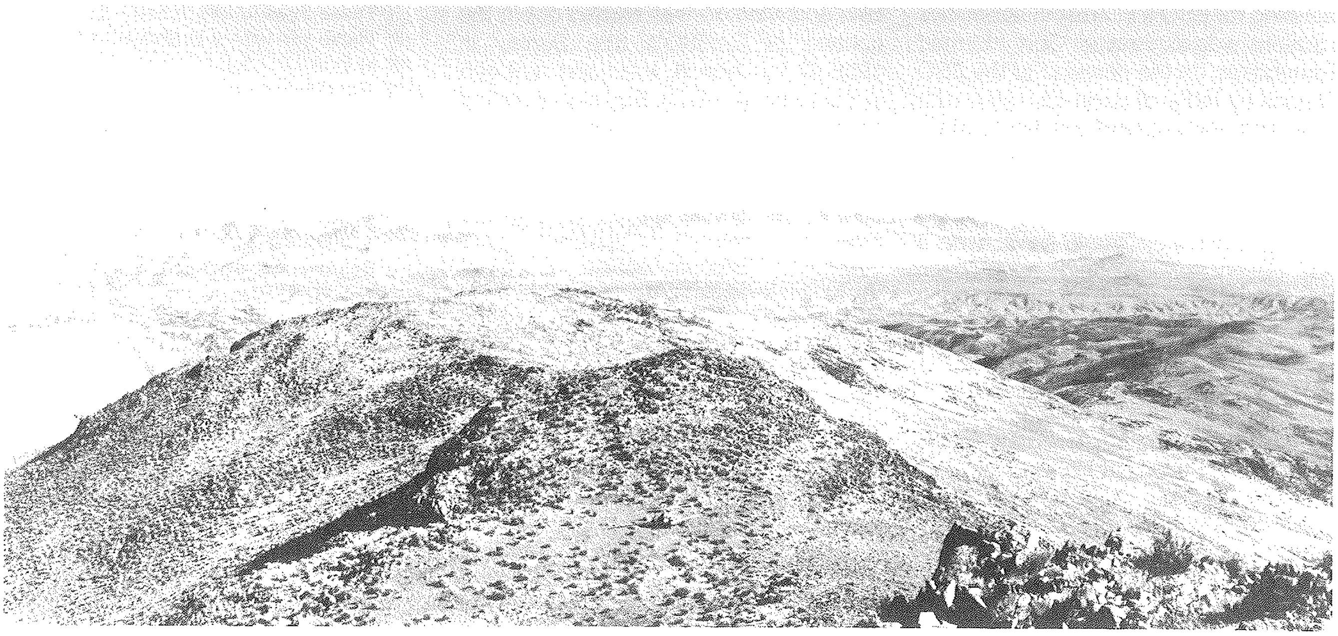
Although some temporary stiffening of the relation between AURA and ESO cannot be denied, nor a shadow on the high expectations of intimate collaboration, a desire remained on the part of both to continue the negotiations. Mayall's letter of November 27 in reply to Oort's letters mentioned before concludes with the statement *"With the obvious goodwill that exists between all parties, I see no reason why we cannot come to an agreement acceptable to all interested parties. For my part, I try to keep foremost in mind the very desirable objective of a close community of astronomers, who would benefit very much by scientific discussions with their neighbouring colleagues. I think this situation is especially important to have in a remote area like that in Northern Chile."* [26]. It is also worth mentioning at this point, that throughout the whole period of contacts between Heckmann and Edmondson, dating from well before Heckmann's activities for ESO till the time of his death in 1983, a relationship of close personal friendship existed between the two, not perturbed by the wrinkle in the formal relation between the two organizations [27].

Negotiations between ESO and AURA were continued on the occasion of a visit of representatives of AURA and CARSO to Europe. They met ESO representatives on January 21, 1964 in Paris. The meeting had been preceded by informal consultation between Heckmann and Mayall in December [28]. It arrived at a draft cooperation agreement between AURA and ESO *"– – – desirous to arrive at an efficient coordination in the exploitation of their Observatories in Chile – – –"* and it agreed – pending approval by AURA Board and ESO Council – on a number of recommendations which essentially implied that AURA would be willing to sell to ESO property on their area south of Morado, possibly extending to the southern border of the AURA domain, including Cinchado but excluding in first instance Pachón (in which CARSO was interested). It also stated that, might Morado or Pachón prove superior to any of the other sites, ESO be allowed to erect its largest instrument on Morado or Pachón on a restricted area [29]. The AURA Executive Committee approved the agreement on January 31 [30], and so did the ESO Council in its first "legal" meeting on February 5 and 6, 1964. Thus, the road remained open for further shaping close collaboration between AURA and ESO and there was a concensus of opinion among the ESO Council that the draft agreement with AURA balanced in a satisfactory manner co-operation and independence.

Meanwhile, however, there had been for some time already an undercurrent in the internal ESO deliberations favouring a still more independent position. This was advocated particularly from the side of the government representatives; such greater independence might be preferred even at the cost of more delay in the operations and higher investment expenses [31].

ESO Chooses La Silla

In preparation for the final decision on the site, the February 1964 Council meeting appointed a working group consisting of Fehrenbach, Rösch (also from France, Rösch had succeeded Siedentopf as Chairman of the committee for the evaluation of the site tests) and Muller, together with Heckmann. Its



First photograph of La Silla, taken from the top in North-Westerly direction, by Heckmann on the occasion of his first landing on La Silla in the company of Fehrenbach and Muller in April 1964. In the foreground the helicopter made available by the Chilean Air Force. Behind the helicopter is the knoll which first carried only the water tanks and now also the New Technology Telescope. Behind this, the ridge on which now most of the telescope park is located. Reproduced from two photographs in the ESO Photographic Archives stored in an envelope marked "Helikopterflug April 1964" in Heckmann's handwriting. From these two photographs, covering the left and right hand part of the view, the ESO Information Service produced this uninterrupted panorama.

assignment was, to have a new look at Cinchado and other sites within the AURA domain as well as in the general vicinity. By letter of February 20, 1964, Oort informed Edmondson about the decision [32]. Heckmann left on March 18 for Chile where Muller joined him and so did, for part of the time, Fehrenbach and Rösch. He returned to Europe at the end of April. During his stay Heckmann reported to Oort in two long letters, of March 30 and April 21 [33].

These two letters are of considerable interest for proper understanding of the developments soon leading to the choice, not of a site within the AURA domain, but of one that came only rather late in the picture. I summarize here the most relevant points.

In the first of these letters, after briefly reporting on his visits to the AURA area and AURA Headquarters in La Serena with Muller and Rösch, including talks to Stock, Heckmann, reflecting on the earlier discussions with Mayall, states that he may have interpreted these erroneously; that once AURA had acquired its extensive property and resolved to invite others like ESO to *"share its luck"*, it must have appeared presumptuous and unnatural to AURA if such parties would approach it about sale of part of this territory, and that AURA's agreeing, in Paris, to such sale was a special concession and by no means a matter of course. However, according to Heckmann, even then a certain restriction on the part of AURA would remain because in several respects, particularly in the context of the construction activities, ESO would necessarily have to adjust itself to AURA rules. Reflecting next on the philosophy of AURA-ESO collaboration, Heckmann wonders what this would amount to in practice: observers at work during the night would have little time to meet, and at Headquarters only few astronomers would be present at any given moment. Sharing costs in practice probably would not really lead to appreciable reduction . . . On the other hand, it should be in such matters as joint observing programmes, joint colloquia and seminars, possibly at the University of Chile in Santiago – not really requiring physical proximity of the Observatories – that collaboration should take shape.

The second letter reports, among other items, on the selection of three mountains which on the basis of inspection by helicopter and by car and aerial photographs were left for further investigation: Guatulame, South-East of Ovalle; Cinchado on AURA territory; and Cinchado-North. The positions of the three are marked on the map. The last one of the three turned out to be the most interesting one from the point of view of accessibility, climatology (dry), proximity of a flat area to be used for a landing strip, and the fact that it was government property and hence probably obtainable without complication. Let me quote some parts of this letter of April 21, 1964:

"Lieber Jan:
Unsere Tätigkeit hier beginnt auszuklingen. Alle werden in dieser Woche wieder nach Europa fliegen. – – – Ich glaube, wir können mit unserer Arbeit zufrieden sein, und hoffentlich ist es der Council auch. – – –
Der interessanteste Berg scheint uns bisher Cinchado-Nord zu sein, ca. 100 km NNO von La Serena, – – – erreichbar von der schnellen Panamericana auf ca. 35 km sehr primitiver Straße. – – – Ohne Dich zu fragen, haben Fehrenbach und ich uns für berechtigt gehalten, Muller zu ermächtigen, auf dem Berg vorläufige Arbeiten zu beginnen. Wir haben Luftbilder bekommen und werden eine Karte herstellen lassen. Zum Council-Meeting werden wir schon mehr wissen. Fehrenbach und ich haben den Eindruck, daß der Berg ein großer Glücksfall ist. – – –".

The name we now use for this mountain: La Silla.

Heckmann reported at the Council meeting of May 26 and 27, 1964. Council resolved to choose La Silla provided reasonable solutions could be found for the provision of water and for the question of the mining rights, and if the price would be acceptable; it accordingly authorized Heckmann to enter negotiations. Naturally, also the relation to AURA was discussed. Heckmann reported on a discussion on Tololo with AURA representatives on April 12, and on a later discussion between Fehrenbach and Mayall, in which full understanding for ESO's interest in alternative solutions was expressed. Oort informed Edmondson on the decision of the ESO Council by letter of June 12, 1964, with copy and accompanying letter to Mayall. From the last one I quote: *"– – – Personally I am disappointed that this decision will make our relations in Chile less intimate than they would have been if our observatories could have been erected on Morado, as had been provisionally planned during our beautiful common trip, last year. But, considering the circumstances as they have gradually developed, I believe that the course we have now decided on, may be the best. – – –".* Mayall, in his reply of June 20, expressed the same feelings. From Edmondson's reply of July 7, let me quote: *"– – – I see no reason why there should not be frequent contact between ESO and AURA astronomers, even though ESO locates outside of the AURA domain. I am sure that such contacts will develop in a very natural way. – – –"* [34].

As we know now, the conditions imposed by Council were satisfactorily met by Heckmann's subsequent negotiations, and so the decision of the Council meeting on May 26, 1964, did imply the final choice for ESO's site: La Silla.

With many suitable mountains in the Andes around La Serena, how had the working group arrived at narrowing down the choice to La Silla and Guatulame, besides Cinchado Sur on the AURA property? The basic idea, as described by Heckmann [35] was, to look first of all for government property, as this would facilitate the negotiations for purchasing, especially in view of the recently concluded Convenio. Rösch, according to Heckmann, managed to borrow from the Ministerio de Tierras y Colonisación a unique atlas, scale 1 : 200,000 of all government property. From it they selected the two new sites and they obtained further information on water sources and mining activity from maps of the Instituto de Investigaciones Geológicas. Closer inspection of the sites was done by means of a helicopter put at their disposal by the Chilean Air Force.

Reviewing these developments, the reader may be surprised by the absence of a thorough test of La Silla before it was adopted by ESO. André Muller reminds me of the conviction established at that time by Stock's tests: almost any mountain top in the La Serena area at the level 2000 to 3000 metres, well isolated from the surrounding peaks, should be adequate. The almost universal property of the near-absence of temperature drop during the night on these mountain tops virtually guarantees good seeing quality.

A comparison of seeing between La Silla and Morado was carried out in the context of CARSO's Site Survey in 1966/67 by John B. Irwin and reported in ESO Bulletin No. 3. Equality of seeing conditions on the two sites, confirming the above expectation, is implicit in Irwin's Table 1. Explicit is John's praise of ESO's *"meals that are the envy of the Morado observers".*

Acknowledgement

It is a pleasure to acknowledge many helpful comments I received from Dr. F.K. Edmondson, former President of the AURA Board.

References and Notes

Note: for a list of the ESO Committee meetings see the Table in article I.

Abbreviations used:

EC = ESO Committee, the committee that preceded the Council.

EHA = ESO Historical Archives (see the article in the *Messenger* of December 1989).

FHA = Files Head of Administration at ESO Headquarters.

Heckmann Sterne = O. Heckmann, *Sterne, Kosmos, Weltmodelle,* Verlag Piper & Co., München–Zürich, 1976.

[1] See, for instance, Kuiper's report in *Lunar and Planetary Laboratory Communication* No. 156 of October 1970 in EHA-I.C.2.7.b.
[2] A copy of these reports is kept in EHA-I.C.5.
[3] See accounts by Stock in *Chile Site Survey Technical Report* No. 2, Kitt Peak Nat. Obs., 1963 in EHA-I.C.2.7.b., and in *Information Bulletin Southern Hemisphere,* No. 7 Oct. 1965, Ed. J. Sahade.
[4] I am indebted to Dr. F.K. Edmondson for informing me about these developments.
[5] See Addendum C to the Minutes of the 2nd EC meeting of January 1954.
[6] See page 5 of Stock's Report mentioned in Note [3].
[7] These three letters in EHA-I.C.1.1.c.
[8] These two letters in EHA-I.C.1.5.b.
[9] In EHA-I.C.1.5.c.
[10] The detailed report is in EHA-I.A.2.7.
[11] In EHA-I.A.2.7., see also reports in EHA-I.C.1.5.f.
[12] These two letters in EHA-I.A.2.8.
[13] See EHA-I.A.2.8. for letters OH to FKE of August 26 and FKE to OH of September 3, 1963.
[14] See minutes of the discussion in EHA-I.A.2.8.
[15] See, for instance, G.W. Preston's account "That Special Mountain", Carnegie Inst. of Washington, May 1986.
[16] EHA-I.A.2.8.
[17] Communicated by F.K.E. to the author.
[18] In EHA-I.A.2.8.
[19] The full title reads: Convenio entre el Gobierno de Chile y la Organización Europea para la Investigación Astronómica del Hemisferio Austral, para el Establecimiento de un Observatorio Astronómico en Chile. See the volume *ESO Basic Texts.*
[20] For reports on these meetings see EHA-I.C.2.7.a.
[21] H. Siedentopf, Comparison between South Africa and Chile. *ESO Bulletin* No. 1, p. 11, 1966.
[22] Heckmann Sterne, p. 288.
[23] In EHA-I.A.2.8.
[24] See notes by Oort and the telephone bill in EHA-I.A.2.8.
[25] In EHA-I.A.2.8. and I.C.1.5.e.
[26] EHA-I.A.2.8.
[27] Communication by F.K. Edmondson to the author.
[28] See EHA-I.A.1.22.
[29] See EHA-I.A.2.8. as well as the minutes of the meeting prepared by AURA, in EHA-C.1.5.e.
[30] See the letter of February 2, 1964 of Edmondson to Heckmann in EHA-I.A.2.8.
[31] See, for instance, the minutes of the informal EC meeting on 20 January 1964, Council Doc no. 20 in FHA.
[32] EHA-I.A.2.8.
[33] EHA-I.A.2.10.
[34] All four letters in EHA-I.A.2.8.
[35] Heckmann Sterne, p. 290ff.

New ESO Scientific Preprints

March–May 1989

636. L.K. Kristensen and R.M. West: On the Lost Minor Planet (719) Albert. *Astronomy and Astrophysics.*
637. P.A. Shaver and M. Pierre: Large-scale Anisotropy in the Sky Distribution of Extragalactic Radio Sources. *Astronomy and Astrophysics.*
638. R. Buonanno and G. Iannicola: Stellar Photometry with Big Pixels. *Publications of the Astronomical Society of the Pacific.*
639. E. Brocato et al.: Synthetic Colours and the Chemical Evolution of Elliptical Galaxies. *Astrophysical Journal.*
640. M.-H. Ulrich: The Host Galaxy of BL Lac Objects or What's in a Name? To be published in the proceedings of the workshop: "BL Lac Objects, 10 Years Later", Como, Sept. 1988.
641. L. Binette et al.: Relation between the Ionizing Continuum and the Emission lines in Fairall 9. *Astrophysical Journal.*
642. M. Marcelin et al.: Kinematics of the Jet of the Crab Nebula. *Astronomy and Astrophysics.*
643. J. Barbero et al.: The Age Calibration of Integrated UV Colours and Young Stellar Clusters in the Large Magellanic

Cloud. *Astrophysical Journal.*
644. L.F. Rodríguez and H. Reipurth: Detection of Radio Continuum Emission from the Herbig-Haro Objects 80 and 81 and their Suspected Energy Source. *Revista Mexicana de Astronomía y Astrofísica.*
645. C. Aspin et al.: CCD Observations of Bipolar Nebulae. IV: S. 106. *Astronomy and Astrophysics.*
646. F.R. Ferraro et al.: A Method to Study the Star Formation History of Dwarf Irregular Galaxies: 1: CCD Photometry of WLM. *Monthly Notices of the Royal Astronomical Society.*
647. M. Roth et al.: Near-Infrared Images of Young Objects in the HH 1–2 and HH 3 Regions.
648. C.N. Tadhunter, R.A.E. Fosbury and P.J. Quinn: The Kinematics of the Ionized Gas Around Powerful Radio Galaxies. *Monthly Notices of the Royal Astronomical Society.*
649. A. Soubeyran et al.: 3C 120. Study of Continuum-Emitting Condensations Close to the Nucleus. *Astronomy and Astrophysics.*
650. M.-H. Ulrich: Intermediate Resolution Spectra of Quasars with $Z > 2$. *Astronomy and Astrophysics.*
651. A. Cavaliere, E. Giallongo and F. Vagnetti: Evolutionary BL Lacs? To appear in the proceedings of the workshop "BL Lac Objects! 10 Years After", Como, Sept. 1988.
652. M. Heydri-Malayeri, P. Magain and M. Remy: Two More Very Massive Stars Resolved. *Astronomy and Astrophysics.*
653. H.E. Schwarz, C. Aspin and J.H. Lutz: He2–104: A Symbiotic Proto-Planetary Nebula? *Astrophysical Journal.*

Astronomy at 6000 m!?

S. BRUNIER, "Ciel et Espace", Paris, France

High-altitude Observatories

The astronomer and the mountain have always been good friends, the first knowing well that the higher he mounts on the second, the clearer and the more transparent is the sky he can study . . .

During the past century, high altitude observatories have sprung up in various places of the globe. They are real eagles' nests, the objects of cult and dreams of amateur astronomers: Pic du Midi (2870 m above sea level), Gornergrat (3100 m), Jungfraujoch (3580 m) and recently the famous Mauna Kea which now has the world record at 4210 m elevation.

As a science journalist and amateur astronomer, I was impressed during my visit to La Silla last year by the efforts which ESO currently invests in the VLT site selection. At that time I learned that at La Silla (2400 m) and Cerro Paranal (2660 m), and also at even higher places, very advanced meteorological research has been going on in the hope of finding a site with ideal sky conditions.

At that time a crazy idea germinated in my amateur astronomer's mind, envious of the large telescope observatories: why not try to install under the Andean sky a temporary astronomical observing station at extremely high altitude, indeed the "highest observatory in the world"?

This idea became reality this February, thanks to the studies undertaken by ESO in the Atacama desert and the experience by La Silla Andinist specialists Christian Gouiffes and Bertrand Kohler. Together with seven amateur astronomer friends and four French and Chilean high mountain guides, I was able to transport an equatorially mounted telescope through the Atacama desert to the slopes of the Ojos del Salado volcano, whose peak is the highest point in Chile at almost 7000 m altitude.

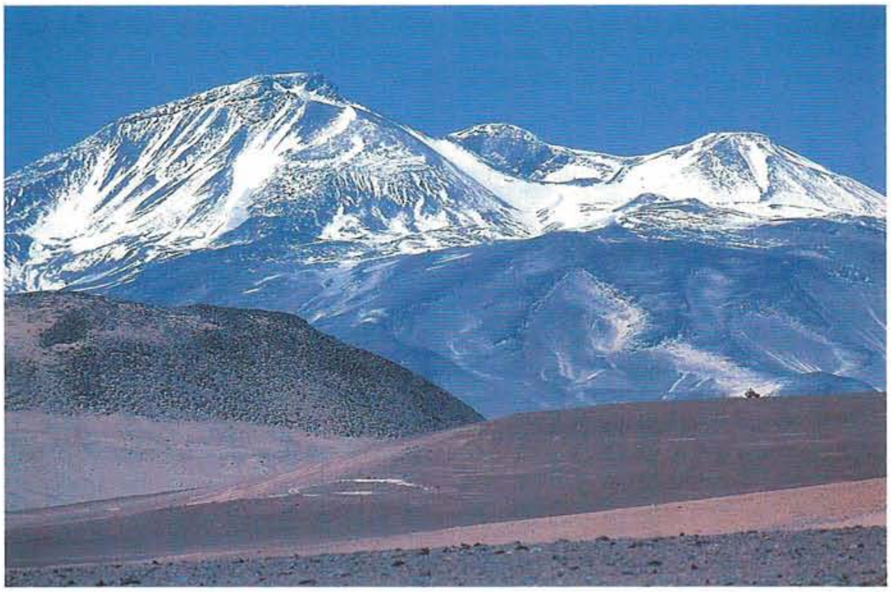


Figure 1: *Nevado Ojos del Salado in the Atacama is the tallest volcano in the world and the second highest peak in the Americas.*

Figure 2: *"The highest observatory in the world". At the second camp, 5200 metres above sea level, all members of the team gather proudly behind the telescope.*

Figure 3: *The Small Magellanic Cloud, observed from 5200 m altitude. Taken with a piggyback 135-mm f/2.8 lens during a 10-min exposure. This photo was obtained by Jean Vichard; the others accompagnying this article are by the author.*

Our goal was multiple: first of all to try to determine whether the sky at very high altitude, visually spoken, is more beautiful and allows deeper limiting magnitudes than for instance the sky at La Silla. We were also interested in trying to profit from the natural "hypersensitization" conditions in the high altitude desert, that is the intense cold and virtually zero moisture content of the thin air. Finally we wanted to obtain sky photographs with our telescope, a Celestron 8; it is a veritable small, transportable observatory in which the electrical equatorial motion is fed by a battery which in turn is charged by solar cells. It also has a control system for the exposures and the guiding, interference filters, etc.

The Conditions Above 6000 m

Altogether, the expedition lasted three weeks and we installed the observatory at increasing altitudes in order to acclimatize ourselves to the thin air at 4500 m, 5200 m and finally 5800 m.

Unfortunately, our rather ambitious programme could not be entirely fulfilled. The climatic conditions in the high Cordillera are clearly less optimal than in other areas of the Atacama desert. In particular, the wind, the thunderstorms and finally the heavy snowfalls severely perturbed our expedition. Quite apart from the purely meteorological problems, the altitude in itself is quite hostile to the human organism. Above approximately 4500 m, it is difficult to reconcile an intellectual and technical activity (optical alignment, pointing of the telescope, making exposures, etc.) with simple survival, that is the fight against fatigue and also the various symptoms of high altitude sickness, which has been known to cause death in severe cases.

What concerns the sky over Atacama . . . Having at the end of our expedition attempted to ascend Ojos del Salado, we were able to admire it with the naked eye from altitudes between 6000 and 6600 m. In the *daytime* it appeared to me that the sky at high altitude possessed an extraordinary clarity and transparency, much more so than at any other astronomical site in the world, including La Silla and Hawaii. However, during the *night* it appeared less good than at La Silla. It should be noted, though, that according to medical specialists, the altitude degrades the visual acuity.

Finally, after having experienced the fascinating but hostile environment of the high altitude desert, our small group was very happy to sample the joys of the regained civilization: the La Silla oasis and the warm welcome which we received from the entire ESO staff!

For us, who took part in this adventure, one conclusion was obvious: with the exception of possible, short-term expeditions dedicated to extremely specialized studies, it is not possible to seriously envisage the permanent installation of an astronomical observatory above 4000–4500 m altitude. Mankind (even astronomers!) has not been made to live at that extremity of our planet . . .

Acknowledgements

Our expedition to the Atacama could not have been realized without the help of ESO. The Information Service in Garching enabled us to visit La Silla, that Mecca of modern astronomy. We also thank Mrs. Elly Berliner for her warm welcome at the guesthouse in Santiago and Patrice Bouchet, Christian Gouiffes and Daniel Hofstadt for their help and counsel at La Silla, as well as to Ray Wilson who understood so well to convey to us his passion for the newborn telescope at the Observatory. We are also grateful to the entire staff at La Silla for their infinite kindness, although we could not thank them appropriately while we were there, due to our lack of knowledge of their languages.

Figure 4: *The ultimate photo, obtained at 5800 m altitude during a 90-min exposure. It shows the Milky Way and the Magellanic Clouds turning around the celestial South Pole, just above the summit of Nevado Ojos del Salado. Two things that this picture cannot show are the intense cold and the lack of oxygen at this altitude . . .*

The Data of the Surface Photometry Catalogue of the ESO-Uppsala Galaxies are Now Available

A. LAUBERTS, ESO
E. A. VALENTIJN, ESO and Kapteyn Laboratorium, Groningen, the Netherlands

We are happy to announce that most of the results of our extensive project on the surface photometry of the 16,000 ESO-Uppsala galaxies are now publicly available.

We have scanned 15,467 Southern galaxies on 407 Blue and 407 Red original ESO-Schmidt plates with the PDS micro-densitometer. The galaxies were selected from the ESO-Uppsala Catalogue, which was based on a visual inspection of the ESO Quick Blue Schmidt survey plates. The original selection criterion was a minimum visual angular diameter of 1 arcmin. The ESO-Uppsala catalogue was published in 1982 by Lauberts and provided visually determined information on the positions, morphological types, diameters, axial ratios and position angles for galaxies up to $\delta = -17.5°$.

In the new Surface Photometry project, computerized processing played a leading role, and was based on the original ESO-Uppsala catalogue, south of $\delta = -17.5°$, as the reference data base. An outline of the basic procedures for this project was given in the *Messenger* (Lauberts and Valentijn, 1983).

At first we compiled a catalogue with photo-electric standards, with photometric data of 1700 standard galaxies transformed to a photometric standard system (Cousin's). Aperture photometry has been accumulated both from the literature and from our own photo-electric observations. With these photo-electric standards, together with the calibration wedges present on many plates, we calibrated the survey plates involved in this project. Next, all the scanned images of the galaxies were calibrated to intensity. 28,218 images with intensity in surface brightness units are now resident on two optical disks and a facility to retrieve these data is available at ESO, Garching. Provided that the proper optical disk is in ESO's optical disk drive, the user can retrieve and display his desired galaxy in two colours almost instantaneously.

The intensity calibrated images were used by us to extract a great variety of photometric and structural parameters. In the book *The Surface Photometry Catalogue of the ESO-Uppsala Galaxies,* we give a detailed description of the calibration and automated parameter retrieval procedures. This hard cover book is now for sale at ESO.

In total, we reduced the input data (2.8 Gbyte) to 180 entries for 15,467 objects (~11 Mbyte). The extracted parameters include radial surface brightness profiles, allowing further processing according to the user's needs. Furthermore, we determined magnitudes at several isophotal levels, colours, colour gradients, effective radius parameters, structural parameters such as axial ratios, position angles, profile gradients, etc. In the book, we list the measured values for a subset of these parameters. On 440 pages, values of 37 different parameters are printed (~600,000). This data base can be considered the principal result of the project.

A sample page of the printed parameter values is shown for the Right Ascension interval $13^h54^m - 13^h56^m$. Let us focus on the 12^{th} magnitude galaxy NGC 5365 with coordinates $13^h54^m46^s$, $-43°41'.2$. Its ESO identifier is 271-G 08, here coded as 2710080. Note that companion objects, when present, have identifiers terminating on '1' or '2'. The morphological type is a lenticular, S0, here coded as −2.0. The galaxy belongs to the 'diameter limited' sample, left flag is 1, but not to the complete subsample according our V/V_{max} tests, which were labeled with the left flag equal to 2. The morphological type was visually revised – right flag equal to 1. The galaxy is located somewhere near the Centaurus complex of galaxies and has a recession velocity of 2472 km/s; it is pretty bright, having a blue total magnitude of 12.20. The upper '‾' sign means that the innermost data was corrected with photo-electric data, well motivated by the high central surface brightness $\mu_B = 18.81$ per square arcsec. The red B-R colour, 1.62, and the small colour gradient, −0.06, are typical for an early-type galaxy. The very extended faint envelope made the big difference between the half total light radius and the 27 isophote.

The shape of such a galaxy is very difficult to characterize by the eye. With two rivaling algorithms, we let the computer sort out its structure. One code was more sensitive to the structure at maximum extent, the overall structure (upper line), while the second code determined the intensity weighted structure (second line). This resulted in quite different estimates – 1.62 and 1.14 – for the axial ratio, a/b. On the other hand, the two estimates for the position angle differed by not more than 11°. The radial intensity profile may be expressed by an index of the exponent in the so-called generalized exponential law, where a value of the index of 0.25 characterizes a perfect $R^{1/4}$-law light profile, usual for elliptical galaxies and bulges, while an index value of 1.0 represents a pure exponential disk light profile. In this case the blue image returned a value 0.30, while the red image admitted 0.23. Both values are reasonably close to 0.25, indicating that the profile of this S0 galaxy is dominated by a bulge component, typical for early type galaxies.

Being positioned in the outskirts of a large cluster, our object is seen against a projected galaxy density, 1.3 per square degree, constituted by neighbouring bright galaxies. The fraction of spiral galaxies amounts to 77 per cent. The final number on the line of printed data, 0.33, is the estimated blue extinction, a typical average value for an object at Galactic latitude +17°.

We have attempted to code the galaxy parameters in a transparent way. As fanatic as astronomers can be, with some understanding of the coding, one can read the printed lines as a novel. We guarantee, that there are some quite exciting characters on our printed pages. As one of the readers remarked, the data base contains sufficient information to accurately reconstruct from the parameters the original input images.

The data are also available to the astronomical community in several other forms: on the ESO data base computer (IDM), as a MIDAS table on the ESO VAX computers and on magnetic tape.

The calibration coefficients of the 814 plates form an interesting auxiliary data base on the properties of sensitized (RED) and unsensitized (Blue) plates. Sky brightness values are also included in the calibration coefficient tables.

In the book we give an extensive discussion on the photometric accuracy of the data base. Both internal consistency checks and comparisons with other photometric observations are presented. The nominal accuracy of total magnitudes is expected to be better than 0.09, while surface brightness profiles are found to have residuals from

TABLE 1: *Subsamples in ESO-LV data base. Distribution over* Type *and available* cz

	SAMPLES											
	ALL			DIAMETER $\geq 1'$			$B_T < 14.5, 1'$			VMAX		
Type	#	%	# cz	#	%	# cz	#	%	# cz	#	%	# cz
− 5.0:− 4.5	339	2.2	158	249	2.1	137	163	5.4	119	126	2.1	73
− 4.5:− 3.5	102	0.7	58	91	0.8	53	73	2.4	47	71	1.2	40
− 3.5:− 2.5	632	4.1	309	504	4.3	283	320	10.7	228	286	4.8	172
− 2.5:− 1.5	970	6.3	403	752	6.3	332	368	12.3	238	434	7.3	202
− 1.5:− 0.5	501	3.2	175	355	3.0	150	136	4.5	99	235	3.9	116
− 0.5:+ 0.5	697	4.5	199	513	4.3	158	133	4.4	83	107	1.8	35
+ 0.5:+ 1.5	1663	10.8	382	1329	11.2	316	246	8.2	141	237	4.0	58
+ 1.5:+ 2.5	949	6.1	212	646	5.5	173	133	4.4	96	221	3.7	55
+ 2.5:+ 3.5	2248	14.5	421	1873	15.8	384	350	11.7	219	874	14.6	143
+ 3.5:+ 4.5	996	6.4	323	807	6.8	301	314	10.5	222	470	7.9	173
+ 4.5:+ 5.5	1060	6.9	333	828	7.0	315	306	10.2	226	578	9.7	226
+ 5.5:+ 6.5	1754	11.3	233	1395	11.8	207	158	5.3	100	945	15.8	141
+ 6.5:+ 7.5	1046	6.8	123	659	5.6	112	103	3.4	61	463	7.7	95
+ 7.5:+ 8.5	791	5.1	77	524	4.4	71	66	2.2	38	362	6.1	61
+ 8.5:+ 9.5	824	5.3	80	590	5.0	80	71	2.4	50	304	5.1	71
+ 9.5:+ 10	898	5.8	90	730	6.2	87	59	2.0	34	266	4.4	64
− 5.0:− 2.5	1073	6.9	525	844	7.1	473	556	18.5	394	483	8.1	285
− 2.5:+ 0.5	2168	14.0	777	1620	13.7	640	637	21.2	420	776	13.0	353
+ 0.5:+ 10	12226	79.0	2274	9381	79.2	2046	1806	60.2	1187	4720	78.9	1087
− 5.0:+ 10	15467		3576	11847		3159	2999		2001	5979		1725

photo-electric photometry less than 0.15 for $20 < \mu_B < 24$.

The photometric and structural parameters were used to determine morphological types for ~3500 galaxies that could not be classified in the ESO-Uppsala catalogue, mostly because they were too faint. The availability of colours and profile gradient parameters allowed us to evaluate the expected morphological types with an automated computer programme. All early type galaxies have been re-classified by means of a visual inspection of Blue and Red digitized images. We made also extensive use of the recently published classifications by Corwin et al. (1985). Altogether, this resulted in a complete update of the morphological types of ESO-Uppsala galaxies and their companions.

An important quality of the data base is that it has been acquired in a homogeneous fashion for all types of galaxies in various environments. Thus it appears that scientific studies of galaxy properties as function of environment might be fruitful with this data base. In order to facilitate such studies, we computed a local projected galaxy density parameter. The catalogue was also cross-correlated with the recent Southern Cluster Catalogue (Abell, Corwin and Olowin, 1989). The projected galaxy density parameter, whose value is normally less than 10, has been updated for the galaxies supposedly associated with clusters, by replacing the value of the projected galaxy density with a representative value of the 'cluster count' (always greater than 10). About 900 galaxies were found to be associated with a Southern Cluster. On the example page, one can easily notice that six galaxies were found to be associated with two different clusters – one with a scaled 'cluster count' = 18.7, the other

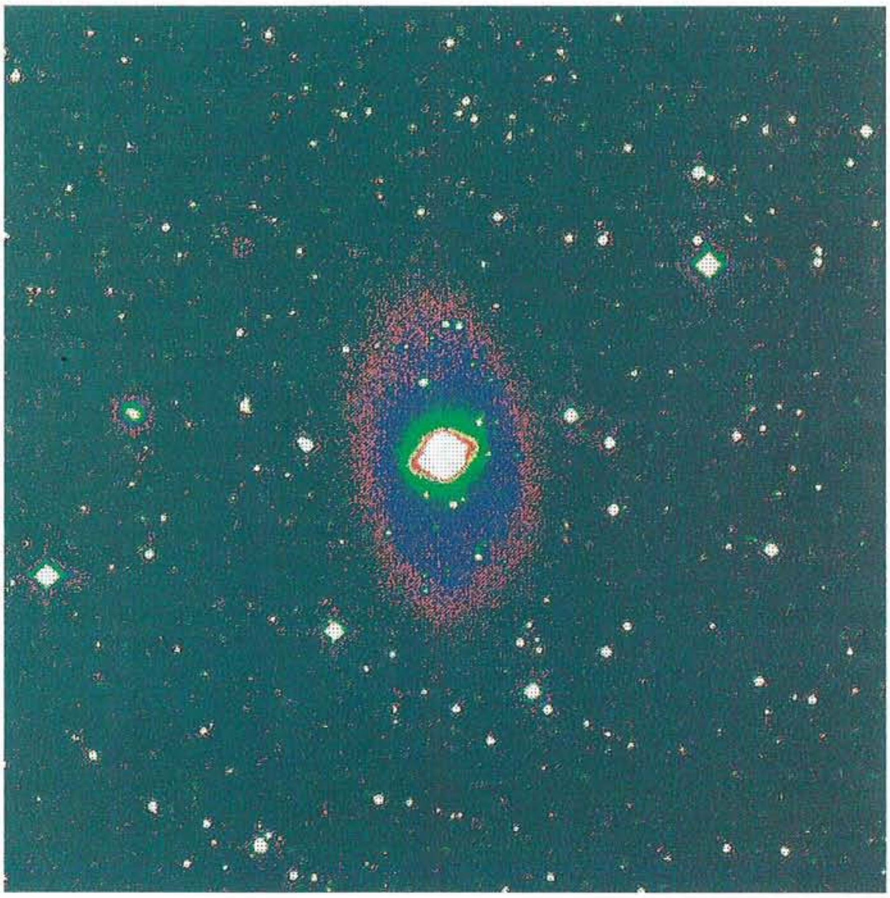


Figure 1: *False colour picture of the Red image of NGC 5365 = ESO 271-G08, as it is resident on the ESO-LV optical disk archive of 16,000 ESO-Uppsala galaxies. North is at the top, east to the left. The total NS extent of the picture is 10 arcmin. The green part of the galaxy corresponds to the half total light area. The purple outermost part extends to the 26th Blue isophote.*

Ident	Position	Type	Redsh	Magnitudes		SB		Colour		Dimensions			Orient		Grad	Dens	Ext
ESO	RA(1950)	type	cz	B_T	B_{25}	μ_e^B	μ_0^B	T	10″	D_e^B	D_{25}^B	D_{27}^B	a/b^0	p.a.^{0}	N_{oct}^B	N_{tot}	A_{BH}
NGC	DEC(1950)	sample	err	R_T	B_{26}	μ_e^R	μ_0^R	D_e	Δ	A_e^B	D_{26}^B	D_{90}^B	a/b^1	p.a.^{1}	N_{oct}^R	N_{Sp}	
445 0820	13 54 21	3.0	-	15.55	15.68	22.73	21.54	1.07	1.04	19.1	47	68	1.57	162.0	0.66	0.3	0.26
	-31 21.4	1 3	-	14.48	15.58	21.62	20.50	1.13	-0.12	15.1	61	48	1.30	169.3	0.82	0.3	
271 0070	13 54 25	0.0	-	15.30	15.39	22.35	21.77	1.58	1.28	28.5	62	90	3.00	53.0	0.83	0.6	0.70
	-47 02.0	2 3	-	13.72	15.34	21.10	20.49	1.21	0.40	20.7	77	58	4.29	54.8	0.73	0.3	
510 0220	13 54 25	2.0	6157	13.70	13.93	22.36	20.21	1.64	2.13	50.7	112	221	2.54	132.9	0.39	3.8	0.32
I 4350	-25 00.1	1 1	40	12.06	13.83	21.03	18.08	1.80	-0.12	34.3	162	172	2.16	134.4	0.29	2.5	
384 0180	13 54 26	1.0	4200	15.65	15.73	22.80	21.70	1.52	1.52	38.0	88	116	6.00	120.0	0.56	3.2	0.21
	-34 32.0	2 3	40	14.13	15.68	21.29	20.18	1.56	-0.11	16.8	105	82	3.65	118.8	0.77	0.6	
510 0230	13 54 27	-2.0	-	15.15	15.43	23.05	21.09	1.52	1.68	22.6	56	104	1.88	148.9	0.39	3.8	0.32
	-25 08.7	2 1	-	13.63	15.29	21.46	19.41	1.66	-0.21	18.0	80	90	1.64	150.3	0.33	2.9	
445 0830	13 54 28	6.0	-	16.06	16.19	23.20	22.59	1.52	1.55	67.6	122	174	15.00	50.0	1.01	2.9	0.22
	-27 56.9	2 3	-	14.54	16.12	21.84	21.04	1.47	-0.02	25.1	148	127	8.73	54.7	1.08	2.2	
510 0240	13 54 32	2.0	-	14.96	15.12	22.90	22.07	1.09	1.19	28.5	50	77	1.18	8.0	0.86	4.1	0.24
	-26 55.7	2 3	-	13.87	15.06	21.87	20.88	1.13	-0.05	26.3	60	57	1.18	8.0	0.96	2.9	
510 0250	13 54 43	2.0	11025	15.80	15.88	22.66	21.50	1.41	1.44	15.3	37	108	1.56	50.3	0.36	18.7	0.32
	-24 29.7	1 1	40	14.39	15.83	21.26	20.06	1.45	-0.10	13.6	45	35	1.83	45.7	0.30	-	
384 0190	13 54 44	-2.0	4211	13.66	13.93	22.58	19.91	1.56	1.60	30.5	79	176	1.20	92.1	0.35	13.0	0.21
	-33 58.5	1 2	40	12.10	13.76	20.99	18.32	1.59	-0.13	28.2	132	129	1.20	92.1	0.30	-	
271 0080	13 54 46	-2.0	2472	12.20^-	12.30	22.73	18.81	1.62	1.67	60.3	221	305	1.62	4.0	0.30	1.3	0.33
N 5365	-43 41.2	1 1	45	10.57^-	12.23	21.06	17.14	1.69	-0.06	44.7	269	216	1.14	173.1	0.23	1.0	
510 0260	13 54 46	9.0	-	15.49	16.29	25.09	23.36	0.49	0.85	60.3	58	-	1.65	20.8	0.78	2.9	0.30
	-25 32.9	2 2	-	15.00	15.88	24.49	22.50	0.72	-0.23	48.4	90	135	1.65	20.8	0.66	1.9	
325 0371	13 54 47	3.6	-	16.63^0	16.63	-	21.59	1.28	1.26	< 10	20	-	3.34	125.2	3.00	-	0.22
	-38 48.1	0 4	-	15.35	16.63	-	20.33	-	-	18.8	21	15	3.34	125.2	3.00	-	
325 0370	13 54 47	0.2	10810	15.91^0	16.03	-	21.34	1.28	1.35	< 10	27	45	1.16	119.9	0.54	0.6	0.22
	-38 47.9	1 4	119	14.63	15.96	-	19.99	-	-	17.0	36	28	1.16	119.9	0.54	0.6	
221 0190	13 54 51	7.4	-	16.23	16.51	23.86	22.58	1.15	1.01	27.5	46	76	2.00	148.0	0.91	2.2	0.72
	-47 48.4	1 4	-	15.08	16.33	22.95	21.57	1.01	0.12	19.7	62	60	1.85	148.9	1.21	1.6	
384 0200	13 54 52	2.0	-	15.37	15.47	22.51	21.25	-	1.39	29.2	79	-	4.67	144.0	0.43	1.0	0.24
	-35 47.7	1 3	-	-	15.41	21.17	19.86	1.32	-0.22	16.4	99	78	3.65	145.8	0.41	0.6	
510 0270	13 54 53	3.0	-	16.30	16.41	22.84	22.14	1.24	1.31	37.2	79	114	10.00	38.0	1.10	18.7	0.32
	-24 20.6	2 3	-	15.06	16.34	21.42	20.83	1.35	-0.25	14.0	98	78	4.32	36.8	1.35	-	
325 0380	13 55 00	6.0	-	14.90	14.97	23.06	21.96	0.80	1.17	31.6	63	79	1.38	20.0	1.44	0.6	0.26
	-40 35.0	2 3	-	14.11	14.92	22.28	20.79	0.95	-0.33	26.9	73	58	1.48	176.0	0.98	0.6	
384 0210	13 55 02	-2.0	4333	14.26	14.44	22.86	20.27	1.56	1.48	25.7	75	122	1.33	178.0	0.33	13.0	0.21
	-33 45.9	2 1	40	12.70	14.33	21.27	18.80	1.42	0.09	23.2	101	90	1.35	175.9	0.26	-	
445 0840	13 55 02	4.0	2661	12.61^-	12.73	22.99	19.98	1.50	1.69	162	359	519	6.67	17.0	0.40	1.3	0.16
I 4351	-29 04.3	1 2	8	11.12^-	12.66	21.54	18.29	1.72	-0.49	74.1	447	359	4.54	20.3	0.32	1.3	
510 0280	13 55 11	1.0	-	15.61	15.70	22.52	21.51	1.35	1.50	24.3	57	82	3.33	74.0	0.70	18.7	0.31
	-24 26.1	1 3	-	14.26	15.65	21.19	20.01	1.48	-0.33	14.8	70	54	3.01	74.4	0.43	-	
510 0290	13 55 11	3.0	-	15.41	15.47	22.56	21.74	1.36	1.17	26.0	58	75	2.50	123.0	1.39	4.1	0.30
	-25 46.8	1 3	-	14.04	15.42	21.46	20.57	1.23	0.05	19.5	68	52	3.33	123.4	0.92	2.5	
510 0300	13 55 12	6.4	-	15.90	15.98	23.04	22.21	-	-	25.4	48	64	2.20	130.0	1.20	2.9	0.21
	-27 33.1	1 4	-	-	15.92	-	-	-	-	18.4	57	46	2.12	130.8	-	2.2	
221 0200	13 55 13	-5.0	-	13.25	13.54	23.35	19.57	1.80	1.60	47.3	129	226	1.20	118.4	0.32	1.9	0.74
	-48 13.9	2 1	-	11.45	13.31	21.71	17.96	1.65	0.20	39.4	193	176	1.22	72.0	0.25	1.6	
325 0390	13 55 20	6.0	-	16.50	16.60	23.00	22.85	1.14	1.28	30.9	57	78	5.00	71.0	1.18	0.6	0.22
	-41 18.5	2 3	-	15.36	16.53	21.92	21.57	1.26	-0.28	20.7	68	56	8.56	73.7	0.82	0.3	
221 0210	13 55 23	7.0	-	14.90	15.00	22.56	21.81	1.51	1.69	39.8	82	117	3.20	172.0	1.64	1.9	0.74
	-48 16.9	2 3	-	13.39	14.95	21.12	20.12	1.62	-0.21	28.2	99	79	4.18	168.3	1.33	1.3	
384 0220	13 55 29	2.0	5071	13.59	13.65	21.94	20.06	1.76	1.68	39.8	111	157	2.50	88.0	0.47	13.0	0.22
I 4352	-34 16.5	1 2	40	11.83	13.62	20.15	18.38	1.73	-0.02	27.5	135	94	2.89	87.7	0.58	-	
510 0310	13 55 29	2.0	-	15.71	16.07	23.44	22.07	0.88	1.17	24.8	48	91	2.00	75.0	1.07	2.2	0.19
	-23 07.7	1 3	-	14.83	15.90	22.38	20.89	1.15	-0.25	19.7	69	88	1.70	70.7	1.13	1.9	
384 0230	13 55 34	-2.0	-	14.44	14.52	21.68	20.69	1.54	1.78	26.6	66	105	2.40	62.0	1.28	4.1	0.21
	-33 59.9	2 1	-	12.90	14.49	20.19	18.90	1.59	-0.06	18.4	81	57	2.39	60.1	0.87	1.3	
271 0090	13 55 35	0.5	2550	14.14	14.22	21.57	20.82	1.51	1.64	36.3	102	162	4.00	51.0	1.15	1.0	0.33
	-43 43.2	2 2	100	12.64	14.18	20.24	19.19	1.42	0.17	24.5	133	89	4.46	53.6	0.77	0.6	
445 0850	13 55 35	6.0	-	16.30	16.41	23.15	22.70	0.97	1.12	60.3	115	158	16.00	64.0	2.25	1.3	0.29
	-31 32.0	2 3	-	15.33	16.33	22.32	21.58	1.04	-0.22	25.1	140	115	6.69	64.6	1.16	1.3	
325 0400	13 55 40	-5.0	-	14.48	14.60	21.59	20.33	1.50	1.55	18.0	52	94	1.60	169.0	0.53	-	0.29
	-38 10.0	0 1	-	12.98	14.55	20.26	18.78	1.52	0.14	14.3	71	53	1.81	163.3	0.39	-	
325 0410	13 56 02	-0.2	1643	15.81	16.06	23.31	21.60	0.49	0.61	16.0	38	-	1.25	11.0	0.42	-	0.27
	-42 15.9	0 4	40	15.32	15.83	22.65	20.99	0.60	-0.24	14.3	60	49	1.25	11.0	0.37	-	
578 0110	13 56 18	4.0	9290	14.63	14.67	22.00	20.83	1.19	1.12	23.4	54	74	1.71	20.0	0.80	0.6	0.23
	-18 48.9	1 3	100	13.44	14.65	20.83	19.71	1.17	0.03	19.3	63	44	2.66	22.2	0.75	0.3	
325 0420	13 56 19	3.0	-	14.23	14.26	21.75	20.75	1.39	1.66	38.5	102	130	4.00	144.0	1.31	0.3	0.04
	-39 49.6	2 3	-	12.84	14.23	20.40	19.09	1.54	-0.34	24.3	120	82	4.43	144.9	1.00	0.3	
510 0320	13 56 38	3.0	-	16.00	16.26	24.06	22.69	0.61	1.18	29.5	48	73	1.55	24.5	0.35	5.4	0.26
	-25 19.5	1 3	-	15.39	16.09	23.41	21.50	0.79	-0.26	23.7	62	60	1.55	24.5	0.29	3.8	

with a scaled 'cluster count' = 13.0. For two systems without measured redshift our identifications were done on a positional basis.

An extensive discussion is given in the book on the selection effects and completeness. Various sub-samples were drawn from the total sample. Flags were defined to label these various samples.

In Table 1 we list the distribution over morphological types of the various samples, together with the number of available redshifts. In total, redshifts of 3576 galaxies, acquired from the literature, are present in the data base.

In summary, the resulting data bases include:

– A catalogue with *photometric standards,* at least one per survey field.

– A table with the *plate characteristics* of all 407 B and 407 R survey plates.

– A set of 28,218 B or R *images* with calibrated surface brightness and resident in FITS format on a set of two ESO optical disks, ready for direct access and display.

– A table with many *photometric parameters* – e.g., magnitudes, colours, dimensions, profile shapes and also including several environmental parameters.

This table is now available in several forms:

– An abstract in *printed version in the book.*

– An abstract in the IDM *data base computer at ESO.*

– The full table in *MIDAS table* format, resident on the ESO VAX computers, and also available on magnetic tape both in FITS format and in MIDAS table format.

We are now preparing some scientific papers describing the interesting statistical properties of the galaxy parameters. This will include also a discussion on the fundamental properties of early-type galaxies (bulge to disk ratios, isophotal twists in relation to the environmental conditions) and the role of central surface brightness in relation to morphological type, scale length and formation scenarios for late-type galaxies. A new Galactic extinction model for the Southern hemisphere, based on our own data, is also in preparation.

Copies of the book "The Surface Photometry Catalogue of the ESO-Uppsala Galaxies" by Andris Lauberts and Edwin A. Valentijn are available for sale at the European Southern Observatory. The price of the volume is DM 50,–.

Also, some copies are still available of "The ESO Uppsala Survey of the ESO(B) Atlas" at a price of DM 40,–.

Orders should be accompanied by prepayment and directed to the European Southern Observatory, Information Service, Karl-Schwarzschild-Str. 2, D-8046 Garching bei München, FRG.

Copies of the magnetic tape may be ordered from the Centre de Données Stellaires, 11, rue de l'Université, F-67000 Strasbourg.

References

Abell, G.O., Corwin, H.G., Olowin, R.P.: 1989, submitted to *Astrophys. J. Suppl.*

Corwin, H.G., de Vaucouleurs, A., de Vaucouleurs, G.: 1985. *Southern Galaxy Catalogue* = SGC (Univ. Texas Press, Austin).

Lauberts, A.: 1982, *The ESO/Uppsala Survey of the ESO(B) Atlas,* European Southern Observatory.

Lauberts, A., Valentijn, E.A.: 1983, *The Messenger* **34,** 10.

STAFF MOVEMENTS

Arrivals

Europe:

BERNOTAT, Petra (D), Secretary

JANSSENS, Lucas (B), Building Project Engineer

KÄUFL, Hans Ulrich (D), Infrared Instrument Scientist

MICELI, Donatella (I), Receptionist

PRUGNIEL, Philippe (F), Fellow

WALSH, Jeremy (GB), Fellow (Scientific Instrument Information Scientist ST-ECF)

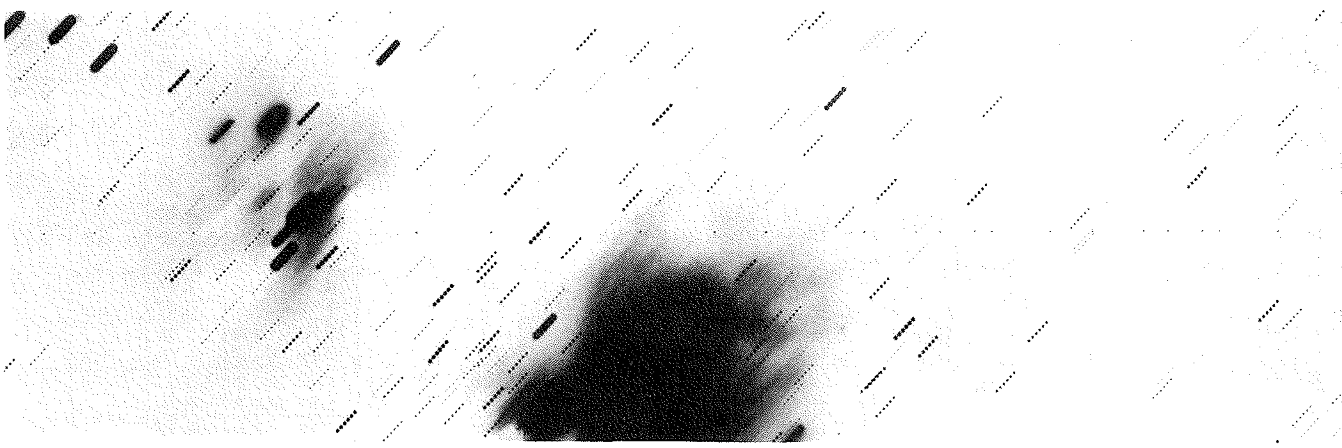
WENDORFF, Karl-Heinz (DK), VLT Project Civil Engineer

Departures

Europe:

SANSONE, Carlo (I), Remote Control Operator

Another "Flashing" Object!



On a multi-exposure GPO-plate, taken in Orion on January 2, 1989, at UT $1^h18^m–2^h23^m$, as part of a flare star project (Aniol et al., 1988, *The Messenger* **52,** 39), an unusual flashing object was found. Along the apparent path, 37 flashes are seen above plate limit (m_p = 17.2). The brightest ones have m_p = 13.3. The flashes belong to two overlapping long cycles. These in turn probably consist of seven short cycles with 3 flashes each, at times 43.6 %, 33.2 %, 23.2% of the total cycle time from the last flash of the previous cycle and from each other, respectively. In the second long cycle (assuming the object to enter from the west) the flash intervals occur in reverse order from the first cycle.

The intricate pattern of the flashes suggests an active source on a satellite or a reflected pulsed laser beam used in satellite tracking. A high flying plane can be ruled out on the basis of signal strengths and cycle times. The pattern was easily detected because all stars show multiple images, but it is doubtful that it would have been recognized on a single exposure plate. Several "new variables" might have been discovered instead.

The message is: the sky is getting dangerously polluted!

M. K. TSVETKOV, Westfälische Wilhelms-Universität, Münster, F. R. Germany

What's New Around Supernova 1987A?

S. D'ODORICO and D. BAADE, ESO

New Hints of Resolved Gaseous Emission from Circumstellar Material Surrounding the Supernova Location

The apparition of SN 1987A on February 23, 1987, in the Large Magellanic Cloud, the brightest SN in the last 3 centuries, provides a unique opportunity to test the theory of supernovae and also to follow for the first time the birth of the gaseous supernova remnant and to check the theory of the interaction of the radiation and the blast wave of the SN with the surrounding gas.

Two years after the event, evidence starts to become available on extended gaseous emission from ionized gas in the vicinity of the SN, based both on spectra and on direct imaging. Heathcote, Suntzeff and Walker (IAU Circular 4753) reported the detection of diffuse emission around the SN extending up to 2 arcsec in CCD observations on March 7, 1989 through broad band filters in good seeing.

On April 1, one of us (S.D.) observed the SN with EFOSC at the 3.6 m telescope in the light of B, V, R and through an interference filter centred on the [O III] emission line. One hour for these observations was kindly made available by J. Melnick.

The FWHM of stellar images in the original image (Fig. 1a) is 0.85 arcsec with a sampling of 0.34 arcsec/pix. The supernova is well separated from its two "companion" stars and extended emission is clearly detected between PA 320° and 360° at a distance of about 2 arcsec from the SN: the feature is not seen in the broad band filters which have slightly worse image quality.

In order to determine the position of the two stars and the supernova, we have deconvolved the image with an empirical point spread function (PSF) constructed from the images of 17 other stars in the rest of the frame. Figs. 1b and c show the effect of the deconvolution after 5 and 20 iterations, respectively. The astrometry was then done by fitting simple gaussians to the deblended stellar images. One should be aware that the ring-like structure which evolves around the supernova with increasing deconvolution (Fig. 1c) is an artefact which, however, occurs only if a point source is superimposed on an extended object. This is an additional hint that there is an extended component around the supernova.

In the next step, we have scaled the PSF by trial and error to best match the flux in the raw image. From the positional information and the flux scaling factors a synthetic image was constructed and subtracted from the raw data. The residuals are shown in Figure 1d. There are some artefacts which are due to the spatial truncation of the PSF and an imperfect compensation of the diffraction pattern of the secondary mirror support structure. Both effects occur because the PSF had to be constructed from much fainter stars than the supernova. There is no doubt that a highly significant extended emission in the [O III] band is present around the supernova (note that the stellar component of the SN almost certainly was considerably overcompensated). The stronger components seem to be aligned in the East-West direction but the farthest extension of the emission is seen to the North of the SN.

The results reported here are only preliminary, and we feel that additional observations under good seeing conditions are required for confirmation of the structural details. The presence of [O III] emission up to 2 arcsec from the SN is however proved beyond any doubts. A quick inspection of the R image suggests that diffuse emission is present at these wavelengths as well and it is particularly strong between position angles 270° and 300° within 2 arcsec from the SN.

We know from spectroscopic observations that the ionized gas is indeed there. A detailed study of the tiny, barely

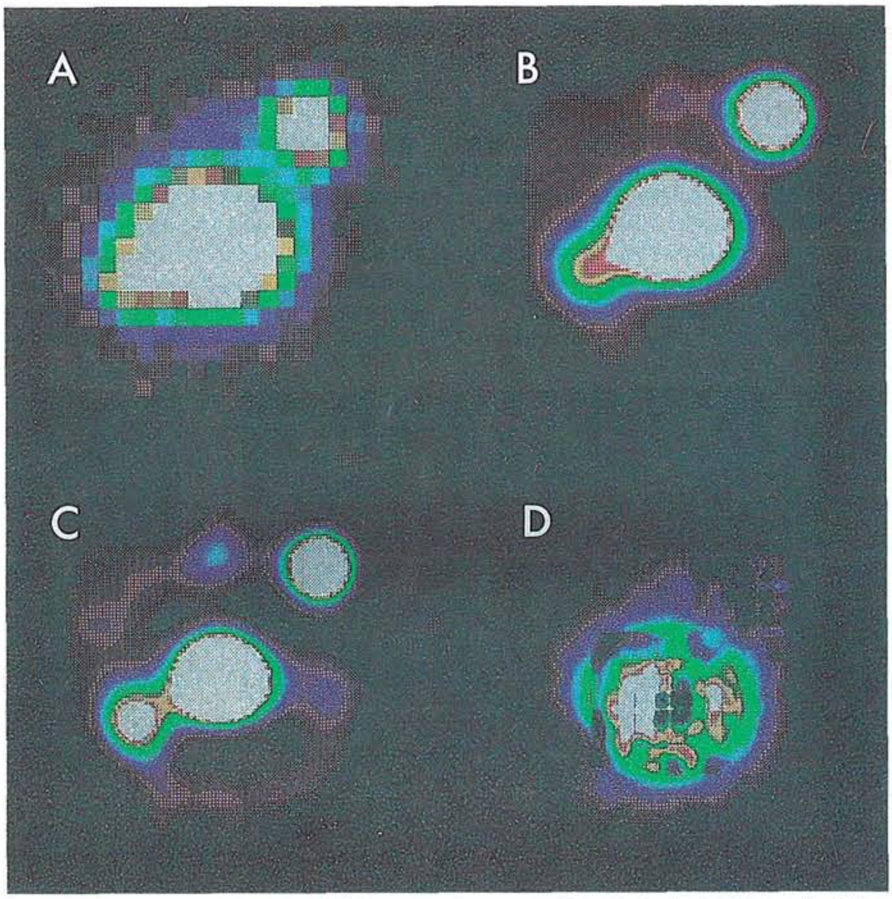


Figure 1: *Panel a: SN 1987A in a CCD image taken on April 1, 1989 with EFOSC at the 3.6 m telescope through a narrow filter centred at 5007 Å. The SN has a V magnitude of about 12.5, the companion star No. 2 is at 2.9 arcsec and PA = 320° and 2.5 magnitude fainter, the companion No. 3 is at 1.5 arcsec at PA = 120° and 3.2 mag fainter. Panel b: The same image after rebinning to a step of 0.2 the original pixel size and simultaneous deconvolution (5 iterations) with the point spread function. Panel c: Dito, except for 20 iterations. See text for a discussion of the ring structure. Panel d: The residual of the observations from the image reconstructed as described in the text. (This image was rebinned in a straightforward linear way to a step of 0.1 the original pixel size.) Apart from some artefacts explained in the text, there is significant extended emission around the supernova. – Note that all four figures have identical spatial scales and colour codings.*

resolved emission nebula around the SN has been carried out with the ESO echelle spectrograph by Wampler and Richichi (1988, *The Messenger* No. 52) and Wampler (1989, preprint). The emitting gas is likely to be the remnant of the stellar winds of the supernova precursor star and it appears unevenly distributed.

In March 89, three high resolution spectra (R = 60,000) were also obtained by S.D. with the CES spectrograph, linked via a fibre to the 3.6 m telescope, which provide additional information on the circumstellar gas. The aperture on the sky corresponds to 3.4 arcsec. A first spectrum was taken in the region of the interstellar NaI absorption lines. A cursory inspection shows no strong variations in the absorption components with respect to the spectra taken immediately after the explosion. Two more spectra were obtained at the strong [NII] and [OIII] emission lines (658.4 and 500.7 nm respectively) seen at a velocity of about 287 km/sec. The [NII] line shows a single, narrow component. The [OIII] line shows close to the main component of FWHM = 17 km/sec a much fainter one, of about the same width, blueshifted by 29 km/sec. On the red side of the main component a faint, broader component extends to about 90 km/sec. The velocity structure points to the presence of different components of highly ionized gas moving at different velocities.

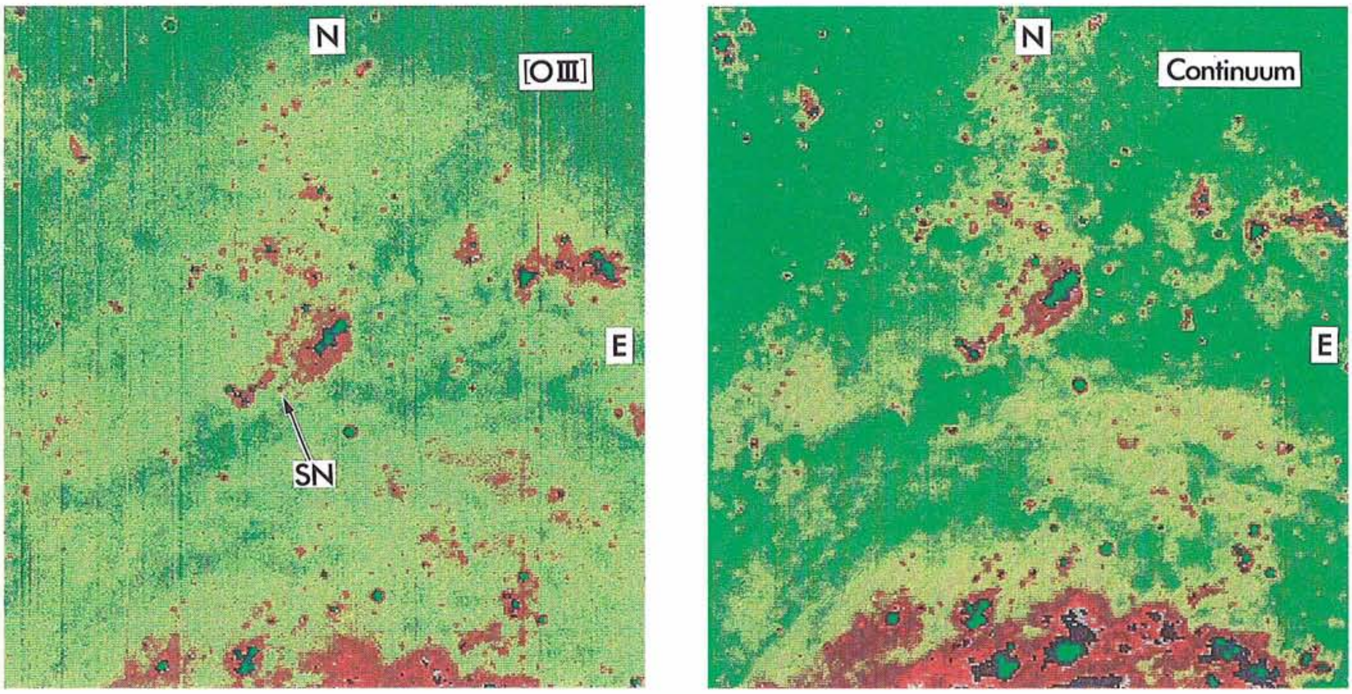
While the full interpretation of these features require more data, it is clear that a new, fascinating phase in the formation of the remnant of SN 1987A has started. Close monitoring of its evolution in the next year bears great promise of new interesting discoveries.

The Remnant of SN 1957d in M83

M. TURATTO, E. CAPPELLARO, Asiago Astrophysical Observatory, Asiago, Italy
I.J. DANZIGER, ESO

A pilot programme dedicated to studying previously reported extragalactic supernovae of advanced age (> 300 days) has had some early success with observations made at La Silla in April 1989. We report here the detection from direct imaging, and subsequent spectroscopy of the remnant of SN 1957d in M83. This galaxy has been a prolific producer of SNe this century (5 so far), and therefore offers a good opportunity for studying evolutionary effects in SNe of different types concentrated in a small area of sky. Unfortunately SN 1957d was not a well observed SN at early phases, and therefore neither the light curve nor the early spectroscopy was available to ensure an unambiguous classification. We now know that many SNe, as they age, develop strong lines of [OI] $\lambda\lambda$ 6300,63 or strong lines of [OIII] $\lambda\lambda$ 4959, 5007, and these characteristics facilitate detection by using narrow band filters to image objects in the light of these emission lines. Figure 1 shows the result of imaging of an area of M83 in the light of (a) [OIII] λ 5007 and (b) a nearby continuum wavelength with EFOSC on the 3.6 m telescope. The arrow points to the position of an object with enhanced brightness in the [OIII] λ 5007. This object coincides closely with the known reported position of SN 1957d.

Figure 2 shows a spectrum of this object, of approximately 20 Å resolution, resulting from a total exposure time of 200 minutes with the B300 grism in EFOSC. The most striking feature of this spectrum is the broad line blend of [OIII] $\lambda\lambda$ 4959, 5007. A weaker broad line feature due to [OI] $\lambda\lambda$ 6300,63 is also evi-



(a) (b)

Figure 1: *(a) Direct CCD image of M83 with narrow band filter isolating [OIII] λ 5007 emission. (b) Direct CCD image of M83 with narrow band filter isolating continuum emission.*

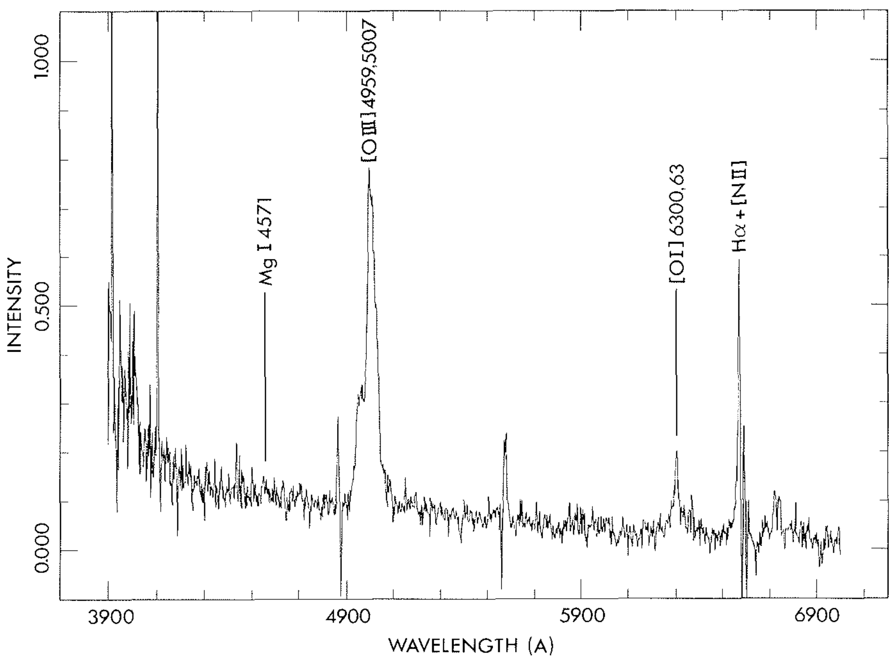


Figure 2: *Spectrum of SN 1957d. Wavelength identifies features discussed in the text, since the redshift of M83 is only 500 km s^{-1}.*

dent, as is a feature (not shown here) at 7320 Å presumably due to the [O II] λλ 7319,30 doublet. There is some weaker evidence that a feature corresponding to a blend of Hα + [N II] λλ 6548,83 has a broad component, although this is obscured by the imprecise subtraction of the overlying spectrum of narrow line H II regions in the vicinity of the object. There is also weak evidence for the presence of a line of MgI λ 4571. Other possible lines may be present and will be the subject of a more detailed analysis.

In a qualitative way the spectrum is similar to that of Cas A (320 years) and N 132 D in the LMC (~1500–2000 years) although the relative line strengths are different for the various remnants. Since we have not detected [O III] λ 4363 we are unable to establish an indicative temperature for the [O III] line emitting region. Thus at present we can only arrive at some lower limit for the mass of O^{++}. Nevertheless our measured flux of [O III] λλ 4959, 5007 $\sim 2 \times 10^{-15}$ ergs cm^{-2} s^{-1}, converted to an absolute flux for a distance of M83 = 3.7 Mpc, is not so different from that of Cas A, when account is taken of the uncertainties in reddening and distance.

More information is available by virtue of the high S/N in the [O III] λλ 4959, 5007 line. The width (FWHM) of the [O III] λ 5007 feature is ~2700 km/sec. In addition, the red wing of this line extends to ~4500 km/sec beyond the zero velocity position (+500 km s^{-1}) in the rest frame of M83. How this transforms into a determination of the real expansion velocity of the oxygen-rich material is complicated by the fact that the [O III] lines are clearly asymmetric with a velocity of the maximum emission of approximately −650 km s^{-1} relative to the rest velocity. [O I] λ 6300 also shows this effect, although possibly to a lesser degree.

It has been pointed out by Danziger, Bouchet, Gouiffes and Lucy (IAU Circ. 4746) that this asymmetry with a blue shift of the peak of the emission lines noted since September 1988 in the spectrum of SN 1987A is a characteristic created by the presence of dust filling the envelope or the line forming region. Other interpretations in the case of SN 1957d with the data currently available are possible if one concedes the possibility of large deviations from spherical symmetry. However, if dust is the cause, then a rather careful analysis of the possible, but not inevitable, effects of differential reddening will be necessary in order to ascertain to what extent relative line strengths are affected.

The ESO Exhibition Tours Europe

Following the successful presentation in The Hague (see *the Messenger* **55,** p. 37), the ESO Exhibition moved on to Münster (F.R. Germany), where the opening took place at the Westfälische Museum für Naturkunde on April 20, 1989. More than 100 invited participants listened to brief, introductory talks in the Planetarium of this beautiful, modern museum and then continued on a guided tour through the exhibition. It will be on display until June 4, and since the number of visitors to the museum normally reaches a maximum during the month of May, it is expected that well over 15000 persons will make use of this opportunity to learn more about ESO and modern astronomy.

The ESO Information Service has recently concluded the planning for the next 12 months; in view of the many invitations, the exhibition photos will be duplicated at the ESO photographic laboratories during the coming summer months. Upcoming stations now include Klagenfurt, Austria (June 23–August 27), Copenhagen, Denmark (October 31–January 3, 1990), Stuttgart, F.R. Germany (mid-November 1989–mid-February 1990) and CERN, Geneva, Switzerland (early March 1990–late May 1990). ESO material will also be shown in connection with various meetings and local activities, e.g. in Groningen (the Netherlands) on the occasion of the 375th anniversary of the Groningen University (first three weeks in June 1989); in Vienna (Austria) at the "World Tech Vienna" (June 18–22, 1989); in Montpellier (France) at the "Colloque Européen sur l'Astronomie et l'Espace" (September 20–23, 1989). Further exhibitions are being planned for 1990 in other cities, mostly in the member states, but also in Austria and Portugal.

Moreover, it has been decided that ESO will have an information stand at the European Symposium of Hypersonics, which will take place at the European Patent Office in Munich, on July 13–14, 1989. This symposium, which is concerned with the solutions to known technological problems and also addresses social, economical and environmental aspects of hypersonics, will serve to promote contacts and cooperation between aeronautical/astronautical professionals and students in Europe. It is organized by the EUROAVIA association with domicile in Munich. This meeting offers a good opportunity for ESO to make itself and its wide spectrum of activities better known to specialists from academic institutions and industry, working in an important neighbouring high-technology field.

Near Infrared Spectrophotometry of Mars at ESO

TH. ENCRENAZ[1], P. BOUCHET[2], E. LELLOUCH[1] and J. ROSENQVIST[1]

[1] Observatoire de Paris, Meudon, France; [2] ESO

In spite of an extensive space exploration programme during the seventies, the planet Mars still raises several unresolved questions about the aeronomy of its atmosphere, the composition of its surface, and, more basically, the whole history of the planet. Infrared spectroscopy has proven to be a major tool for these studies, as illustrated recently by the discovery of HDO at 3 μm and the measurement of the deuterium abundance (Owen et al., 1988). Infrared spectroscopy between 1 and 5 μm is well adapted to the study of the martian atmosphere, as strong vibration bands of several atmospheric compounds (carbon dioxide, the major component, and minor constituents such as H_2O and CO); it is also well suited, even with a low resolving power, for the study of mineralogic signatures of the martian surface (olivine, pyroxene, hydrated minerals, carbonates and other salts . . .).

Mars is going to be the major target of space planetary exploration in the forthcoming decade. Mars Observer, planned by NASA for 1992, and the Mars-94 and forthcoming missions planned by the Soviet Union are part of an intense international effort aiming at a martian sample return by the end of the century. In spite of the recent failure of the soviet Phobos mission, a few days before its approach of the martian satellite Phobos, a major first step has been achieved with the two months observation of Mars from this spacecraft in February and March 1989. In particular, about 40,000 infrared spectra of the planet – in addition to a few hundreds of the Phobos satellite – have been recorded by the ISM experiment 0.76 and 3.16 μm, with a resolving power of 60 and a signal-to-noise ratio close to a thousand (Bibring et al., 1989).

In preparation and support to the ISM experiment, a ground-based coordinated effort was undertaken in 1988, taking advantage of the extremely favourable configuration of the September 1988 opposition. Visible and infrared images (using IRAC in particular) were recorded, for monitoring the dust activity; CO was observed in the millimetre range at IRAM and SEST, and in the infrared range at CFHT (Encrenaz et al., 1989).

At ESO, infrared spectrophotometry was achieved at the 1 m telescope between September and December 1988, in the 1.4–2.4 μm and 2.8–5.2 μm ranges. The objectives of this study were (1) to provide an additional absolute calibration to the ISM instrument; (2) to make absolute measurements of the albedos and surface temperatures in a given set of locations and (3) to obtain measurements or estimates of the gaseous abundances (CO_2, CO and H_2O), just before the beginning of the Phobos mission.

The Observations

Spectra of Mars were recorded during 7 nights from September 30, 1988 (two days after opposition) to December 24, 1988, using the InSb spectrophotometer of the 1 m infrared telescope of La Silla, with the 3 circular variable filters (1.4–2.4 μm, 2.8–4.2 μm and 4.5–5.2 μm). The CVF resolving power is about 60. The aperture diameter was 4 arcsec and the chopping throw was 30 arcsec in the east-west direction.

At the time of our observations, the south pole of Mars was observable, and the north pole was hidden; the latitude of the sub-Earth point was close to −20°. The angular diameter of Mars ranged from 23″5 in September to 10″3 at the end of December 1988. In most of the cases, for a given spectral range, three spectra of Mars have been recorded each night, at the centre of the disk, in the northern region (latitude of about +25°) and in the south pole region. Our aperture corresponded to a region of about 1500 km on September 30, and about 3400 km on December 24 at the centre of the disk.

Taking into account the diaphragm size, the exposure time of each spectrum and the rotation of the planet, the longitude extent of the region observed at the centre is about 35°.

During each exposure, the tracking was achieved on the visual image of the disk, sent to a TV camera through a dichroic plate.

The Infrared Spectrum of Mars

As for any Solar System object, the near-infrared spectrum of Mars is a combination of the reflected sunlight component and the thermal emission of the planet itself which increases at longer wavelengths. Apart from the gaseous and solid signatures, the continuum spectrum of Mars is thus expected to be, at first approximation, the combination of two blackbody curves, at 5770 K and 220–290 K, respectively. The thermal component starts to be im-

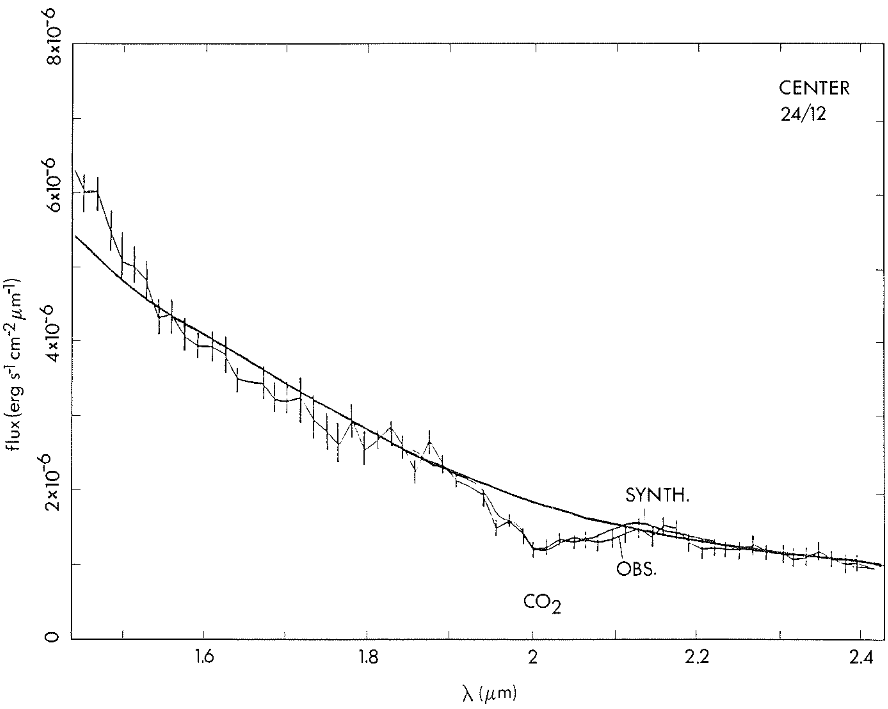


Figure 1: *Spectrum of Mars recorded between 1.4 and 2.4 μm on December 24 at the disk centre. The synthetic curve is calculated for a CO_2 pressure of 7 mb and an airmass factor of 2.*

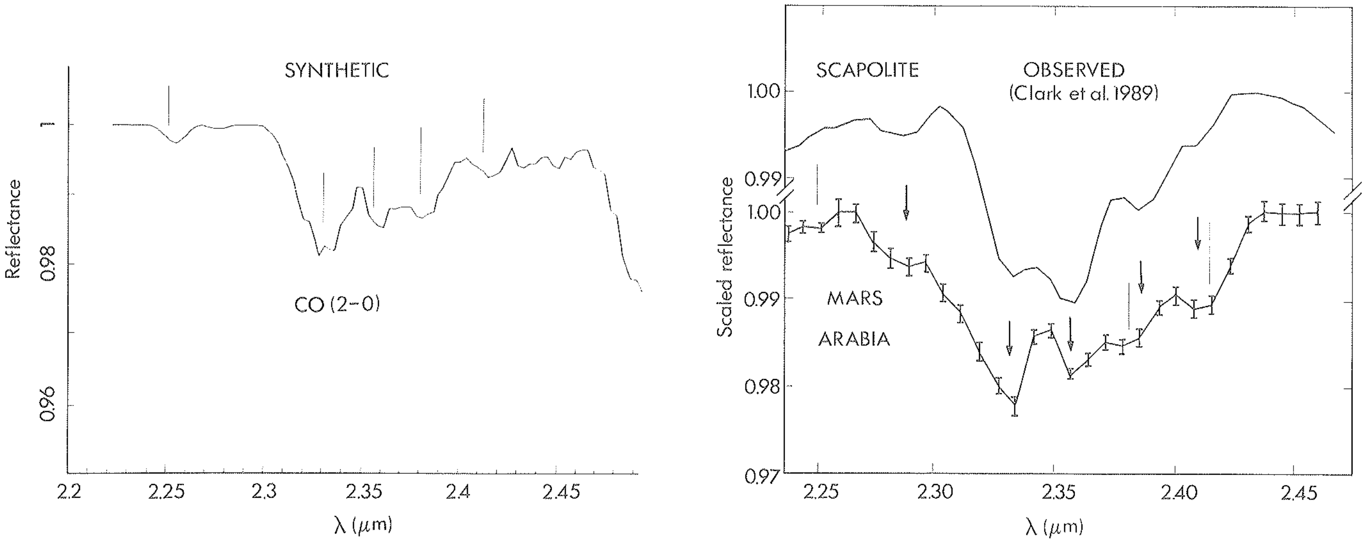


Figure 2: *Synthetic spectrum of the 2.35 μm region, showing absorption by the (2-0) band of gaseous CO. Data of Clark et al. (1989) are shown for comparison. The synthetic curve is calculated for CO/CO_2 = 0.001 and an airmass factor of 2.*

portant above about 3.5 μm, and gives a precise measurement of the surface temperature of the observed area.

A critical problem for understanding the infrared spectrum of Mars is to separate the gaseous and solid signatures. In order to discriminate between these two contributions, the atmospheric absorption spectrum of Mars has been modelled, including the contributions of CO_2, H_2O and CO, for the reflected and thermal components. A statistical band model was used (Goody, 1964; Wallace et al., 1977) with the spectroscopic data of the GEISA bank (Husson et al., 1986; Chedin et al., 1986). In the reflected sunlight component, the absorption depth is basically a function of the column density of the absorber; in the thermal component, the absorption is generally much weaker, and is a critical function of the column density of the absorber; in the thermal component, the absorption is generally much weaker, and is a critical function of the thermal profile. As a consequence, the reflected part of the spectrum, below 3.5 μm, is better suited for an analysis of the features, either of atmospheric or mineralogic origin.

The 1.4–2.4 μm Region

Figure 1 shows a spectrum of Mars recorded on December 24, 1988 at the disk centre, between 1.4 and 2.4 μm. A solar blackbody curve is shown for comparison. It can be seen that the albedo of Mars decreases by about 10 % as the wavelength increases. The broad absorption band around 2.0 μm is due to CO_2 and is well fitted with a CO_2 pressure of 7 ± 1 mb. Watervapour might be marginally present at 1.85 μm; an upper limit of about 3 cm-Am is derived, which corresponds to a H_2O/CO_2 ratio of $3\ 10^{-4}$, in reasonable agreement with previous estimates. Carbon monoxide has a band at 2.35 μm, but the quality of our data is not sufficient for identifying it. However, it has to be noticed that, under nominal conditions (CO/CO_2 = 0.001), the CO absorption band has a depth of a few per cent (Fig. 2). Gaseous carbon monoxide is most likely responsible for the absorption feature reported and tentatively identified as scapolite (Clark et al., 1988, 1989). Figure 2 shows that a good fit is obtained for a CO/CO_2 value of 0.001 and an air mass factor of 2, assuming a CO_2 surface pressure of 7 mb. This CO value falls within the range of the CO mixing ratios derived in the past from infrared (Kaplan et al., 1969) or millimetre (Lellouch et al., 1989) observations.

The 2.8–5.2 μm Spectrum

In this spectral range, the Mars spectrum is the sum of the reflected and thermal components. The relative intensities of these two components depend upon two factors, the albedo of the observed region and its temperature. If the region is dark and/or warm, the thermal component dominates at long wavelengths; this is illustrated in Fig-

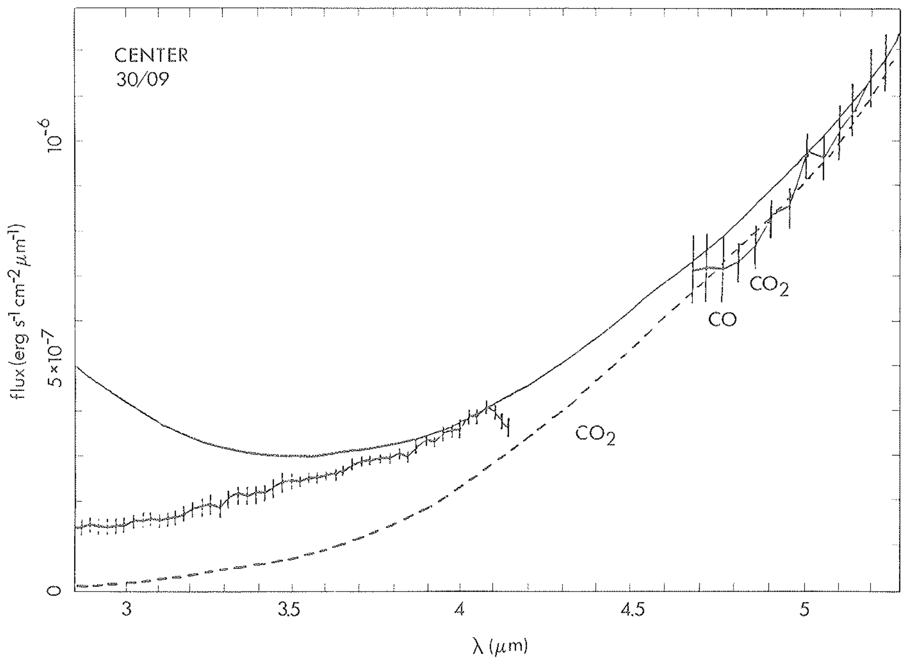


Figure 3: *Spectrum of Mars at the disk centre recorded on September 24 between 2.8 and 5.2 μm. The solid line is the retrieved continuum, sum of a blackbody at the surface temperature and a solar blackbody at 5770 K. The lower curve is the thermal component only.*

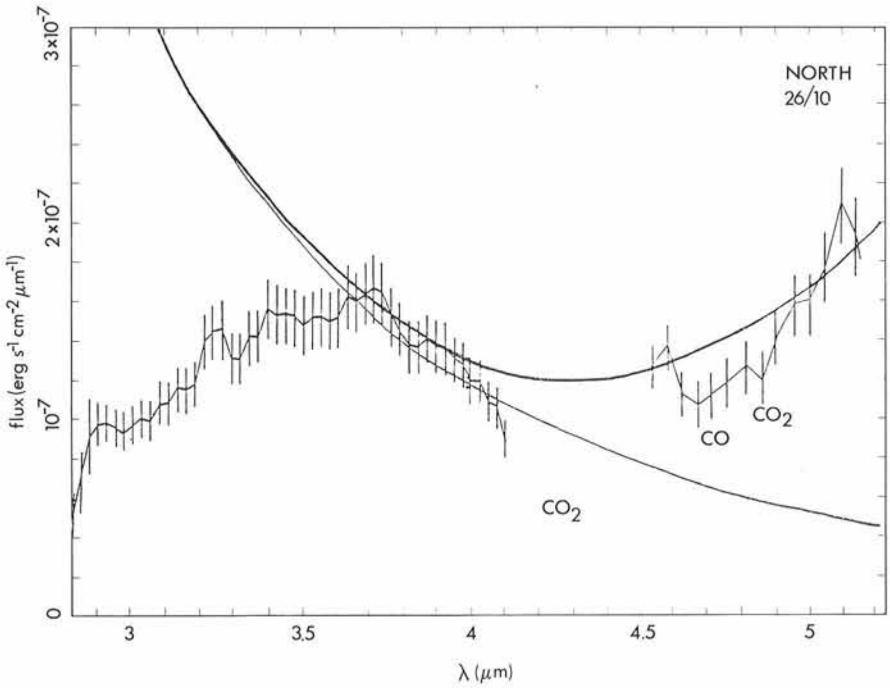


Figure 4: *Spectrum of Mars in the northern region, recorded on October 26 between 2.8 and 5.2 μm. The solid line is the retrieved continuum, sum of a blackbody curve at 5770 K. The lower curve is the reflected component only.*

ure 3. If the region, in contrast, is bright and/or cold, the reflected component dominates at short wavelengths, as illustrated in Figure 4. Albedos and temperatures have been measured from the 2.8–5.2 μm spectra of 15 different areas (see Table 1). An important characteristic of the Mars spectra in this spectral range is the strong and continuous absorption in the 3–4 μm region (Figs. 3 and 4), already identified as hydrated material by previous authors (Houck et al., 1973; Pimentel et al., 1974). The absorption depths of the observed areas is also listed in Table 1.

Between 4.2 and 4.5 μm, the terrestrial atmosphere is opaque, due to the strong CO_2 band at 4.25 μm. However, weaker CO_2 bands are also present between 3.5 and 4.2 μm, and have to be carefully subtracted for a proper analysis of mineralogic features. These features are marginally visible in Figure 3, but were observed with a very good signal-to-noise ratio by Blaney and Mc Cord (1989) who suggested the presence of S-H mineralogic compounds. Assuming an airmass factor of 2, we derive for Blaney and Mc Cord's data a CO_2 pressure of 7 mb in very good agreement with independent estimates.

Beyond the strong CO_2 band at 4.3 μm, other atmospheric bands can be detected: CO_2 at 4.85 and 5.15 μm, CO at 4.7 μm. A remarkable result is the apparent depletion of CO in the spectra of the South pole area.

TABLE 1: *Characteristics of Mars Spectra*

Spectrum	Surface Temperature	Albedo	Depth of hydrated silicated (2.8 μm)	Longitude	Latitude
Centre, Sept. 30	291.5	0.30	72%	268	−22
Centre, Oct. 20	283.0	0.43	81%	86	−24
Centre, Oct. 21	286.0	0.31	73%	80	−24
Centre, Oct. 26	283.0	0.31	81%	375	−24
Centre, Nov. 23	286.0	0.33	70%	102	−26
Centre, Dec. 24	272.0	0.39	70%	157	−25
North, Sept. 30	225.0	0.27	80%	282	27
North, Oct. 20	245.0	0.43	82%	100	25
North, Oct. 26	240.0	0.30	87%	27	25
North, Nov. 23	250.0	0.45	82%	123	15
South, Sept. 30	245.0	0.22	80%	294	−72
South, Oct. 20	240.0	0.26	78%	112	−72
South, Oct. 21	250.0	0.26	82%	96	−72
South, Oct. 26	267.0	0.33	84%	38	−72
South, Nov. 23	250.0	0.29	91%	140	−68

Conclusions

In conclusion, infrared spectroscopy of Mars between 1 and 5 μm is a powerful means for studying both the planet's atmosphere and mineralogy. A careful analysis of the atmospheric absorption features has to be performed to make possible the identification of possible weak mineralogic signatures. Finally, substantial information is expected from the data recorded by the ISM-Phobos experiment in February–March 1989, on both the atmosphere and the mineralogy of the planet. In particular, the CO and H_2O mixing ratios, and eventually their vertical profile, will be investigated; mineralogic features should be detectable at a level of about 0.1%. In support of the future space exploration of Mars, ground-based observations will be especially useful beyond 3 μm with infrared cameras combining both spatial and spectral resolutions.

References

J.P. Bibring et al.: 1989, submitted to *Nature*.
D.L. Blaney and T.B. McCord, Proceedings of the Forth International Mars Conference, Tucson, January 1989, p. 71.
A. Chedin, N. Husson, N. Scott, I. Cohen-Hallaleh and A. Berroir: 1986, Internal Report No. 127, Laboratoire de Météorologie Dynamique.
R.N. Clark, G.A. Swayze, R. Singer: 1988, *BAAS,* **20,** 849.
R.N. Clark, R.B. Singer, G.A. Swayze and A. Tokunaga: 1989, Proceedings of the Fourth International Mars Conference, Tucson, January 1989.
T. Encrenaz, F. Billebaud, E. Lellouch, F. Combes, M. Gérin, J.P. Maillard, G. Paubert: 1989, Proceedings of the 22nd ESLAB Symposium "Infrared spectroscopy in Astronomy", Dec. 6–10, 1988, Salamanca.
R.M. Goody: 1964, *Atmospheric Radiation,* Oxford Clarendon Press.
J.R. Houck, J.B. Pollack, C. Sagan, D. Schaack and J.A. Decker: 1973, *Icarus,* **18,** 470.
N. Husson, A. Chedin, N. Scott, D. Bailly, B. Graner, N. Lacome, A. Levy, C. Rossetti, G. Tarrago, C. Camy-Peyret, J.M. Flaud, A. Bauer, J.M. Colmont, N. Monnaneuil, J.C. Hilico, G. Pierre, M. Loete, J.P. Champion, L.S. Rothman, L. Brown, G. Orton, P. Vanarasi, C. Rinsland, M. Smith and A. Goldman: 1986, *Annales Geophysicae,* **2,** A, 1986.
L.D. Kaplan, J. Connes and P. Connes: 1969, *Astrophys. J.,* **157,** L187.
E. Lellouch, M. Gerin, F. Combes, S. Atreya and T. Encrenaz: 1989, *Icarus,* **77,** 414.
G.C. Pimentel, P.B. Forney and K.C. Herr: 1974, *J. Geophys. Res.,* **79,** 1623.

Search for Dark Matter Around Neptune

B. SICARDY, A. BRAHIC, Université Pierre et Marie Curie et Observatoire de Paris, Meudon, France

Introduction

On August 25, 1989, the Voyager 2 spacecraft will point its instruments to the presently most remote planet of the solar system. As the probe grazes the upper layers of Neptune's atmosphere, planetary science will take a step forward. This event is eagerly awaited by the scientific community, and as shown below, is a new example of how Earth-based and space observations complement each other.

Intense efforts in the last decade have been undertaken to better understand the structure, composition and environment of the giant planets. High quality observations and new theoretical works have shown that the giant planets store part of the memory of the solar system. This is true in particular for the rings encircling each of these bodies. In spite of the fact that the rings contain a very small fraction of the mass of the central planet, they exhibit an amazing variety of physical processes, which are precious clues to the dynamicist. A few examples should convince the reader:

– Space data have revealed in rings important mechanisms like spiral waves, strong confinement, sharp edges, particle size distribution, electromagnetic forces, dust production, and ring-like arcs in the vicinity of the four giant planets.

– The above mechanisms are not only important for better understanding the origin and evolution of planetary rings, but they are also common to many other astrophysical objects more difficult to observe. For instance, the galaxies often exhibit spiral structures akin to those observed in Saturn's rings. Accretion disks are thought to be submitted to the same kind of "shepherding mechanism" at work among Uranus' rings. In that sense, the circumplanetary disks are extremely important natural laboratories where new theories can be tested.

– Whether the rings are young or not, compared to the age of the solar system, they certainly experience today some processes at work during the early stage of solar system formation. The rings lie inside the Roche limit of the central planet, so that tidal stresses prevent the particles from accreting into a single small satellite. In other words, we are lucky enough to replicate today some of the conditions prevailing in the primordial collisional planetesimals swarm.

The Stellar Occultation Technique

Except for the case of Saturn's rings, the search and study of circumplanetary matter is extremely difficult from direct ground-based imagery. For instance, Neptune is only 2.3 arcseconds in diameter as seen from the Earth, with a visible magnitude brighter than 8, while its rings lie within less than one second of arc of the limb, with a magnitude fainter than 18! In such conditions, imaging the rings is a challenge . . . However, a powerful tool has been developed two decades ago, namely the stellar occultation technique.

While the planet moves in the sky, due to its orbital motion, it may block the light of a star and an "occultation" occurs (Fig. 1). This technique has been developed and used extensively by a group at Paris Observatory since the early 70's (M. Combes, J. Lecacheux, L. Vapillon), to observe among others occultations by Jupiter, asteroids and comets. In the early 80's, a systematic programme of observations of stellar occultations by Uranus and Neptune was set up by the authors in Paris, first to prepare for the Voyager encounters with the respective planets, but also to answer, at least in part, the many questions raised by the Voyager observations of Saturn's rings. Similar observational efforts were made at Cornell University (P.D. Nicholson, Ithaca), Massachusetts Institute of Technology (J.L. Elliot, Cambridge), California Institute of Technology (K. Matthews, Pasadena), University of Arizona (W.B. Hubbard, Tucson) and Lowell Observatory (L.H. Wasserman and R.L. Millis, Flagstaff).

The occultation of a bright star (e.g. one of the SAO catalogue) by a planet is actually quite a rare event, and several decades are necessary for such a coincidence to occur. However, the advent of fast infrared photometry in the late 70's increased the frequence of observ-

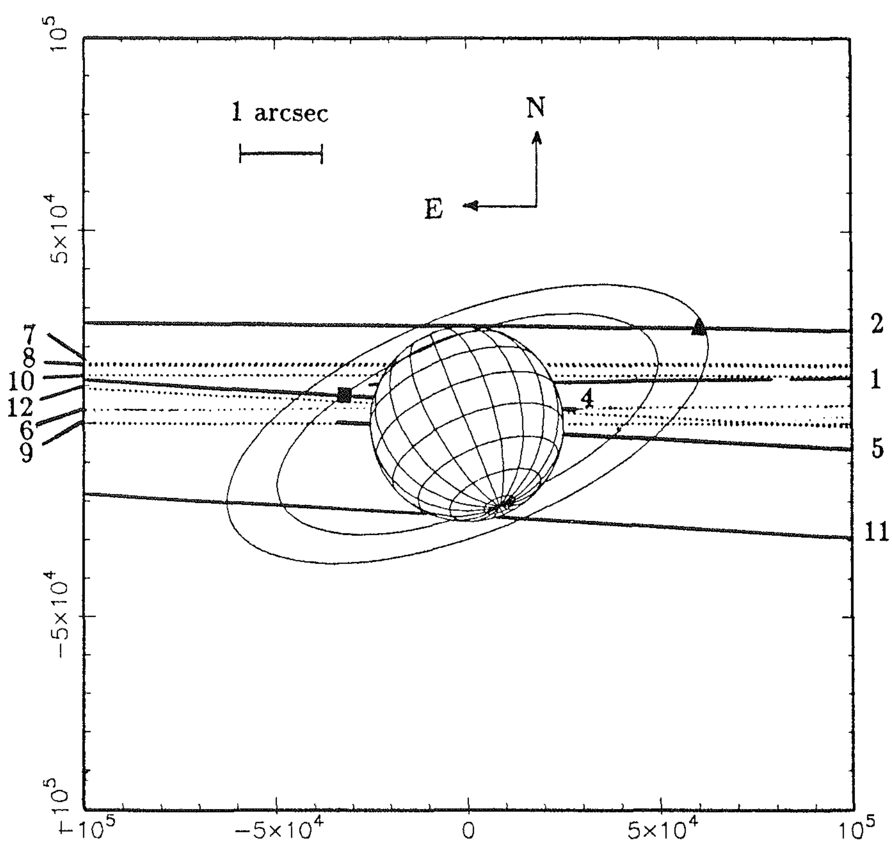


Figure 1: *Tracks of stars for different occultations observed by the Paris Observatory group between 1983 and 1987. Tracks 2, 5, 6, 8 and 11 were observed from ESO, the rest were observed from the Canada-France-Hawaii telescope, Brazil and Pic du Midi. Solid lines indicate observations with high signal-to-noise ratio. The triangle indicates the position of the arc observed on July 22, 1984 at ESO and Cerro Tololo, while the square gives the position of the arc observed on August 20, 1985 from CFHT (Mauna Kea, Hawaii). The distances on the axes are in kilometres, projected in the sky plane at the level of Neptune.*

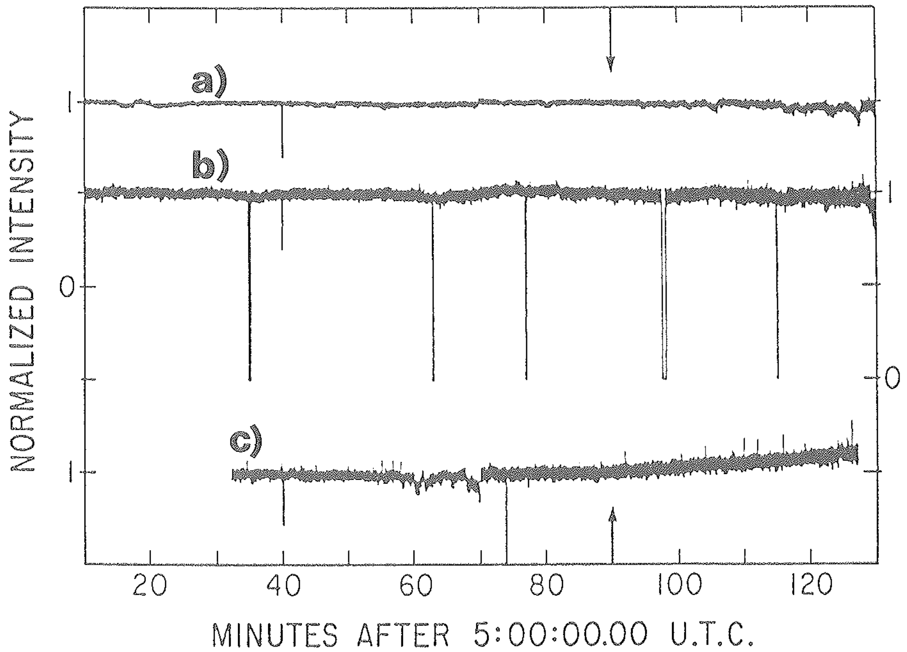


Figure 2: *Recordings made from ESO and Cerro Tololo on July 22, 1984. Curve a: 1 m ESO telescope (2.2 μm); curve b: 0.5 m ESO telescope (0.9 μm); curve c: 0.9 m Cerro Tololo telescope (0.9 μm). All three telescopes recorded a dip of signal around 5 h 40 mn U.T., while no corresponding event was observed when the star crossed the arc's orbit again (arrow).*

able occultations to *several per year.* This is because all the giant planets exhibit strong methane bands in the near infrared, so that their albedo is reduced by several orders of magnitude in these bands (0.9 μm, 2.2 μm), while the star is essentially unaffected by these absorption bands. Consequently, the contrast of the occultation (fractional drop of signal when the star disappears behind the planet), is accordingly increased.

Many spectacular applications of stellar occultations have been made. The most obvious quality of this technique is its high spatial resolution. The latter is ultimately limited by diffraction of light on the edge of the occulting bodies and by the stellar diameter projected at the distance of this body. Both effects give typical resolutions of 4–20 kilometres at the distance of Neptune, i.e. an angular separation of 0.5 millisecond of arc! Consequently, the occultation technique is presently the most accurate method to derive the shape of the occulting bodies, and extract important parameters like the radius, oblateness, irregularities of the limb, etc. . . .

Also, the stellar flux observed from the Earth is extremely sensitive to small deviations due to a tenuous atmosphere. In particular, the temperature profile of the planet's upper stratosphere (1 to 10 μbar) may be inferred, together with the turbulent properties of this atmosphere. No other technique, including space observations, is presently able to compete with stellar occultations for studying such a dilute atmosphere. We shall also mention here the recent discovery of Pluto's atmosphere to illustrate the efficiency of the occultation technique (Hubbard et al., 1988, Elliot et al., 1989).

Finally, the occultation method is able to detect a very small amount of material orbiting the planet. Any drop of signal, observed before or after the occultation by the central body, may betray the presence of a small body, otherwise invisible in the glare of the planet. This method has been used with success for Neptune. An active collaboration among the different groups involved in this programme has allowed the elimination of spurious events, and to cross-check the real ones! This also tightened the links between colleagues observing at Cerro Tololo, Las Campanas, and the ESO La Silla observatories.

Dark Matter Around Neptune?

The history of the elusive Neptune rings is spotted with ups and downs, partly caused by the behaviour of these strange structures, and also by terrestrial difficulties (see the article by A. Brahic and W.B. Hubbard in the *Sky and Telescope* issue of June). The first recorded observation of a stellar occultation by Neptune occurred on April 7, 1968, when the bright star B.D. −17°4388 disappeared behind the planet. As several stations observed the event, an accurate radius and oblateness of the planet could be derived (Kovalesky and Link, 1969). More than ten years later, and after the discovery of the narrow rings of Uranus, an exhumation of the data led Guinan and Shaw to the conclusion that some dips observed in the 1968 lightcurve could have been caused by a ring orbiting close to the planet, at less than 10,000 kilometres from the planet's stratosphere (see the *Sky and Telescope* issue of August 1982).

However, an observation from Australia in August 1980, and a subsequent one from Chile (Cerro Tololo) in May 1981 did not reveal any rings (Elliot et

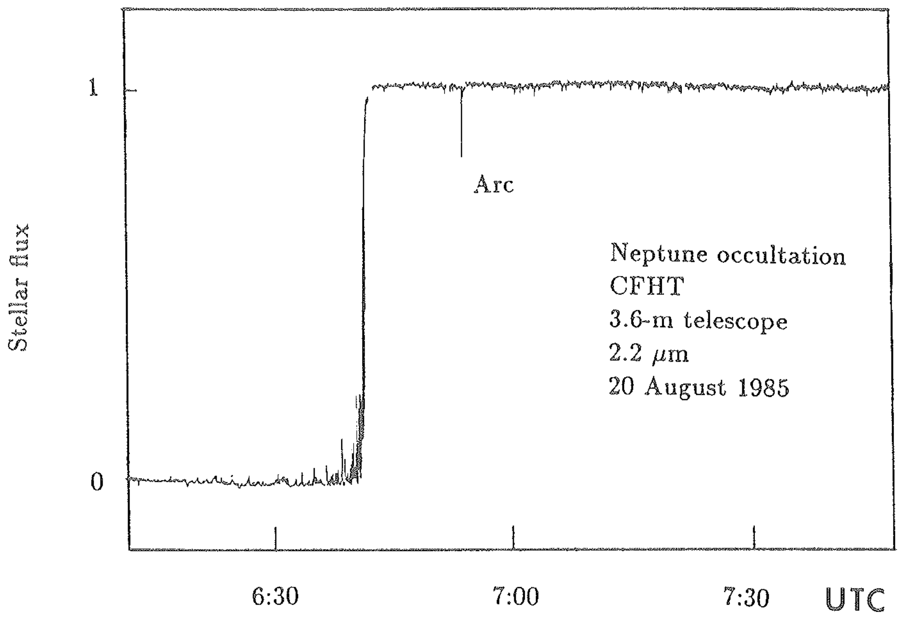


Figure 3: *A second arc was discovered on August 20, 1985 from the Canada-France-Hawaii telescope (Mauna Kea, Hawaii). Simultaneous observations made at ESO and Cerro Tololo show no event on the other side of the planet.*

al., 1981). In the meantime, an observation made from two telescopes in Arizona in May 1981, showed a coincident interruption of signal, while no such dip was observed in Flagstaff, only 600 kilometres away. The conclusion was then that the event had been caused by a new satellite of Neptune, 180 kilometres in diameter (Reitsema et al., 1982). Several other "isolated events" (i.e. observed with only one telescope, and thus not firmly established), were reported in subsequent observations, casting some confusion as to the existence or non-existence of Neptune's rings.

A very favourable observation made on June 15, 1983, from different stations scattered around the Pacific Ocean (Australia, Tasmania, Hawaii, China) showed no suspect events, besides the occultation by the planet, of course! The high signal-to-noise data obtained at the Canada-France-Hawaii Telescope put an upper limit of 300 metres for the width of any continuous opaque rings of Neptune, and an upper limit of 0.006 for the normal optical depth of diffuse rings of the planet (Sicardy et al., 1986).

As the observations of Neptune's surroundings were refined, and hope for detecting rings faded, it became more difficult to obtain telescope time for observing such events. However, the persistence of the Paris and Tucson group made possible simultaneous observations of an occultation of a bright star by Neptune on July 22, 1984, with two telescopes at ESO and one telescope at Cerro Tololo. The star actually missed the northern limb of the planet (see track 2 in Fig. 1), so that no occultation was observed, but all three telescopes recorded a dip in the signal, with virtually the same profile and same timing (Fig. 2). A careful analysis and comparison of the data by the Paris and the Tucson groups led to the conclusion that the event was due to an incomplete ring of Neptune (Hubbard et al., 1986). The basic reasons for such a conclusion are the following:

– The event was observed at the same time in the three curves, with identical shape. This ruled out spurious events due to bad seeing or electrostatic discharges.

– The width of the event corresponded to a 15 km wide body at the level of Neptune, while the distance between the two stations implied a 100 km long object. Unless a very improbable configuration took place, the dip could not have been caused by a spherical satellite of Neptune.

– The shape of the dip was compatible with the diffraction pattern of light caused by a body at the distance of Neptune, ruling out the possibility of an occultation by a closer object (like an asteroid in the main belt for instance).

– The slight time delay between the two stations put the segment of ring aligned with an equatorial ring of the planet, projected in the plane of the sky, thus confirming that the structure was probably associated with Neptune.

– The absence of dip when the star again crossed the orbit of the supposed arc ruled out the possibility of a continuous ring (Fig. 2). This was in any case known from previous high-quality data (see above).

From these arguments we could conclude that Neptune was orbited by a ring-like arc, at 67,000 km from the planet's centre (2.6 Neptunian radii), 15 kilometres in width, at least 100 kilometres in length, and 40% in optical depth.

This detection led to a renewal of interest in Neptune occultations. Search for infrared sources in the path of the planet were again supported, and led to new catalogues of events, in particular by Philip Nicholson, from Cornell University. In June 7, 1985, a double star was occulted by Neptune, and the event was recorded in South Africa. It turned out that one of the companions was occulted during its approach to the planet, but not the other! (Covault et al., 1986). If real, this event places a stringent limit of 5000 kilometres for the length of the corresponding arc.

New surprises were to come with the occultation of a very bright star (K = 6) by Neptune on August 25, 1985. The occultation took place as predicted, and two large telescopes at Mauna Kea mountain (3 m of the NASA Infrared Facility, IRTF, and 3.6 m of the Canada-France-Hawaii consortium, CFHT), recorded the emersion of the star from behind the planet. Ten minutes later, both instruments recorded a 15% drop of signal in the lightcurve (Fig. 3). The coincidence of the events ruled out again spurious effects, while an internal structure in the observed profile ruled out a satellite as the cause of the dip. The observed arc was however different from that observed in July 1984 since its distance to the planet was 52,000 kilometres (2.1 Neptunian radii), while its width and optical depth were comparable to the July 1984 event (13.5 km and 0.15 respectiveley, see Sicardy, 1988).

A simultaneous recording was made in Chile from the Cerro Tololo station and from ESO. Not surprisingly, no arcs were detected on either side of the planet from these two sites. However, a rare event took place since Chile passed in the middle of the Neptune's shadow, so that a "central flash" was observed. This flash was caused by the focusing of light by the planet's limb on the Earth. This was a unique opportunity to independently derive Neptune's oblateness and to put some constraints on the abundance of methane in the stratosphere of the planet (Lellouch et al., 1986).

The most recent positive detection of a possible body in the vicinity of Neptune was made on July 22, 1987 from the 3.6 m telescope of ESO. While the star and Neptune were moving away from each other after the occultation, it was noted that a near miss with the satellite Triton would occur. No occultation by this body was observed, but as the star crossed the satellite's orbit in the sky, a brief event was noted, corresponding to an object 10 kilometres in size (Sicardy, 1988). The excellent conditions of observation (near zenith, good seeing) argue for a real "event", however the ESO observation was not duplicated elsewhere on that night, so that no confirmation has been made of the "Triton torus".

We made special efforts in 1988 to observe Neptune occultations. Five occultations were recorded, three of them with a good signal-to-noise ratio (at ESO, CFHT and Pic du Midi), but without secondary events reminiscent of arc occultations. Although somewhat frustrating, the negative detections are as important as the positive ones, since they improve the statistics of the coverage. From all the occultations to date, the present status of Neptune arcs is the following:

– Unlike the other giant planets, Neptune does not possess significant continuous rings or ringlets. More precisely, the present upper limit for the normal optical depth of opaque continuous rings is 300 metres, and 0.006 for diffuse rings.

– Neptune is orbited by at least three structures. Two of them have been identified as parts of ring-like arcs, at 52,000 km and 67,000 km from the planet's centre, while the third one may be a 200 km moonlet of Neptune or a 80 km wide ring-like structure. The typical width of the two arcs is 10–20 km, and their maximum length is of the order of 3000 km. Thus the arcs occupy quite a small fraction of the orbital circumference, typically less than 3 degrees.

– Several other events are suspected to be due to arcs around Neptune. The number of "isolated events" is of the order of half a dozen, so that the probability to get a positive detection during an occultation is of the order of 10%. This shows that a small fraction of the azimuth inside the Roche limit of the planet is actually occupied by dense material.

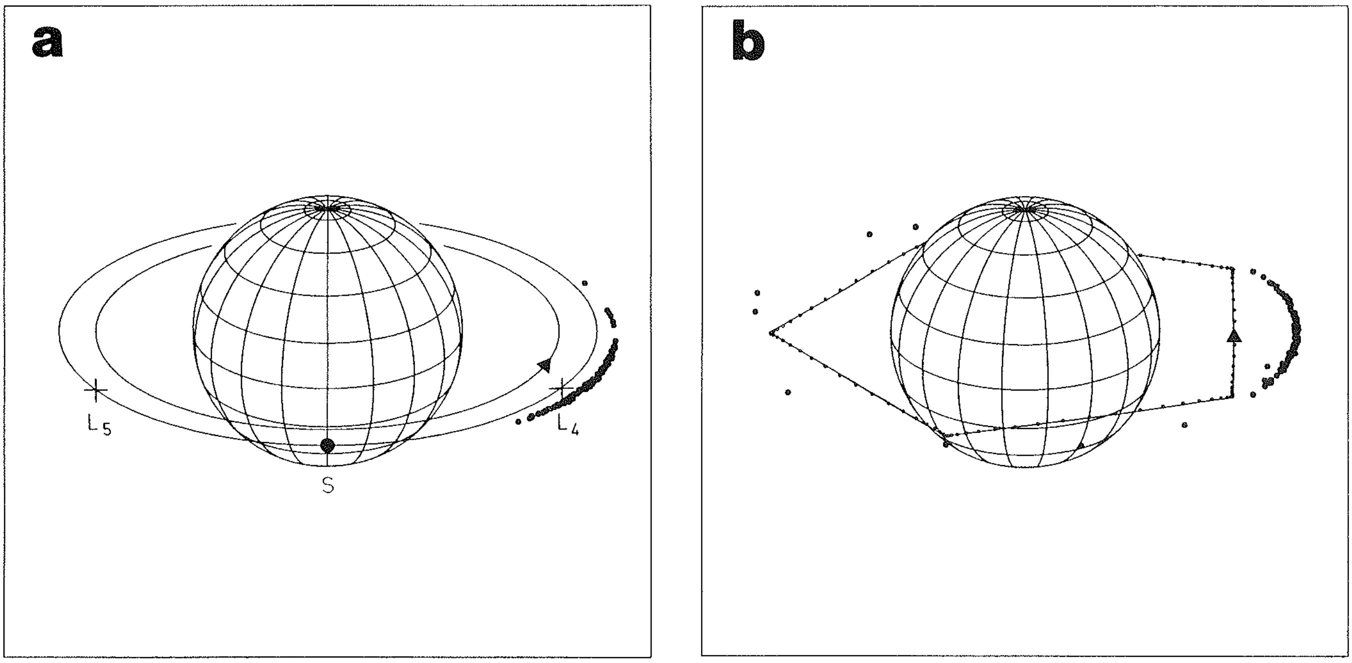


Figure 4: *Two cases of stabilization of ring arcs by small satellites of Neptune. The two diagrams show the results of a numerical simulation implemented on a CRAY computer. The particles are identical spheres, colliding inelastically, while being perturbed by nearby satellites. The typical masses of the satellites used in this simulation are 10^{-4} to 10^{-5} the mass of the central planet.*
Case a: The arc lies near an L_4 Lagrange point of a satellite S, and receives energy from a second satellite in resonance with the arc (inner orbit with the arrow). After more then 200 collisions per particle, the arc is still well confined. If the satellites were not there, everything equal besides, the same kind of simulation would show that the spreading of the arc is very rapid (a few collisions per particle).
Case b: The arc is at a corotation resonance of an eccentric satellite. The satellite's orbit, as observed in the frame corotating with the arc, has been drawn as a solid line. The satellite is then able to confine the arc in azimuth, and also to provide the energy lost by collisons, through a resonance with the arc. The system is shown after about 120 collisions per particle.

Interpretation

From such a small sample, it may seem hazardous to propose a theory accounting for the observations. After all, nobody knows at present whether the arcs are really well-defined clumps of material, or rather the densest parts of a more complex continuous ring. In any case, these structures may be an important clue to a much more general problem, namely the origin of the planets. The image of rings a decade ago was smooth collisional disks, where any structure would be rapidly erased by diffusion. The current image is the opposite, with many highly detailed structures, and a great variety of different physical processes. In particular, the efficiency of resonances to confine material in narrow regions of space has been widely demonstrated. Such "shepherding" mechanisms may have played an important role at the beginning of the solar system, where a multitude of small bodies were to accrete and form a small number of big planets.

Neptune's arcs may be an extreme example of confinement since not only they are confined in radius, but also in azimuth. The stability of such structures is problematic. Any free arc would spread around the planet in a few years, because of the differential Keplerian motion between the inner and the outer edges. Lissauer (1985) proposes a model where the arc is confined near the stable Lagrangian points of a small moon of Neptune. Such an equilibrium, although dynamically stable, is however secularly unstable because collisions will inevitably dissipate energy, and drive the particles away from the Lagrange points (which are local *maxima* of potential). For reasonable assumptions on the particle size in Neptune's arcs, it would take less than 10,000 years to spread these structures in horseshoe orbits. Lissauer proposes that a second moonlet may confine the arc, which would receive, through a series of resonances, the energy lost by collisions.

An alternative model has been developed by Goldreich, Tremaine and Borderies (1986). Instead of two satellites, only one is required, but its orbit must be inclined with respect to the equatorial plane of the planet. Although equivalent to Lissauer's model from the dynamical point of view, this new theory is more "economical" since it requires fewer satellites around the planet. In any event, both models agree that the putative satellite(s) responsible for the arc stability should be at least 200 kilometres in diameter, i.e. visible from the Voyager 2 spacecraft quite early (June 1989) in the encounter. If actually made, this detection could usefully constrain the possible sites for the arcs, and thus allow a more efficient coverage of these objects during the closest approach (August 1989).

Some illustrations of these theoretical models are given in Figure 4. They are derived from a numerical simulation of colliding particles near corotation resonances, and were intended to check the validity of the previously described analytical approaches (Sicardy, 1988). It can be seen that the combined effect of the satellite perturbations can efficiently confine a swarm of particles. It must be emphasized however that all these models do not take into account non-gravitational forces like Poynting-Robertson or plasma drag. Such forces could in particular spread away the dust produced in the arcs by meteoritic impacts or inelastic collisions. Although the arcs themselves do not present a hazard for the Voyager probe, because of their vanishingly small cross section, an extended sheet of diffuse dust may well endanger the spacecraft as it crosses the equatorial plane of the planet, at about three Neptunian radii.

Conclusion

Neptune's arcs represent a challenge from the triple point of view of the observer, the theoretician and the space engineer. It is remarkable, and fortunate, that a successful effort was made at the very moment when a spaceship was about to observe for the first time the remote planet. The harvest of data sent by Voyager is eagerly awaited, but no doubt several more earth-based observations will be necessary for fully understanding these mysterious formations. In the meantime, a very favourable occultation will be observed from ESO, Brazil, Tenerife and Pic du Midi on July 8, 1989, giving a last terrestrial glance before the rendez-vous . . .

References

Covault, C.E., Glass, I.S, French, R.G. and J.L. Elliot: 1986, *Icarus* **67,** 126.

Elliot, J.L., Mink, D.J., Elias, J.H., Baron, R.L, Dunham, E., Pingree, J.E., French, R.G., Liller, W., Nicholson, P.D., Jones, T.J. and O.G. Franz: 1981, *Nature* **294,** 526.

Elliot, J.L., Dunham, E.W., Bosh, A.S., Slivan, S.M., Young, L.H., Wasserman, L.H. and R.L. Millis: 1989, *Icarus* **77,** 148.

Goldreich, P., Tremaine, S. and N. Borderies: 1986, *Astron. J.* **93,** 730.

Hubbard, W.B., Brahic, A., Sicardy, B., Elicer, L.R., Roques, F. and Vilas, F.: 1986, *Nature* **319,** 636.

Hubbard, W.B., Nicholson, P.D., Lellouch, E., Sicardy, B., Brahic, A., Vilas, F., Bouchet, P., McLaren, R.A., Millis, R.L., Wasserman, L.H., Elias, J.H., Matthews, K., McGill, J.D. and Perrier, C.: 1987, *Icarus* **72,** 635.

Hubbard, W.B., Hunten, D.M., Dieters, S.W., Hill, K.M. and Watson, R.D.: 1988, *Nature* **336,** 452.

Kovalesky, J. and Link, F.: 1969, *Astron. Astrophys.* **2,** 398.

Lellouch, E., Hubbard, W.B., Sicardy, B., Vilas, F. and Bouchet, P.: 1986, *Nature* **324,** 227.

Lissauer, J.J.: 1985, *Nature* **318,** 544.

Reitsema, H.J., Hubbard, W.B., Lebofsky, L.A. and Tholen, D.J.: 1982, *Science* **215,** 289.

Sicardy, B., Roques, F., Brahic, A., Bouchet, P., Maillard, J.P. and Perrier, C.: 1986, *Nature* **320,** 729.

Sicardy, B.: 1988, *Thèse de doctorat d'état ès sciences physiques,* Univ. Paris 7.

International Halley Watch Meets at ESO

On April 22, 1989, members of the Steering Group and Discipline Specialists of the International Halley Watch (IHW) met at ESO Headquarters to discuss recent progress with the Halley Archive.

This group of cometary scientists was established in 1982 through an initiative by NASA; the same year it was recognized by the International Astronomical Union as the body responsible for coordination of the various programmes in connection with the Halley passage in 1985–86.

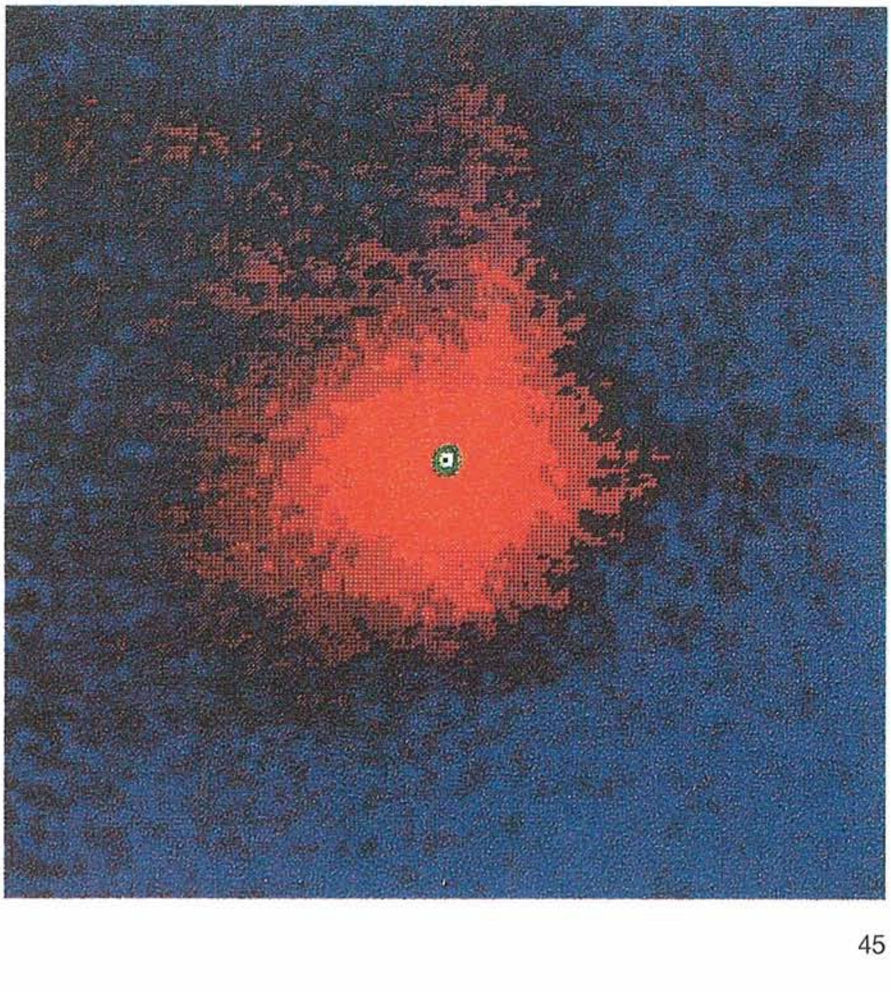
At this supposedly final IHW meeting with about 40 participating scientists, mostly from North America and Europe, it became clear that the main goal is now within reach. All of the "Networks" reported good progress in collecting the available data from all over the world. It is expected that the "final" deadline will be June 30, 1989 and by that time, about 22 Gbytes of data will have been gathered. In addition to the ground-based data, many will come from the highly successful space experiments in March 1986.

The archive will be made available on 22 computer readable Compact disks, of which 20 will include about 1000 selected, large scale images of the comet, the others carry spectra and photometry in the visible and infrared regions, astrometric positions, radio observations, meteor data, close-up images of the near-nucleus region and the best amateur observations. A magnetic tape version will also be produced. It has not yet been decided whether a subset of this enormous quantity of data will be published in printed form, although a book with the best pictures will appear in early 1990.

By early May 1989, Comet Halley was more than 1600 million kilometres from the Sun and still going strong. The false-colour picture shown here was made when it was at heliocentric distance 10.14 A.U., or 1517 million kilometres, i.e. beyond the orbit of Saturn. It is a composite of 29 CCD exposures obtained with the Danish 1.5 m telescope at the ESO La Silla observatory during five nights in early January 1989. The total integration time is 860 minutes.

The nucleus is seen as a point of light near the centre of an asymmetric dust cloud (coma) which measures ~80 arcsec across, or 550,000 km. The mean magnitude of the nucleus is V = 23.5, and its brightness is seen to vary by ~1 mag from night to night. The total magnitude of the comet is V = 18.4.

A comparison with the coma observed with the same equipment in April–May 1988 shows that the overall



dust density has remained virtually unchanged in the meantime. There is a broad, fan-shaped area of excess luminosity towards East; i.e. in the direction opposite to the comet's motion. This apparently represents the projected image of a normal dust tail, seen almost head-on. There is also a rather narrow fan that extends towards North, possibly a result of an earlier dust ejection event.

Some technical information: Johnson-V filter; stars, galaxies and cosmics cleaned from individual frames before addition; smoothed by 3×3 gaussian filter; outermost isophote corresponds to ~ 28 mag/arcsec^2; 1 pixel = 0.464 arcsec; frame size: 201×201 pix = 93×93 arcsec; seeing 1.2–1.5 arcsec; North is up and East is to the left.

R. M. WEST, ESO

Some Highlights from Comet Tempel 2 Observations at ESO

K. BEISSER, H. BOEHNHARDT, V. VANYSEK, Dr.-Remeis-Observatory, Bamberg, F. R. Germany
K. REINSCH, TU Berlin, F. R. Germany
E. GRÜN, MPI für Kernphysik, Heidelberg, F. R. Germany
L. MASSONNE, ESOC, Darmstadt, F. R. Germany

1. Introduction

During its 1988 perihelion passage, periodic comet P/Tempel 2 (orbital period of 5.3 years) was an object of intense ground-based observations, because it was one of the possible targets for the NASA Comet Rendezvouz and Asteroid Flyby mission (CRAF) in 1993. Although due to funding problems the CRAF project has been postponed to at least 1995, thereby automatically rejecting P/Tempel 2 from the mission target list, the ground-based study of this comet continues.

ESO has granted observing time for P/Tempel 2 to several groups of observers. Here we present preliminary results from our direct imaging and spectroscopic observations of comet P/Tempel 2. The data were collected at ESO La Silla between early May and early November 1988 with the 2.2 m, the 1.5 m Danish, the 1.5 m ESO and the GPO telescopes. Table 1 summarizes the geometrical aspects of the Sun-Earth-Comet constellation during the observation intervals.

2. Direct Imaging of P/Tempel 2

On May 4, 1988, comet P/Tempel 2 was observed with the 2.2 m telescope + CCD through a Johnson V filter. Two short exposures of 30 seconds and 3 minutes were taken. The nucleus of the comet appears star-like in the images, no coma can be detected around the comet (see Fig. 1). The small brightness extension to the west of the nucleus arises from a faint background star close by the cometary position. From the CCD images a nucleus brightness of 16.45 ± 0.05 mag is derived. From that one can estimate the effective nucleus radius R of comet P/Tempel 2 by (Spinrad et al., 1979)

$$R^2 A \Phi(\alpha) = r^2 10^{0.4 (M_{\odot} - (m - 5 \log \Delta))}$$

$M_{\odot}$ and m are the filter brightnesses of the Sun and the comet, respectively, r (in km) and Δ (in AU) the solar and Earth distances of the comet, A the albedo and $\Phi(\alpha)$ the phase function of the nucleus for the phase angle α. Using the albedo $A = 0.024$, derived by A'Hearn et al. (1988) for P/Tempel 2 from simultaneous optical and infrared observations, the effective nuclear radius R of the comet is about 6.1 km, when using the phase function of the Moon and about 5.1 km when using the phase function of Spinrad et al. (1979). A'Hearn et al. (1988) found an effective nuclear radius $R = 5.6$ km for comet P/Tempel 2, the data published by Spinrad et al. (1979) lead to $R = 4.1$ km when scaled to the much lower albedo $A = 0.024$ measured recently. Sekanina (1988) suggested nucleus dimensions of $18 \times 11 \times 7$ km for P/Tempel 2 based on observations of Luu and Jewitt (1988a, b) in 1987 and 1988. Photometric obser-

Figure 1: *3-min V exposure of comet P/Tempel 2, obtained with the 2.2 m telescope at ESO La Silla on May 4, 1988. North is up, east is to the right, the field of view is 1 × 1 arcmin. The small image extension of P/Tempel 2 to the west arises from a faint background star.*

vations of the comet also indicate that P/Tempel 2 may have an aspherical nucleus of 2 : 1 axes ratio, rotating with a period of about 9 hours (Jewitt and Luu, 1988; Wisniewski, 1988; A'Hearn et al., 1988). Hence the different effective radii of P/Tempel 2 derived from data obtained at different observation dates may be due to the unknown and changing attitude of the nucleus with respect to the Sun and the observers.

It is interesting to note that on May 4, 1988, i.e. at solar distance 1.95 AU pre-perihelion, the nucleus of P/Tempel 2 has not yet started significant gas and dust production like many other comets do even further away from the Sun. On May 16, 1988, West (1988a, b) already found a well developed coma around P/Tempel 2, while from April 9 to 15, 1988, Jewitt and Luu (1988) obtained star-like CCD images of the comet. Therefore we conclude that the nucleus activity started between 135 to 124 days before perihelion passage. This may provide an additional constraint in the nucleus modelling for the illumination of active regions on the cometary surface.

From July 18 to 24, 1988, comet P/Tempel 2 was observed at ESO La Silla with the Danish 1.5 m telescope. During that period the Earth passed through the orbital plane of the comet. Several broad-band B, V, R and a few IAU cometary filter CCD images of the comet were obtained. In the broad-band images, a rather asymmetric coma extension in the solar direction is visible (see Fig. 2), while the tail in the anti-solar direction (position angle γ = 110°) is hardly detectable. The main axis of the sunward coma expansion points to position angle of about 300°, slightly deviating from the direction to the Sun. Sekanina (1987) studied the fan-like coma asymmetries of comet P/Tempel 2 during the past apparitions and derived a quantitative spin-vector model for the rotation of the nucleus. From that he predicted (1988) a position angle of the fan axis of about 325° for the observation interval in the second half of July 1988, which is rather close to what we actually found from the CCD images.

IIa-O plates of comet P/Tempel 2, obtained in early November 1988 with the GPO telescope at ESO La Silla, also show a coma asymmetry with an axis pointing to approximately 340 to 350°. Again, this is close to Sekanina's prediction for this observation interval. Furthermore, the cone angle of the coma asymmetry in November 1988 was definitely broader than in July 1988, which is in agreement with the spin-vector model of the nucleus.

From the preliminary results we therefore expect that a detailed analysis of the imaging data of P/Tempel 2 may help to improve significantly the nucleus model for this particular comet.

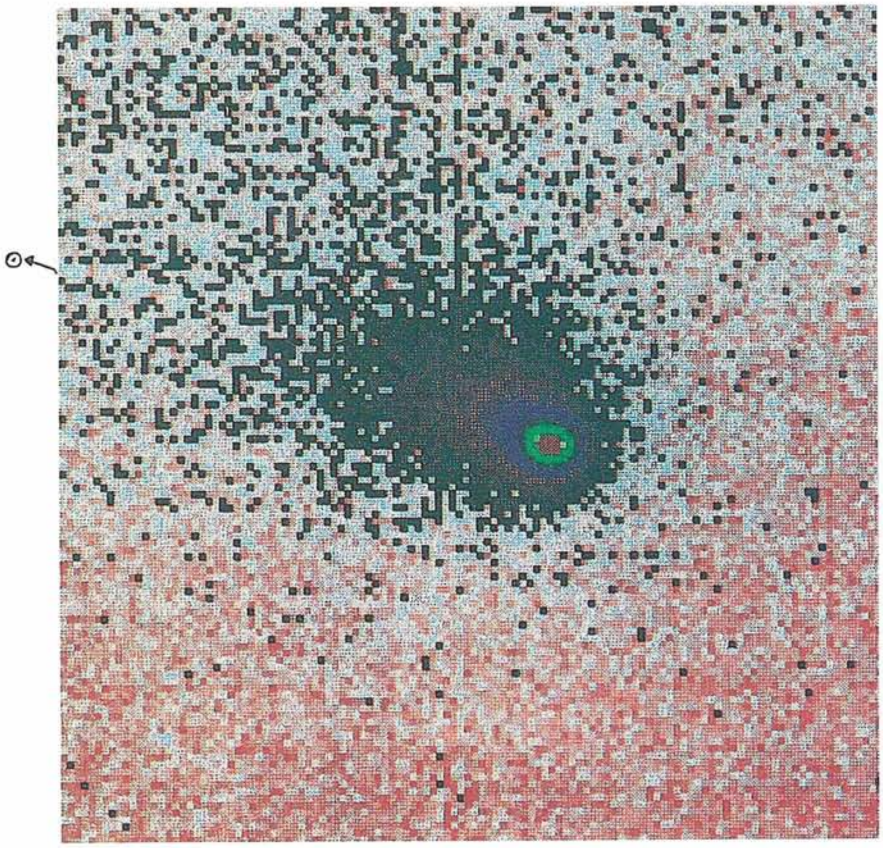


Figure 2: *1-min R exposure of comet P/Tempel 2, obtained with the 1.5 m Danish telescope at ESO La Silla on July 24, 1988. North is up, east is to the right, the field of view is 29 × 29 arcsec corresponding to 16,700 × 16,700 km at the distance of the comet. The direction of the Sun is indicated by the ⊙ symbol.*

3. Spectroscopy of P/Tempel 2

From October 29 to November 2, 1988, comet P/Tempel 2 was observed spectroscopically with the ESO 1.5 m telescope at La Silla. A Boller and Chivens long-slit spectrograph (3 arcmin slit) with CCD was mounted to the Cassegrain focus. The coma was monitored in two slit orientations (in and perpendicular to the projected radius vector) in the wavelength region 3700 to 5400 Å with 114 Å/mm spectral resolution. Beside the production of the molecules (CN, C_2, C_3 and some minor abundant species), the flux ratio of the vibrational sequence in the C_2 Swan band was studied in this observing programme (see Fig. 3).

Since the strongest band sequence of C_2 falls in the visible spectral region, this molecule is one of the best candidates for a test of various hypothesis concerning the dissociation and radiation processes in comets. Like other daughter molecules, C_2 is freed from the parents near the nucleus and radiates until further decomposition or ionization. The flux distribution of the band sequences of the resonance fluorescence spectra reflects the vibrational population distribution in the lowest electronic triplet state of C_2. If this distribution is determined by the statistical equilibrium, the corresponding vibrational temperature T_{vib} would be about the same as the colour temperature T_b of the Sun in the

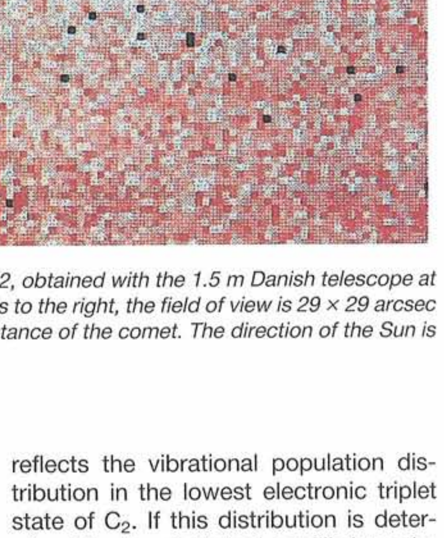


Figure 3: *The C_2 Swan sequence in the spectrum of P/Tempel 2, obtained with the ESO 1.5 m telescope on October 30, 1988. The wavelengths are given in Angstrom, the intensity in arbitrary units.*

TABLE 1: *Sun-Earth-Comet constellation during the observing periods of comet P/Tempel 2 at ESO La Silla*

Date	r (AU)	Δ (AU)	ϑ (o)	α (o)	γ (o)	ESO telescope
4.5.1988	1.94	0.99	152	14	48	2.2 m
18. – 24.7.1988	1.53 – 1.50	0.79	115 – 111	37 – 39	291 – 288	1.5 m Danish
30.10. – 2.11.1988	1.46 – 1.47	1.22 – 1.24	81	42	258	1.5 m ESO
3. – 10.11.1988	1.47 – 1.50	1.24 – 1.31	81 – 80	41 – 40	258 – 256	GPO

r = solar distance of the comet; Δ = Earth distance of the comet; ϑ = Sun-Earth-Comet angle; α = Sun-Comet-Earth angle or phase angle; γ = position angle of the Sun (measured east of north).

spectral range of the Swan bands. However, this would be fulfilled only if there is no exchange of populations between the lowest vibrational levels. Such transitions are indeed forbidden, because the C_2 is homonuclear and one can expect that the ratio of the integrated band fluxes and consequently also the vibrational temperature would be constant and independent on the heliocentric distance. But the observational results obtained for many comets indicate that T_{vib} is systematically lower than T_b. This effect can be explained by a sophisticated model developed by Krishna Swamy and O'Dell in the past decades (1987). They propose a mechanism which allows transitions between triplet state and adjacent lowest singlet state via a cascade-like radiation process.

Due to this process low values of T_{vib} should be derived from the observed flux ratios of the Swan bands. Since the probability of the downward spontaneous transitions is independent of the radiation density, while the upward induced transitions are proportional to the photon flux, the effect of the downward transitions into singlet states becomes more dominant if the radiation field decreases. Thus the apparent T_{vib} decreases with increasing heliocentric distance. Because the relative strength of the ($\Delta v = +1$) band increases with T_{vib}, the flux ratio of ($\Delta v = +1$)/($\Delta v = 0$) is a function of the heliocentric distance.

Ratios of the integrated fluxes of these bands are primarily determined by the rate at which transitions occur between the lowest electronic triplet state forming the Swan bands and the lowest singlet level.

The transition probability between these two states (denoted for simplicity as a-X) is unknown, but can be assumed as a free parameter. In Figure 4, the full lines represent the dependence of the integrated flux ratio of ($\Delta v = +1$)/($\Delta v = 0$) Swan bands on the heliocentric distance, theoretically predicted by Krishna Swamy and O'Dell (1987) for various values of the transition moment $(Re)^2$ expressed in atomic units. The filled circles indicate the most precise values of the flux ratios obtained by O'Dell et al. (1988) for comet P/Halley. Symbols V indicate data obtained from comet P/Halley with high spatial resolution onboard the spacecraft VEGA 2 (Vanysek et al., 1988). V_o stands for the impact parameter (i.e. minimal distance of the line of sight from the nucleus) < 1000 km and V the same for 2500 km.

Our preliminary result for the ($\Delta v = +1$)/($\Delta v = 0$) flux ratio of C_2 in comet P/Tempel 2, marked by symbol T in Figure 4, falls between data for comet P/Halley. Hence the most probable value of the transition moment seems to be about $2.5\ 10^{-6}$ and the corresponding Einstein coefficient for the downward spontaneous transition to be about $7\ 10^{-3}\ s^{-1}$.

Since the C_2 molecules can be formed either in the singlet and/or in the triplet state, the time required for establishing the triplet/singlet equilibrium would be several hundred seconds and the vibrational temperature would be time-dependent. Immediately after the C_2 formation which occurs in the innermost part of the coma, the vibrational temperature should be high and close to the colour temperature of the Sun, but during the expansion of the C_2 molecules into space, the populations in the lower states become redistributed and T_{vib} as well as the relative flux of the ($\Delta v = +1$) band decreases. This effect seems to be confirmed by VEGA 2 data obtained for comet P/Halley.

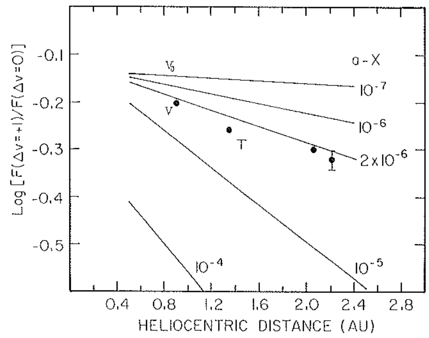


Figure 4: *The dependence of flux ratio C_2 ($\Delta v = +1$)/($\Delta v = 0$) on the heliocentric distance. Full lines represent theoretical model calculations for various values of the electronic moment, derived by Krishna Swamy and O'Dell. Full circles are measurements of comet Halley, symbol T for comet P/Tempel 2. V_o and V represent the average value obtained from Vega 2 spectrograms of P/Halley (for details, see text).*

References

A'Hearn, M.F., Campins, H., Schleicher, D.: 1988, IAU Circ. 4614.
Krishna Swamy, K.S., O'Dell, C.R.: 1987, *Astrophys. J.* **317,** 543.
Luu, J., Jewitt, D.: 1988a, IAU Circ. 4582.
Luu, J., Jewitt, D.: 1988b, *Astrophys. J.* **328,** 974.
O'Dell, C.R., Robinson, R.P., Krishna Swamy, K.S., McCarthy, P.J., Spinrad, H.: 1989, *Astrophys. J.*, in press.
Sekanina, Z.: 1987, ESA SP-278, 323.
Sekanina, Z.: 1988, IAU Circ. 4624.
Spinrad, H., Stauffer, J., Newburn, R.L.: 1979, *Publ. Astron. Soc. Pacific* **91,** 707.
Vanysek, V., Valnicek, B., Sudova, J.: 1988, *Nature* **333,** 435.
West, R.: 1988a, IAU Circ. 4599.
West, R.: 1988b, *The Messenger* **54,** 55.
Wisniewski, W.: 1988, IAU Circ. 4603.

Spectral Analysis of A-F Giant Stars

S. BERTHET and B. HAUCK, Institut d'Astronomie de l'Université de Lausanne, Switzerland

1. Introduction

A very large variety of stars of spectral type A-F display abundance anomalies: metallic-line stars, magnetic stars, λ Bootis, . . .

These stars are best distinguished from normal stars by means of photometry. Two photometric systems are especially well adapted to this effect: the uvbyβ and Geneva systems. A description of the latter has been given in

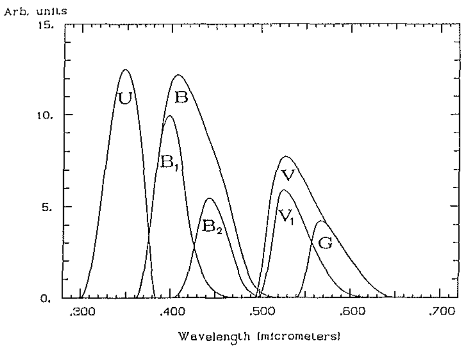


Figure 1: *Responses for the seven colours of the Geneva photometric system to an equiphotonic flux. The determination of these profile are from Rufener and Nicolet (1988).*

the *Messenger* by Rufener (1983). The spectral response of the seven filters used (Rufener and Nicolet, 1988) is given in Figure 1.

The metallic-line stars, or Am stars, were the first to be studied at depth in the Geneva system and all their photometric properties are to be found in Hauck and Curchod (1980). The temperature parameter used for the Am stars is the B2-V1 index, while d = (U-B1) − 1.430 (B1-B2) and m_2 = (B1-B2) − 0.457 (B2-V1) are the parameters for luminosity and blanketing respectively. An important parameter is that of metallicity, Δm_2, being the difference between m_2 observed and m_2 for the Hyades at the same B2-V1 value. The average Δm_2 values are −0.009 ± 0.011 for the AV stars, 0.002 ± 0.011 for the mild Am and 0.013 ± 0.019 for the classical Am stars. We have known for more than a quarter of a century (Van't Veer, 1963) that the Am stars show an overabundance of iron and a calcium and scandium deficiency. Those stars for which [Fe/H] values have been determined confirm the relation between [Fe/H] and Δm_2 obtained by Hauck et al. (1985) for main sequence stars.

If Δm_2 is considered to be a parameter for segregating the Am from the normal stars, an attempt may be made to use it for detecting stars of this type which would not have been considered by spectroscopists. Only six main sequence stars were found by Hauck and Curchod (1980) with a Δm_2 value ≥ 0.015 and classified as main sequence stars. On the other hand, several stars in luminosity class III showed a high Δm_2 value.

2. Metallicity Among A and F Giant Stars

Both spectroscopic and photometric observations confirm that the Am stars are considered to be main sequence stars. However, a small number of them belong to higher luminosity classes (IV and III), and this has been clearly confirmed by a number of studies (Burkhart et al. 1980, Van't Veer et al. 1985, Smith 1971, Faraggiana and Van't Veer 1971, Stickland 1972). Furthermore, another kind of star with a metallic line spectrum similar to that of Am stars belongs to the luminosity classes IV and III: the δ Delphini stars.

A systematic study of A-F spectral type stars with luminosity class III was recently carried out by Hauck (1986). By using an additional photometric criterion, $\Delta d \geq 0.10$, 132 stars could be considered as giants on a spectroscopic and photometric basis. During the study of their photometric properties, a very high proportion (36 %) was found to have a Δm_2 value of ≥ 0.015. However, before concluding that nearly one third of the giants exhibit a high [Fe/H] value, it should be ascertained that there also exists a relation between [Fe/H] and Δm_2 values for these stars. Unfortunately, only six of them belong to the Cayrel et al. (1988) catalogue, and even though their [Fe/H] and Δm_2 values seem to be in good agreement with the relation established for the dwarf stars, this number is too low to draw a valid conclusion. It is for this reason that a campaign for the abundance determinations of giant A-F stars has been undertaken. This study should not only enable a better understanding of the significance of Δm_2 for the A-F giant stars, but also attempt to understand the surface abundance pattern of the evolved stars.

Are these giants, with a high Δm_2, evolved Am stars or are they δ Delphini stars that have not been noticed by spectroscopists? Is there an evolutionary sequence between all these categories?

A first series of spectra was obtained at Kitt Peak by Abt and Hauck in 1985 and Berthet (1989) has recently published the results of an analysis of five observed stars.

3. Observations and Data Reduction

At Kitt Peak, Abt and Hauck used the coudé spectrograph of the 2.1-m telescope. The data were obtained with a CCD camera at a reciprocal dispersion of 9.9 Å/mm in the spectral region 4400–5100 Å. The analysis of these observations was very interesting, and at the same time, at the end of 1987, the 1.52-m ESO telescope was being upgraded in having the Echelec spectrograph equipped with a CCD detector at the coudé focus. The announced performances (Alloin et al. 1987 and Gilliote et al. 1987) of this new equipment and the results from the Kitt Peak spectra induced us to undertake an observing programme to increase our sample of A-F giant star spectra. In September 1988, we obtained for our programme of spectroscopic study of A-F giant stars five nights with this new equipment at La Silla. Thus observations were carried out with the 1.52-m telescope and the Echelec spectrograph working with a

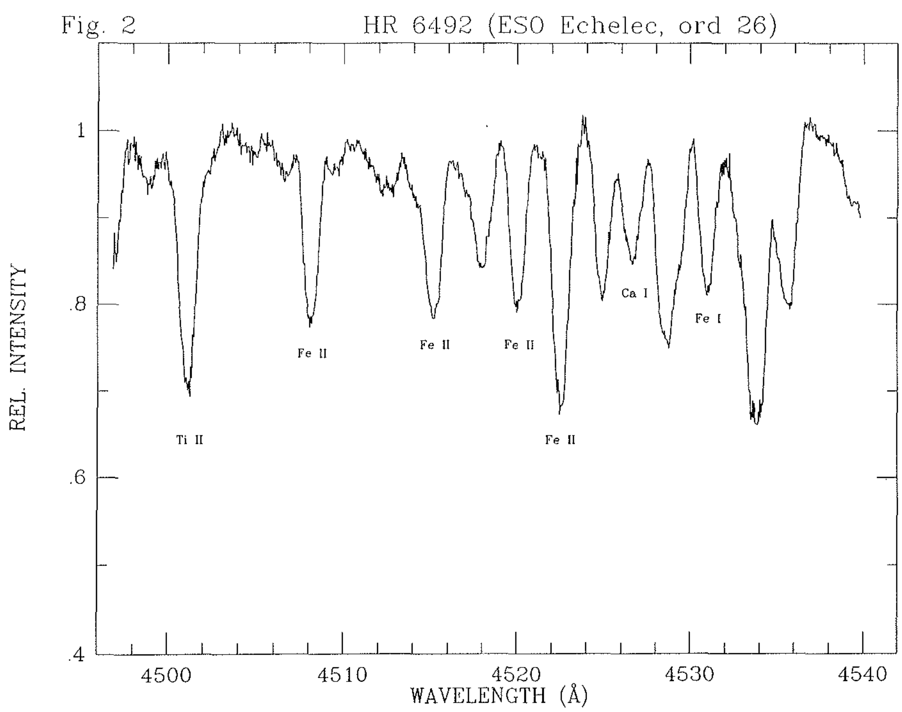


Figure 2: *Portion of the spectrum of star HR 6492 in the spectrum order 26 (4495–4550 Å) observed on September 1988 with the Echelec.*

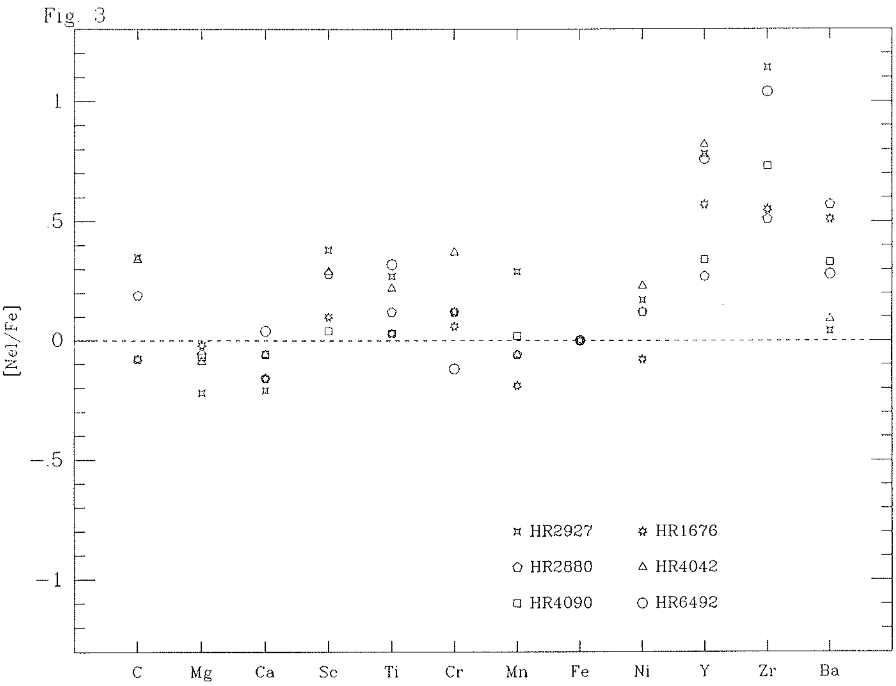


Figure 3: *Logarithmic abundance ratio with respect to the sun normalized to iron.*

high-resolution CCD detector (ESO CCD # 13). The choice of the instrumentation was dictated by the need for observing spectra with a linear dispersion as small as possible and a good S/N ratio (100). In its actual configuration the Echelec allows a linear dispersion of 3.1 Å/mm at 4000 Å to 4.5 Å/mm at 6000 Å. The Echelec resolving power falls between that of the CES (with its short camera R = 60,000) and that of Caspec (R = 20,000), moreover the wide separation of orders permits some binning in the direction perpendicular to the dispersion. This improves the S/N ratio without any loss of resolution. The meteorological conditions were not so good during the observing run and exposure times were 20 to 60 minutes for stars of m_v = 4.3 to 7.4 with a binning of 2 pixels to have at least a S/N ratio $\geq$ 70 (Fig. 2). 15 stars were measured during these 5 nights in the spectral region 4280–4900 Å. The reduction of these spectra is now being carried out according to MIDAS procedures. The first results we obtained with the new configuration of the Echelec are very encouraging, the quality of spectra will allow detailed abundance analysis. In this paper we present the first results.

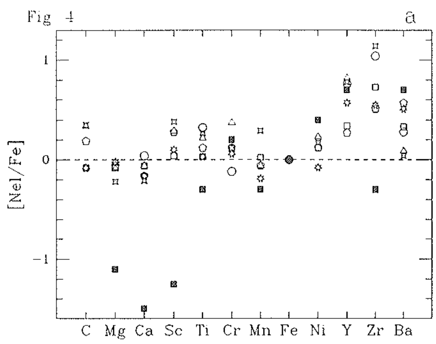
The determination of the atmospheric parameters is presented in detail in a paper to be published in *Astronomy and Astrophysics.* From a temperature distribution with depth ($T(\tau_{5000})$) for a given effective temperature, surface gravity and metallicity, we recompute the ionization equilibrium and hydrostatic equilibrium to determine the total pressure and density at each depth and continuous opacities at selected wavelengths. We then use the model prepared to determine the abundance from the equivalent width by iteration on the solar abundances; this process assumes a homogeneous plane-parallel atmosphere, LTE line formation and Voigt profile for the line absorption coefficient.

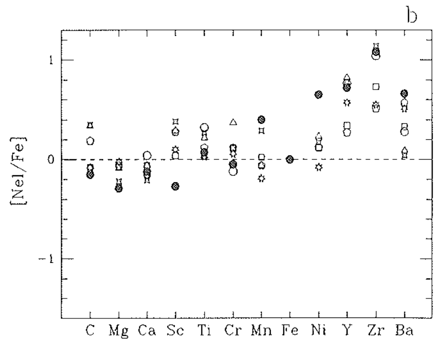
4. Results

The results are summarized in Figure 3 which displays the logarithmic abundance ratio with respect to the sun normalized to the Fe abundance. This normalization minimizes the effect of errors in equivalent width scale and in effective temperature and metallic-line star abundances are best represented in this form. An interesting point is to compare these abundances with those of a classical Am star (63 Tau), an evolved Am star (HR 178) and a δ Delphini star (δ Del). This comparison (Fig. 4) points out the fact that the abundance of the stars presented in this paper does not look like that of an evolved Am star or of an Am star. We do not observe the typical underabundance of Ca and Sc of Am stars but on the other hand the configuration of the abundance distribution is close to that of the δ Del star. The δ Delphini stars with a subgiant or giant luminosity are defined as stars having abundance anomalies comparable with those of the main sequence classical Am stars, except for Ca and Sc which are normal or overabundant.

5. Discussion

The comparison of abundances normalized to Fe of a classical Am star, an evolved Am and a δ Delphini star raises the question of knowing if there is a link or an evolutionary sequence between these three types of star. Can we consider the assumption of an evolutionary sequence in the variation of the Am characteristics? Can we suppose that during the main sequence phase Ca and Sc are underabundant and when the star reaches the giant phase the abundance of Ca and Sc increases to become normal or overabundant? Thus an Am star leaving the main sequence, would become first an evolved Am star (Ca and Sc are not so underabundant as





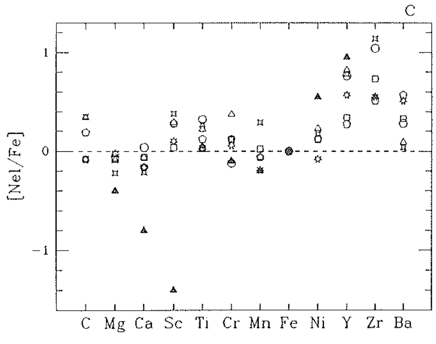


Figure 4 a, b, c: *Comparison of 6 A-F giants whose spectra have been taken at Kitt Peak Observatory (KP) and at ESO (★ HR 1676, ◇ HR2880, ☆ HR2927, △ HR4042, □ HR4090, ○ HR6492) with 63 Tau (■) an Am classic star, HR 178 (▲) an evolved Am star and δ Del (●) a δ Delphini star.*

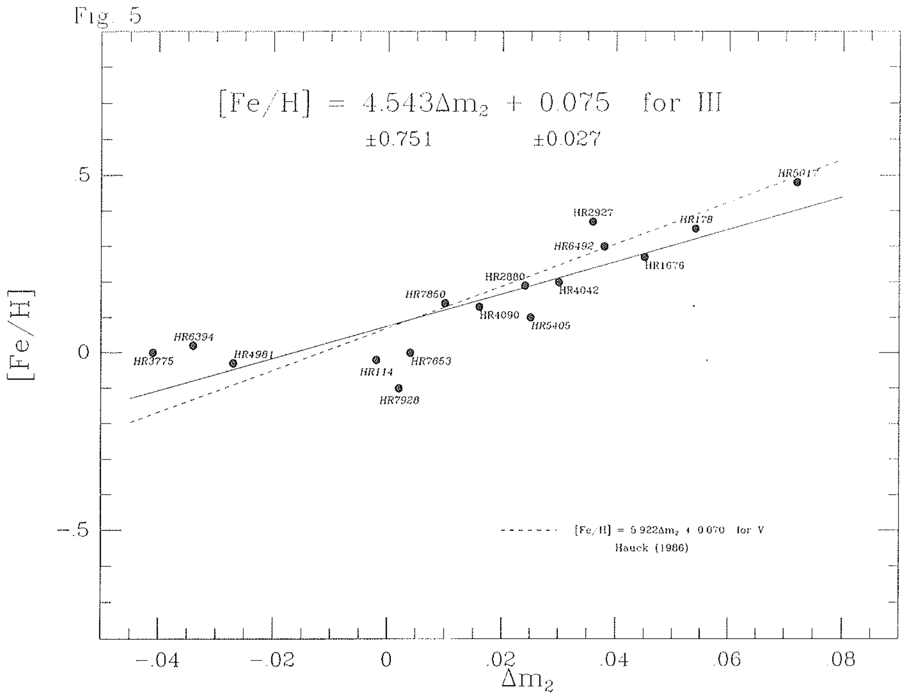


Figure 5: *[Fe/H] vs Δm_2 for A-F giant stars.*

in the main-sequence phase) and then becomes a δ Delphini star, Ca and Sc being normal or overabundant.

Indeed, we observe that the deficiency of Ca and Sc decreases through these three types of star (Am, evolved Am, δ Delphini). But is the disappearance of these Am characteristics really attached to the evolution stage of these kinds of star?

With the help of the evolutionary model (Maeder and Meynet 1988) we plot evolutionary tracks of mass stars 1.5–2.0 $M_\odot$ in the HR diagram. The location of the Am star (63 Tau), the evolved Am star (HR 178) and the δ Delphini star (δ Del) points out the fact that the δ Del star is more evolved than the evolved Am star and that, of course, the evolved Am star is more evolved than the classical Am star. This fact is interesting but the test would be better by using these three kinds of star (Am, evolved Am and δ Delphini) belonging to a cluster, thus the evolutionary state could be determined without ambiguity.

To explain Ca and Sc anomalies, the most useful mechanism is diffusion. The efficiency of this process is strongly dependent on the location of the H-convective zone which is dependent on the temperature, i.e. on the evolutionary stage. Thus observed surface anomalies at a given time mostly depend on the way the diffusion works at this period. The way the abundance stratifications evolve with time depends on the element, and it implies that the star can present different anomalies according to its age.

After these considerations about the possible chemical evolution of the Am stars it is interesting to consider the relation [Fe/H] vs Δm_2 for A-F giants, evolved Am stars and δ Del stars. Stars of Table 1 have been plotted in Figure 5 and it points out a correlation between the spectroscopic value [Fe/H] and the photometric index Δm_2.

The dashed line in Figure 5 shows the relation obtained by Hauck et al. (1985) for the FV stars. The straight line represents the relation, mentioned above, for the A-F giants, the evolved Am and δ Del stars. In the present situation the two relations between Δm_2 and [Fe/H] are relatively close. But a question arises: is

TABLE 1: *A-F Giants, Am evolved and δ Del stars plotted in Figure 5.*

HR	Δm_2	[Fe/H] (Ref)	Sp.T
114	−0.002	−0.02 (2)	Am
178	0.054	0.35 (2)	Am
1676	0.045	0.27 (1)	F2 IV
2880	0.024	0.19 (1)	F0 III
2927	0.036	0.37 (1)	F5 III
3775	−0.041	0.00 (2)	F6 IV
4042	0.030	0.20 (1)	F1 III
4090	0.016	0.13 (1)	F0 V
4981	−0.027	−0.03 (2)	F2 IV
5017	0.072	0.48 (4)	δ Del, F3 III
5405	0.025	0.10 (3)	Am
6394	−0.034	0.02 (2)	F6 III
7653	0.004	0.00 (2)	A4 III, Am
7850	0.010	0.14 (2)	A7 III
7928	0.002	−0.10 (5)	δ Del

References: (1) Berthet (in prep.), (2) Cayrel et al. (1988), (3) Burkhart et al. (1980), (4) Hauck et al. (1985), (5) Lyubimkov et al. (1985).

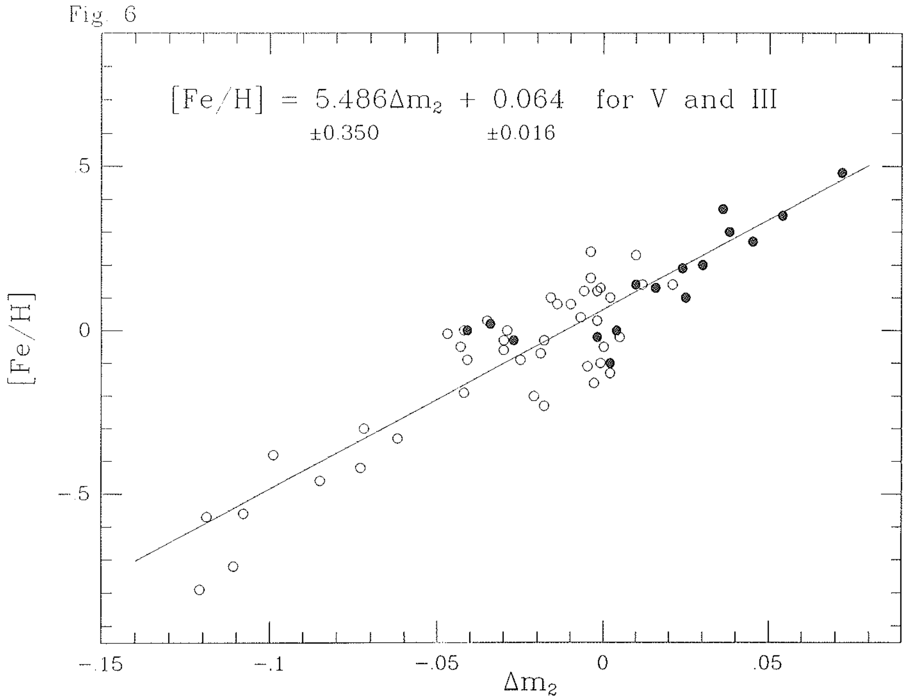


Figure 6: *[Fe/H] vs Δm_2 for A-F giant stars anf F-V stars.*

there one relation for A-F giants and evolved Am stars and another for A-F main-sequence stars? In Figure 6, reproducing our data plus data that Hauck et al. (1985) used to determine his relation, the general trend seems to show that one relation could be sufficient for A-F main-sequence stars, A-F giant stars, evolved Am stars and δ Del stars and this assumption was already suggested by Hauck et al. (1985).

6. Conclusion

The abundance analysis has shown that Ca and Sc abundance of our stars is normal: no deficiency has been found. Thus the answer to one of the introductory questions comes immediately: the A-F giants with a blanketing parameter $\Delta m_2 \geq 0.015$ are not necessarily evolved Am stars, they could also be δ Delphini stars. The relation found between Δm_2 and [Fe/H] is encouraging and supports the possibility of using a photometric parameter to estimate the metal content of these kinds of stars. And perhaps more than that, because it appears that only one relation could be sufficient for the A-F stars. This study points out that it is important to examine the evolutionary stage of the different kinds of stars encountered.

So, with the new configuration of the Echelec spectrograph on the ESO 1.52 m telescope at La Silla we have a very interesting instrument for stellar spectroscopy, working with a wavelength range between 3500 and 5500 Å and a good linear dispersion (3.1 to 4.5 Å/mm). The spectra obtained during our observing run allowed detailed spectroscopic analysis of good quality and encourage us to pursue our programme on the spectroscopic study of A-F giant star atmospheres.

References

Alloin, D. and Hofstadt, D.: 1987, *The Messenger* **49,** p. 18.

Burkhart, C., Van't Veer, C. and Coupry, M.F.: 1980, *Astron. Astrophys.* **92,** 132.

Cayrel de Strobel, G., Hauck, B., Thevenin, P., Francois, P. and Mermilliod, M.: to be published.

Faraggiana, R. and Van't Veer, C.: 1971, *Astron. Astrophys.* **12,** 258.

Gilliote, A. and Magain, P.: 1987, *The Messenger* No. 50.

Hauck, B.: 1986, *Astron. Astrophys.* **155,** 371.

Hauck, B., Foy, R. and Proust, D.: 1985, *Astron. Astrophys.* **149,** 167.

Hauck, B. and Curchod, A.: 1980, *Astron. Astrophys.* **92,** 289.

Lyubimkov, L.S. and Rachkovskaya, T.M.: 1985, Izvestiya Krymstoi Astrofizicheskoi Observatorii vol. 71, pp. 127.

Rufener, F.: 1983, *The Messenger* **31,** p. 17.

Rufener, F. and Nicolet, B.: 1988, *Astron. Astrophys.* **206,** 357.

Smith, M.A.: 1971, *Astron. Astrophys.* **11,** 325.

Stickland, D.J.: 1972 *Mon. Not. R. Astr. Soc.* **159,** 29.

Van't Veer C.: 1963, *Ann. Astrophys.* **26,** 289.

Van't Veer-Menneret, C., Coupry, M.F. and Burkhart, C.: 1985, *Astron. Astrophys.* **146,** 139.

T Tauri Stars Make Us Wonder What They Are

G. F. GAHM, Stockholm Observatory, Sweden

Once upon a time, some 4.6 billion years ago, the sun formed in an interstellar cloud of gas and dust. The planets we see in the sky all move close to the ecliptic. It is therefore clear that at some phase the young sun was surrounded by a flat dusty disk, in which these planets agglomerated.

In cosmogony one is concerned about how the solar system came into being. A standing question has been that of universality: do planetary systems form also around other young stars, like the T Tauri stars, which are located in interstellar clouds?

From what we know, these clouds of today are not very different from those present 4.6 Gyr ago with regard to chemical composition and galactic distribution. I would think that ever since the fifties, when the T Tauri stars were recognized as very young objects, most scientists involved have been thinking of the objects as being similar to the sun, only much more active, and that they have circumstellar regions with a flat geometry. There is an early paper by Poveda (1965) with respect to this latter point. Nevertheless, during the late sixties when the infrared excess emission (from circumstellar dust) and the ultraviolet excess emission were discovered, the models always took spherically symmetric forms. One could speculate that it is generally regarded as more scientific (or maybe just simpler) to choose a spherical form when there is no evidence, other than intuition, of a flat geometry. The cosmogonist, of course, always faces a flat geometry.

By 1980 it was evident that for many of these stars the excess emission extends over the far-ultraviolet into the X-ray region. This high-energy tail of circumstellar origin was usually tied to spherically symmetric chromospheres/coronae. During the next years it was also realized that some of these stars drive powerful molecular flows into the surrounding interstellar cloud, often only in two opposite directions (bipolar flows). I left astronomy in 1983. When I came back a few years later I was surprised to see how much is accomplished in science over such a short period of time. The sky had been painted with numerous bipolar flows, some extending over tens of minutes of arc. Plasma jets were seen to shoot out from the stars. A major break-through was the mapping of rotational velocities of the stars and the discovery that some of the light variability present was of periodic nature and related to rotational modulation of bright and dark areas on the stellar surface (see the article in the *Messenger* by Bouvier and Bertout, 1985). It is certainly interesting, also from a cosmogonic point of view, that for many of the youngest T Tauri stars the angular momentum is smaller than the total angular momentum of our solar system! In other words, when the T Tauri stars contract out of interstellar cloudlets, they have found ways to get rid of angular momentum very rapidly indeed. Last, but not least, a number of independent indications that many of the T Tauri stars are surrounded by flat disks of planetary system dimensions had been found. Flat molecular disks, apparently rotating, had been discovered at some stars. The spherical geometry is gone for ever.

The concept of accretion disks, in which material is transported towards the stars, has replaced earlier views. Even the continuous excess emission is now explained as a disk phenomenon. Here, the ultraviolet excess originates in a warm boundary layer between the accretion disk and the star while the infrared excess originates further out in the disk. Some stars lack the characteristics of disks, and on these so-called "naked" T Tauri stars the X-ray variability, for instance, could have its cause in enhanced surface activity. Such activity may exist also on the "clothed" stars but

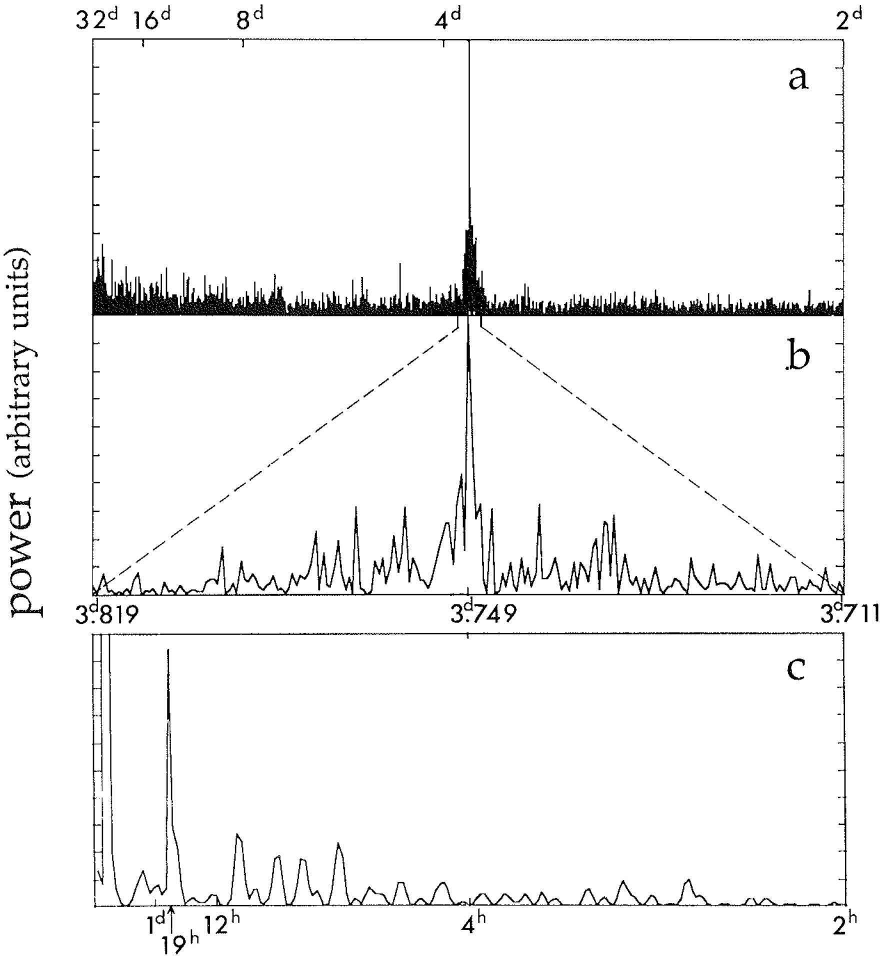


Figure 1: *The Fourier analysis of the light fluctuations of the T Tauri star RY Lupi reveals that there is a periodic component – period 3.75 days – which has been present over the last 52 years (see* ***a*** *and the enlarged fraction of the 1/Period-axis in* ***b****). In addition, a period of about 19 hours seems to be present when the star is faint as was the case in 1986 and 1987 (****c****). The vertical axis gives power in arbitrary units.*

for these the disk emission dominates the spectrum, at least at ultraviolet wavelengths.

These and other exciting discoveries and ideas made me continue to work in the field of star formation. In addition, my colleagues (Carl Fischerström, Peter Lindroos and René Liseau) had continued the work we started in 1980 to collect good observational material on the variability of T Tauri stars. Observations, spectroscopic and photometric, were made at ESO, at the Swedish Station on La Palma, Spain, and with the IUE satellite. A most fascinating data base of information on one star, RY Lupi, is now at hand with extensive observations collected also by other groups starting with the early work by Cuno Hoffmeister and collaborators in 1935.

The star varies by more than 3 magnitudes in the visual (the V band). Already Hoffmeister (1965) found a quasi-period of a little less than 4 days in the light fluctuations. From Fourier analysis of more than 6,000 individual measures (see Fig. 1) we found that this period of 3.75 days has been present over the last 52 years. The periodic fluctuations are severly distorted by superimposed irregular fluctuations. Although it has been quite natural to tie the photometric period to the rotational period of the star, as described above, there are two problems with this interpretation in the case of RY Lupi: 1. The degree of linear polarization of light increases when the star becomes fainter (Bouvier, 1988). 2. The spectrum (with an absorption line spectrum corresponding to spectral type G8) does not change when the star fades. As described by Liseau et al. (1986) these circumstances are not in line with current models of star spots appearing and disappearing when the star revolves.

In addition, there are several remarkable details of the variability of this star which can be summarized briefly as follows.

1. When the star fades, it first becomes redder. However, when fainter than V = 11.5 this trend is changed towards the blue but with a very large spread in colour for a given V. At close to 13th magnitude it happens that the star is bluer than at maximum brightness (see Fig. 2).

2. During these dramatic visual variations, the photospheric temperature stays constant and also the fluxes of the hydrogen line emission, the infrared excess emission and the far-ultraviolet excess emission.

3. When the star is fainter than V = 11.5 it happens that it flips in colour over very short time-scales, even less than ½ hour. On these occasions the (B-V) colour can change in either direction by more than 0.5 magnitudes while the change in V is only about 0.1 magnitude. Similar flips occur also at higher brightness levels but the corresponding colour changes are smaller, as if by con-

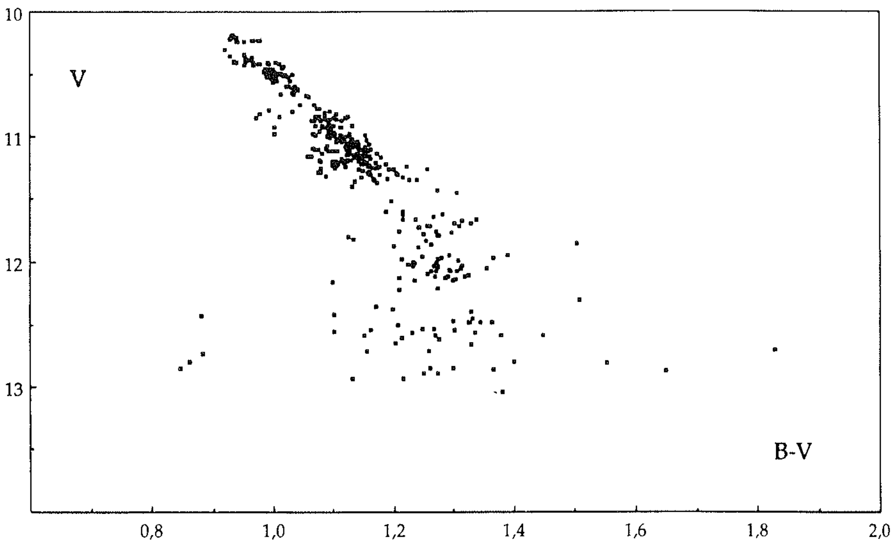


Figure 2: *Magnitude V versus colour (B-V) for all existing photometric observations of RY Lupi. Notice the large spread in (B-V) when the star is faint in the V band.*

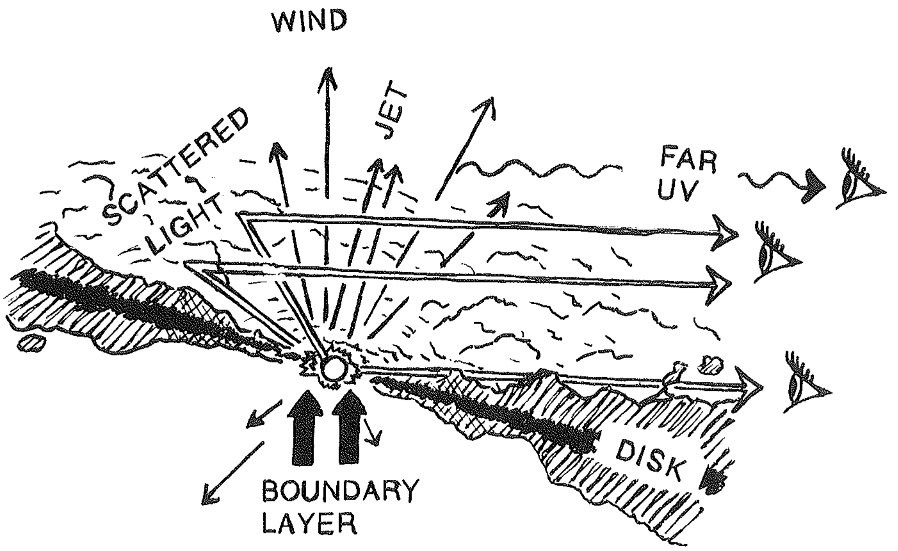


Figure 3: *The contours of a possible model of RY Lupi. The star is seen through the fluffy outskirts of an equatorial disk of dust which is inclined by 20 degrees to the line-of-sight. In the drawing the disk is cut in a plane through the star and directed to the observer to the right. On occasions, when the stellar light is almost totally blocked by foreground dust, the observer instead sees the light scattered or emitted from the extensive disk. The fluxes in the far-ultraviolet and in the emission lines stay relatively constant and must originate outside the star and the disk, like in a stellar wind or a jet. Rapid phenomena take place, possibly in the warm boundry layer between the star and the disk.*

trast. There is evidence that the flips sometimes reappear on a time-scale of close to 6 hours.

There are more peculiar things to be noted. For instance we have found evidence of a second period of about 19 hours in the light variations. The collected information on RY Lupi presents a complex but challenging picture. We cannot claim that we fully understand the unusual behaviour of this star. We have tried to bring together all pieces in what could be the contours of a model for RY Lupi. Some of the ideas can be tested by further specific observations.

In short, we find that the general pattern of variability is consistent with variable circumstellar extinction in the line-of-sight to the star. When the star fades to 13th magnitude in V, most of the stellar light is blocked and instead we see light emitted and/or scattered by circumstellar dust. Then RY Lupi must be a rare case among the T Tauri stars where the line-of-sight to the star happens to pass through the outer, fluffy regions of a flat equatorial disk of dust. On occasions the sight is clear and the star dominates the light. When the star is occulted by cloudlets of dust, we see the light from the remote side of the disk. The infrared emission from the dust grains stays constant in flux and the far-ultraviolet excess emission and the hydrogen line emission must be formed in regions outside the disk – like in a wind or jet perpendicular to the disk. These features are sketched in Figure 3.

The rapid flips are not flares on the stellar surface. They could be of circumstellar origin, like nebular flares which are discussed by cosmogonists in connection to local reheating of the early solar system material, or they are produced by instabilities in a wind or jet. Another possibility is that the flips result from scattered light from hot clumps which orbit around the star with high speed in a boundary layer between the star and the disk. The expected Keplerian orbital period close to the stellar surface is the same as the period found, namely 6 hours. It will be interesting to see if this period can be confirmed by future observers.

So far, the model outlined is very speculative and may be drastically refined by future work. Apparently, the star also changes its pattern of variability from time to time. During the period of a new series of observations, RY Lupi showed almost perfectly gray variations (only very small changes in colour). One of the problems is to understand the well established 3.75-day period. If this is a consequence of a regular structure in the rotating disk, then how could it be so stable over 52 years? Is there in fact a relation to the region of co-rotation between the star and the disk? Can stable spiral arms form in dusty disks?

All these question marks left make it exciting to continue the exploration of the T Tauri stars and their surroundings. There is still the feeling that the T Tauris also have something to tell us about the origin of our own solar system.

References

Bastian, P.: 1988, in *Polarized Radiation of Circumstellar Origin,* Vatican Conference, in press.
Bouvier, J., Bertout, C.: 1985, *The Messenger,* No. **39,** p. 33.
Hoffmeister, C.: 1965, *Veröff. Sternwarte Sonneberg,* **3,** 33.
Liseau, R., Lindroos, K.P., Fischerström, C.: 1987, *Astron. Astrophys.,* **183,** 274.
Poveda, A.: 1965, *Boletin Tonantzintla y Tacubaya,* **4,** 15.

Does the Mass Function of Galactic Globular Clusters Depend Upon Metallicity?

S. ORTOLANI, Osservatorio Astronomico di Padova, Italy
G. PIOTTO, Dipartimento di Astronomia, Università di Padova, Italy
M. CAPACCIOLI, Osservatorio Astronomico di Padova, Italy

Introduction

In the last three-four decades galactic globular clusters (GCs) have been known to constitute an excellent laboratory for the investigation of primordial star formation and chemical enrichment during the collapse of the parent galaxy. Until the advent of the CCDs, however, the study of the faint main-sequence stars, several magnitudes below the turn-off, has remained beyond our reach. The first

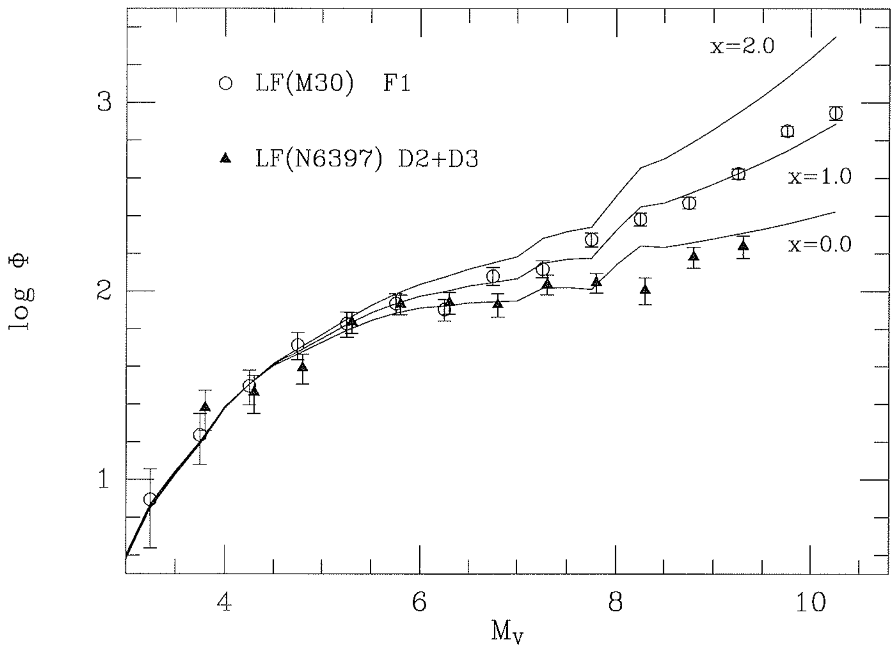


Figure 1: *Luminosity functions of the outer M30 region (light circles) and the composite luminosity function of NGC 6397 (filled triangles) plotted agianst the theoretical curves (solid lines) derived with McClure et al. (1987) mass-luminosity relation assuming a power law mass function and three values of the power index* x. *The error bars indicate Poisson uncertainties (in cluster and field stars).*

high-quality CCD became available at the ESO 1.54 m Danish telescope in the early 80's (followed by the detectors installed at the 3.6 m and 2.2 m telescopes). It provided the European astronomers with the unique opportunity to share the venture of exploring the faint main sequence stellar population of the galactic GCs, particularly numerous in the Southern sky.

The parallel development of *ad hoc* reduction packages (e.g. DAOPHOT, INVENTORY, ROMAFOT) has also permitted to carry on accurate photometry of single stars in the very dense fields closer and closer to the cluster centers. This modern software allows also numerical simulations with artificial stars to evaluate the incompleteness caused by crowding and/or very low signal-to-noise ratios.

Among the most recent and prestigious outcomes of the state-of-the-art photometric observations of galactic GCs are the deep luminosity functions (LFs) of the main sequence stars. Theoretical models have been developed which allow us to transform these LFs into the corresponding mass functions (MFs). The latter (giving the number of stars per mass interval) represent the result of the dynamical evolution applied to the initial mass function (IMF), i.e. the mass function which characterized a cluster stellar population at the epoch of formation (cf. Spitzer 1987).

In the last few years, deep main-sequence LFs for several nearby clusters have been obtained at ESO and elsewhere (CTIO, CFHT, KPNO). An important result of all these studies is that the slope of the MF of the GC stars is not a constant: if the MF is modelled by a power law $\zeta(m) = \zeta_o m^{-(1+x)}$, the index x is found to vary in the interval from $x = -0.5$ (M4 and 47Tuc) to $x = 2.5$ (M15). By collecting and analyzing the available data, McClure and collaborators (1986) pointed out the existence of a strong correlation between the index x and the cluster metallicity ([Fe/H]). If the relation is real, and if it reflects a property intrinsic to the IMF, it has important consequences in our understanding of the chemical enrichment and star-formation history of the galactic halo (e.g. Smith and McClure 1987).

Stimulated by these results, we began a survey tailored to the facilities of the European Southern Observatory. The results for our first two targets, the metal-poor clusters NGC 7099 (M30), and NGC 6397, are at variance with McClure et al. (1986) relation.

NGC 7099

M30 is a high-concentration cluster located at high galactic latitude. It is also one of the most metal-poor clusters of the Galaxy ([Fe/H] = −2.19, Webbink 1986). Using photographic material, Piotto et al. (1986) noted that the c-m diagram of this old object (age ~ 16 Gyr) is not reproduced by theoretical isochrones calculated for the nominal metallicity (VandenBerg and Bell 1985). They showed also that the data are better represented assuming that M30 has an oxygen over-abundance ([O/Fe] = 0.7). These findings are fully confirmed by a more recent study based on CCD material of the ESO 2.2 m and the CTIO 4 m telescopes (Piotto et al. 1989).

At the ESO Workshop on "Stellar Evolution and Dynamics in the Outer Halo of the Galaxy", Capaccioli, Ortolani, and Piotto (1987) reported that the LF of M30 was much flatter than the luminosity function of the only other metal-poor cluster, M15 ([Fe/H] = −2.05), whose MF was available at that time (McClure et al. 1986). Recently Piotto et al. (1989) have derived the slope $x = 1.0 \pm 0.2$ for the MF in an outer ($r = 4\overset{'}{.}4$) region of M30 observed with the ESO 2.2-m telescope (Fig. 1). However, the MF obtained in this way is just a *local* MF; its slope can be quite different from that characteristic of the whole set of stars (*global* mass function) due to the mass segregation consequent to the dynamical evolution of the cluster. In order to investigate the dependence on distance from the centre of the observed power law index x in a relaxed cluster, Pryor, Smith and McClure (1986) have calculated mass-segregation corrections for GC MFs using multimass King-Michie models with power law mass function. The aim of this work was to evaluate the mass-segregation corrections needed to recover the global power law index x_o

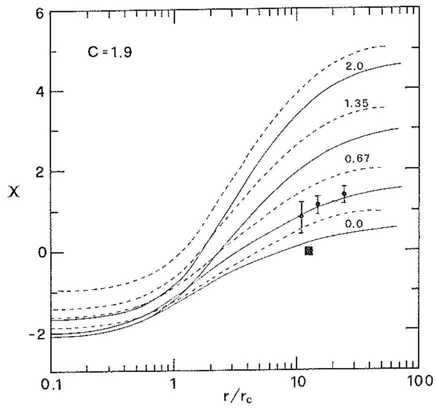


Figure 2: *Mass function power indexes (filled circles) for our three fields (the two inner fields are ESO data, while the outer one has been obtained from CTIO CCD frames) in M30 and for the composite NGC 6397 MF (filled triangle), compared with the theoretical predictions by a multi-mass King-Michie model with concentration parameter c = 1.9: solid lines are for isotropic models, dashed for anisotropic ones. The best estimate for the global power indexes is* $x_{0,\,M30} \simeq 0.7$, *and* $x_{0,\,NGC\,6397} \simeq -0.2$. *The trend of the data points for M30 is consistent with the occurrence of mass segregation. However, the effect to be measured is smaller than the errors.*

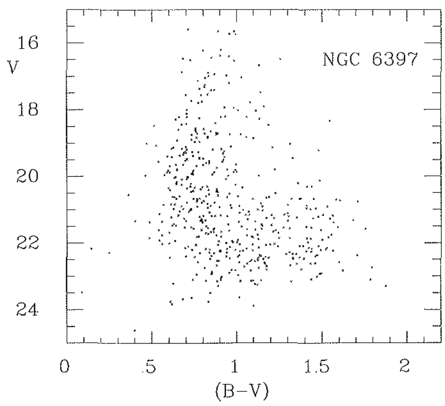


Figure 3: *Colour-magnitude diagram for the foreground/background stars towards NGC 6397.*

from the one observed at a given $\langle r \rangle$ (measured in units of core radius r_c). The models (computed for a set of concentration parameters $c = \log(r_t/r_c)$, where r_t is the tidal radius) predict an excess of the local (observed) MF exponent over the global exponent, x_o, at large distances from the centre: this is due to the fact that the most massive stars tend to concentrate towards the cluster centre. The effect is larger in models with steeper MF and higher central concentration. Assuming that M30 has $r_t = 15\farcm8$ and $r_c = 15''$, Piotto et al. (1989) have found an index x_o as small as 0.7, or even smaller if anisotropy in the outer velocity field is taken into account (Fig. 2). Note that Pryor et al. (1986) give $x_o = 1.4$ for the equally metal poor cluster M15.

The observed trend of the MF slopes at different radial distances is similar to that predicted by the multimass King-Michie models, though the differences between the indexes x found in the inner and outer regions are within 1 sigma (Fig. 2). In any case, Piotto et al. (1989) results seem to exclude the anomalous mass segregation in M30 suggested by Richer, Fahlman and VandenBerg (1988).

NGC 6397

NGC 6397 is one of the nearest globular cluster ($m-M \sim 12.5$). Being at low galactic latitude, its c-m diagram is strongly contaminated by the foreground/background (field) stars of the Galaxy. The c-m diagram of the (control) field stars is presented in Figure 3. Four cluster fields have been covered by B, V deep CCD exposures. We present here the preliminary results for two fields centred at 10′E and 7′W from the cluster centre. A detailed account will be given by Ortolani and Piotto in a forthcoming paper.

Figure 4a reproduces the c-m diagram of the outer region; the same diagram, after field star subtraction, is plotted in Figure 4b. The composite LF for the two regions is in Figure 1, together with the LF for M30 and the theoretical LFs, obtained using McClure, VandenBerg and Bell (1987) isochrones and a power law mass function with different slopes. The mass function for NGC 6397 is flat, with $x = 0$ or even smaller, in agreement with the conclusions of Alcaino et al. (1987) based on a smaller sample of stars. Adopting $r_c = 0\farcm6$ and $c = 1.86$ (Peterson and King 1975), and using the results of Pryor et al. (1986) calculations reproduced in Figure 2, we conclude that the global value of the slope of the mass function for NGC 6397 is $x \sim -0.2$.

Consequences

In Figure 5 we have plotted the observed (x) and global (x_o) power law indexes of the MFs of 10 GCs against their metal content [Fe/H]. It is evident that our new results cast some doubt on the McClure et al. (1986) relation. On the other hand it is not possible to explain the observed spread of the global power law index x_o just with observational errors, nor with the mass segregation alone (Pryor et al. 1986; note that their models tend to overestimate the mass segregation). Our new results do not change the picture.

There is no obvious interpretation for the apparently random behaviour of x. This might result from the combination of several factors, including the uncertainties of the models used to transform luminosity into mass functions (Renzini and Fusi Pecci 1989). It has been also speculated that the power law may not be a good representation of the MF.

Stellar populations other than those of GCs do not seem to present this large spread in the MF slopes. Scalo (1986) concludes that the differences in the index x among most galaxies are less than ± 0.5. No systematic trends of the LF with the morphology of the parent galaxy or metallicity appear in the data, at least for stellar masses $m > 10 \div 20\ M_\odot$. At smaller masses, the LFs in several regions of the Large Magellanic Cloud agree with each other and with the solar neighbourhood LF, suggesting similar IMFs down to about $2\ M_\odot$. For the stars in the vicinity of the Sun, the value of x is likely between $+1.3$ and $+2.4$ for $m > 10\ M_\odot$, and $x = +1.7$ for lower stellar masses ($2 < m < 10\ M_\odot$). Up to now, no significant differences

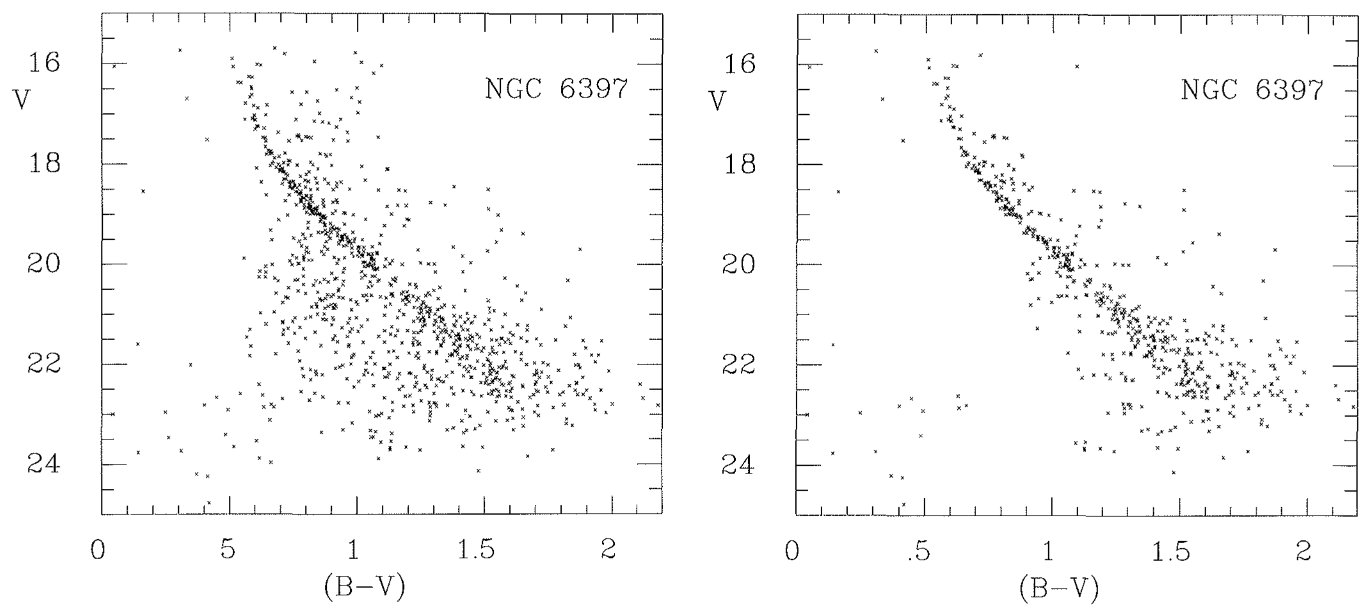


Figure 4: *Colour-magnitude diagram for the outer region of NGC 6397: a) original; b) after field stars subtraction.*

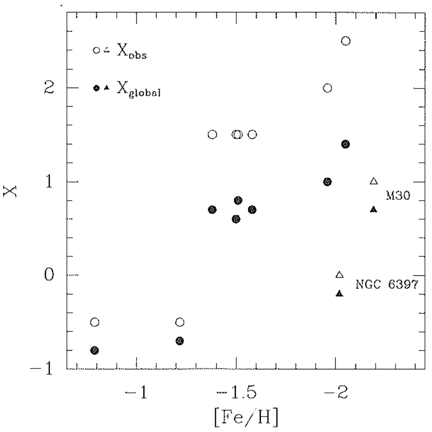


Figure 5: *Observed (light circles) and mass-segregation corrected (filled circles) power law exponents plotted versus metallicity. Note that the present sample seems to exclude any dependences of the MF slopes upon metallicity.*

have been found between the IMFs of disk and halo stars over the range $0.3 < m < 0.8\ M_\odot$. However, we shall note that these investigations consider heterogeneous samples of stars and regions of a vast stellar system which may have experienced a different evolution.

For all these reasons we have started a long-range project aimed at investigating the luminosity functions in different stellar populations. In the present phase we are studying GCs with different structure parameters, with a particular attention for the clusters with low concentration or long relaxation times (such as NGC 1261, M55 and M4), where the amount of mass segregation is expected to be small, and a few irregular galaxies resolved in stars.

References

Alcaíno, G., Buonanno, R., Caloi, V., Castellani, V., Corsi, C.E., Iannicola, G., and Liller, W. 1987, *Astron. J.,* **94,** 917.

Capaccioli, M., Ortolani, S., Piotto, G.P., 1987, ESO Workshop on "Stellar Evolution and Dynamics in the Outer Halo of the Galaxy", eds. M. Azzopardi and F. Matteucci, p. 393.

McClure, R.D., VandenBerg, D.A., Smith, G.H., Fahlman, G.G., Richer, H.B., Hesser, J.E., Harris, W.E., Stetson, P.B., and Bell, R.A. 1986, *Astrophys. J. Letters,* **307,** L49.

McClure, R.D., VandenBerg, D.A., and Bell, R.A. 1987, *Astron. J.,* **93,** 1144.

Peterson, C.J., and King, I.R. 1975, *Astron. J.,* **80,** 427.

Piotto, G.P., Capaccioli, M., Ortolani, S., Rosino, L., Alcaino, G., and Liller, W. 1987, *Astron. J.* **94,** 360.

Piotto, G.P., King, I.R., Capaccioli, M., Ortolani, S., and Djorgovski, S. 1989, preprint.

Pryor, C., Smith, G.H., and McClure, R.D. 1986, *Astron. J.,* **92,** 1358.

Renzini, A., and Fusi Pecci, F. 1988, *Ann. Rev. Astr. Ap.,* **26,** in press.

Richer, H.B., Fahlman, G.G., and VandenBerg, D.A. 1988, *Astrophys. J.,* **329,** 187.

Scalo, J.M. 1986, *Fundamental of Cosmic Physics,* **11,** 1.

Smith, G.H., and McClure, R.D. 1986, *Astrophys. J.,* **316,** 206.

Spitzer, L. 1987, *Dynamical evolution of globular clusters,* Princeton University Press.

VandenBerg, D.A., and Bell, R.A. 1985, *Astrophys. J. Suppl.,* **58,** 561.

Webbink, R.F. 1985, in *Dynamics of Start Clusters,* IAU Symposium No. 113, ed. J. Goodman and P. Hut (Dordrecht: Reidel), p. 541.

Molecular Hydrogen Emission from Star-forming Regions in the Large Magellanic Cloud

R. BECKER, Radioastronomisches Institut der Universität Bonn, F. R. Germany

1. Introduction

Molecular hydrogen is probably the most abundant molecule of the interstellar medium. Giant molecular clouds consist mainly of H_2. There are limited possibilities for direct observations of the H_2 molecule.

Within the ground electronic state, all rotation-vibration transitions are forbidden for electric and magnetic dipole transitions. The electronic transitions in the Lyman and Werner bands of the H_2, which occur in the UV range of the spectrum, can be observed in absorption against the continuum spectrum of bright stars. Due to the strong interstellar extinction in the ultraviolet, such observations are limited to nearby, low-density interstellar clouds. In giant molecular clouds the extinction prevents such observations. The excitation of the electric quadrupol transitions in the near infrared around 2 μm requires high excitation temperatures (≥ 1000 K). Such high excitation temperatures can be obtained by collisional excitation in regions behind shock fronts (Shull and Beckwith, 1982) or intense ultraviolet radiation from bright massive stars (Black and van Dishoeck, 1987).

The first detections of near-infrared H_2 quadrupol emission from star-forming regions in the Magellanic Clouds were reported from Koornneef and Israel (1985) and Israel and Koornneef (1987).

Compared to spiral galaxies, the Magellanic Clouds have, like other irregular galaxies, a lower metallicity, a low dust content and very weak CO line emission. Direct observations of the H_2 molecule can help to clarify whether these characteristics imply a considerable underabundance of H_2 or not.

2. Observations and Reduction

At the beginning of January 1988, we used the cooled infrared grating spectrometer IRSPEC (cf. Moorwood et al. 1986) attached to the ESO 3.6 m telescope to search for H_2 emission from star-forming regions in the Large Magellanic Cloud. The entrance aperture was 6″ × 6″ and the spectral resolution about 2000. For the flux calibration, flat fielding and cancellation of atmospheric absorption, the object spectra were divided by the spectrum of a standard star that has been observed at a similar air mass with the same instrument settings. The sky background was cancelled by chopping 60″ in declination. The total on-source integration times were 30 to 40 minutes.

The observed H_2 spectra were calibrated with the spectrum of the standard star HR 2015. The infrared magnitudes for this star and the absolute flux densities for zero magnitude are given by Koornneef (1983a, b). The flux density distribution of HR 2015 in the photometric K-band window (1.9–2.5 μm) is given by

$$F\lambda\ (\mathrm{W\ cm^{-2}\ \mu m^{-1}}) = 8.43\ 10^{-16}\ \lambda^{-3.75} \quad (1)$$

We observed two compact infrared sources of non-stellar nature within the H II regions N160A and N10, found by Jones et al. (1986). N160A is located in a molecular cloud (see Figs. 3 and 4) that itself belongs to an extremely large complex of molecular clouds extending south from 30 Doradus for over 2000 pc (Cohen et al., 1987). N10 is also embedded in a molecular cloud complex (see Fig. 5). The CO observations have been carried out later than the H_2 observations. The beam size was 43″. We find

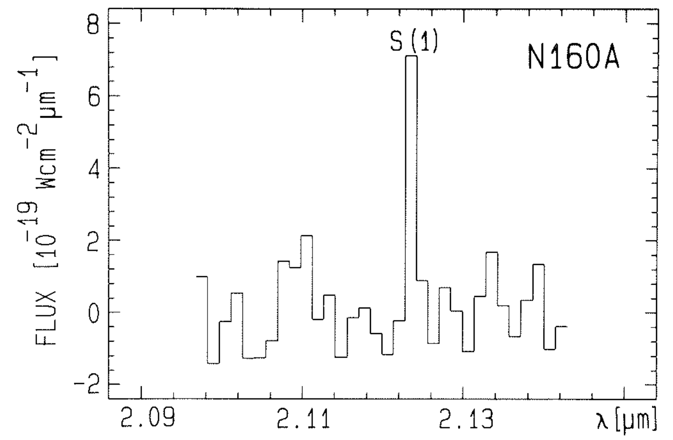


Figure 1: *IRSPEC spectrum of N160A in the wavelength range 2.10 µm to 2.14 µm, with the S(1) line at 2.12 µm.*

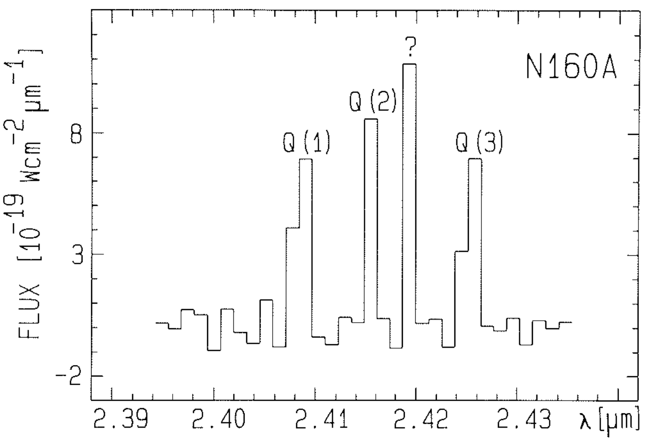


Figure 2: *IRSPEC spectrum of N160A in the wavelength range 2.395 µm to 2.435 µm, with the Q-branch lines and one unidentified line.*

that the observed infrared sources do not coincide with the positions of the strongest CO emission. A more extensive discussion of the CO observations will be given elsewhere.

H_2 emission was detected only from the infrared source in N160A in four quadrupol vibrational-rotational transitions (see Figs. 1 and 2).

The observed transitions occur within the electronic ground state of the H_2 molecule from the first excited vibrational level (v = 1) into the vibrational ground level (v = 0). v is the vibrational quantum number. The vibrational levels themselves split into a number of rotational levels. S-branch lines refer to transitions with $\Delta J = 2$ and the Q-branch lines to $\Delta J = 0$. J is the rotational quantum number.

For the determination of the interstellar extinction, one preferentially compares two lines which arise from the *same* upper state like the S(1) and Q(3) lines in our spectra. A comparison of the observed line ratio to the theoretical one, i.e. Q(3)/S(1) = 0.7, yields the differential extinction between the two wavelength $\lambda = 2.12$ µm and $\lambda = 2.42$ µm. The accuracy of this method strongly depends on a proper cancellation of telluric absorption near the Q(3) line. So some preference may be given to other methods of extinction analysis (see e.g. Israel and Koornneef, 1987).

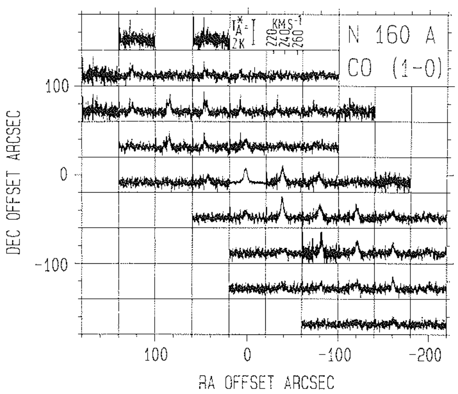


Figure 3: *CO spectra of the J = 1-0 transition of the giant molecular cloud complex associated with N160A, obtained with the 15 m SEST at La Silla. The reference position is α = 05^h 40^m 11.6^s, δ = −60° 40′ 06″ (1950.0). At this position the H_2 spectra were obtained.*

3. Discussion

The observed quadrupol lines are optically thin. The intrinsic intensity of an optically thin transition is given by

$$I = Ah\nu N(v, J)/4\pi \; [\mathrm{W\,cm^{-2}sr^{-1}}] \qquad (2)$$

where A is the Einstein A coefficient, i.e. the spontaneous transition probability, h ν is the photon energy and N (v, J) the molecular level population.

In the thermodynamic equilibrium the level populations are given by a Boltzmann distribution at the temperature T:

$$N(v, J) = N_{H_2} \frac{g(v_J)}{Q(T)} \exp(-E(v_J)/kT) \; [\mathrm{cm^{-2}}] \qquad (3)$$

where N_{H_2} is the total H_2 column density, $g(v_J)$ is the statistical weight of the level v_J, Q(T) is the partition function, and $E(v_J)$ is the energy of the level v_J.

These two equations can be used to determine the excitation temperature T and the total H_2 column density N_{H_2}. From the Q(1) and Q(3) lines we determine an excitation temperature of 1688 K. The value of the partition function for this temperature is 42.8 and we obtain a total H_2 column density of N_{H_2} = 8.9 10^{17} cm^{-2}. Adopting a distance of 53 kpc for the LMC and assuming that the observed source is spherical and exactly fills the beam, the volume density is about 0.2 cm^{-3}. This very low value indicates that the source is probably unresolved and that the value for N_{H_2} is a lower limit.

Because it is so difficult to observe the H_2 molecule directly, the H_2 mass within giant molecular clouds is generally estimated from observations of tracer molecules like CO. The first CO rotational transition J = 1-0 at λ = 2.6 mm is easily excited by collisions with H_2 also at low kinetic gas temperatures. A conversion between the H_2 column density N_{H_2} and the integrated brightness temperature of the ^{12}CO J = 1-0 line of the form N_{H_2}/I_{CO} = const is frequently used. The value of the conversion factor depends on the conditions within the molecular clouds, like the kinetic gas temperature, carbon and oxygen abundance, etc. (Maloney and Black, 1988). It is currently one of the major problems to estimate what values have to be used, especially for low metallicity extragalactic systems like the Magellanic Clouds.

Adopting the conversion factor N_{H_2}/I_{CO} = 1.7 10^{21} [K km s^{-1} cm ^{2}]$^{-1}$ as suggested for the LMC by Cohen et al., we derive from our CO observations an H_2 column density of 1.5 10^{22} cm^{-2} towards the position of the compact in-

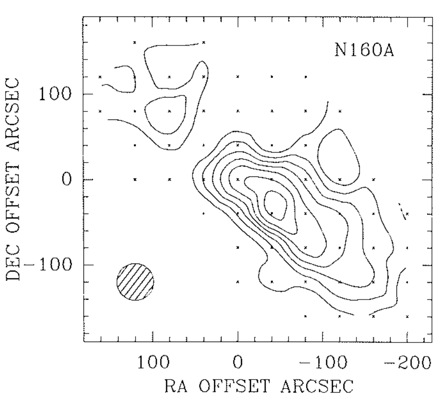


Figure 4: *A J = 1-0 CO contour map of the data shown in Figure 3. The reference position is the same as in Figure 3. Contour levels are 2.5, 4, 5.5 . . . 11.5 K km s^{-1}, integrated over a velocity range of 210 to 255 km s^{-1}. The beam size is indicated in the lower left.*

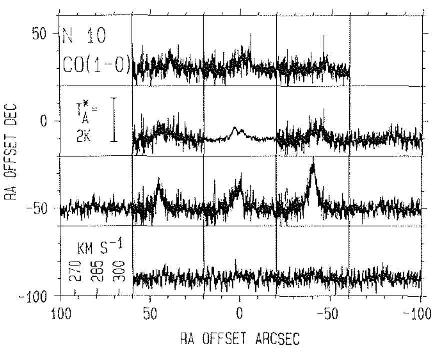


Figure 5: *J = 1-0 CO spectra of the molecular cloud complex associated with N 10 measured with the SEST. The reference position is $\alpha = 04^h 56^m 46^s$, $\delta = -66° 28' 20''$ (1950.0).*

frared source in N 160 A. The reason for the difference to the infrared N_{H_2} value is that in the CO measurements we indirectly observe the much larger amount of cold H_2 gas along the line of sight, while the near infrared H_2 lines yield information only about the very small amount of hot H_2 gas. We also have to consider that the radio beam is much larger than the infrared beam and that the H_2 line emission source is probably unresolved. A comparison of the intensity ratios of the observed lines with those resulting from model calculations for shock excitation (Shull and Hollenbach, 1978) and for radiative excitation (Black and van Dishoeck, 1987) shows that the energy levels may be partly populated from ultraviolet pumping. The strong Q(2) line could result either from a lower ratio of the ortho to para-hydrogen than 3 or from non-thermal equilibrium. In the latter case the gas density would be less than 10^5 cm^{-3}.

Acknowledgements

I thank the ESO staff at La Silla for their help with the observations. I am very grateful to Drs. S. Beckwith and A. Dalgarno for their valuable help and advice. I thank Dr. J. G. A. Wouterloot, who obtained the CO data. For useful discussions, I further thank Drs. A. Moorwood and F. J. Zickgraf. Drs. I. Appenzeller and O. Stahl kindly read the manuscript and Brigitte Farr-Trautmann prepared the figures for publication.

References

Black, J. H., van Dishoeck, E. F.: 1987, *Astrophys. J.* **20,** 163.

Cohen, R. S., Dame, T. M., Garay, G., Montani, J., Rubio, M., Thaddeus, P.: 1987, *Astrophys. J.* **331,** L95.

Israel, F. P., Koornneef, J.: 1987, *Astron. Astrophys.* **190,** 21.

Jones, T. J., Hyland, A. R., Straw, S., Harvey, P. M., Wilking, B. A., Joy, M., Gatley, I., Thomas, J. A.: 1986, *Monthly Notices Roy. Astron. Soc.* **719,** 603.

Koornneef, J.: 1983a, *Astron. Astrophys. Suppl.* **51,** 489.

Koornneef, J.: 1983b, *Astron. Astrophys.* **128,** 84.

Koornneef, J., Israel, F. P.: 1985, *Astrophys. J.* **291,** 156.

Maloney, P. R., Black, J. H.: 1988, *Astrophys. J.* **325,** 389.

Moorwood, A., Biereichel, P., Finger, G., Lizon, J. L., Meyer, M., Nees, W., Paurean, J.: 1986, *The Messenger* **44,** 19.

Shull, J. M., Beckwith, S.: 1982, *Ann. Rev. Astron. Astrophys.* **20,** 163.

Shull, J. M., Hollenbach, D. J.: 1978, *Astrophys. J.* **220,** 525.

Search for HCOCN in Interstellar Space

M. GERIN, Radioastronomie millimétrique, Laboratoire de Physique de l'ENS, Paris, and DEMIRM, Observatoire de Paris, Section d'Astrophysique de Meudon, France

1. Interstellar Molecules

More than 80 different molecular species have been observed in the interstellar medium (ISM) in one or more molecular sources (cf. the review of Irvine et al., 1987). Most of them were discovered and identified via their centimetre and millimetre lines. However, to get a better understanding of the complex chemical processes at work in interstellar clouds, we need to observe many more species. On the one hand, only a few among all species involved in the reaction networks are observed: most of the reactions are exothermic and involve radicals and/or molecular ions. These species have low abundances and complex spectra, and are therefore very difficult to detect, but their observation would provide important constraints on the chemical models. On the other hand, there are often competitive ways to synthesize complex molecules, with poorly known reaction rates. Observations of these elaborated species could provide constraints on the reaction rates, synthesis modes, and give an insight into the degree of complexity that this kind of chemical system can reach (how many heavy atoms, and what structure can we observe/are present in complex molecules?). This research topic was initiated by the search of Glycine and Urea after several organic molecules were found in the ISM in the mid 1970's (Hollis et al., 1980; Guelin 1989).

When searching for new interstellar species, several approaches are possible: systematic frequency surveys of a given molecular source provide a good picture of this source, and some non-identified lines! These lines are due both to new molecular species and to high excitation lines of already known species. The molecular source near Orion IRc2 is very hot, and vibrationally excited molecules like CH_3OH radiate a lot of lines in the millimetre and submillimetre domain. (Methyl formate $HCOOCH_3$ has about 1 line per GHz from 80 to 300 GHz!). The main problem of this kind of work is to achieve a good and uniform sensitivity in a complete frequency range (> 20 GHz).

Another method is to concentrate on a few interesting species and obtain long integration times for a few lines on well-known molecular sources. For both methods, the knowledge of the line frequencies with an accuracy better than 100 kHz ($\Delta v/v < 10^{-6}$) is crucial to get a secure identification; there are so many lines at a noise level of 10 mK that the probability of a random coincidence is quite large. Spectroscopic work in the laboratory is therefore required before each new identification can be made, even though the lines were first detected in the ISM. This is particularly difficult for radicals and molecular ions which are very unstable and difficult to produce in sufficient quantities to complete spectroscopic measurements.

For this observing run, we had scheduled the observations of several lines of two new species: HCOCN and CH_2D^+. The first one was studied by J. L. Destombes and his colleagues at the "Laboratoire de Spectroscopie Hertzienne" of the Lille University. We have a long-term collaboration with them, which has already succeeded in observing new species in the ISM, such as CCD (Combes et al., 1985), C_3HD (Gerin et al., 1987), Acetone (Combes et al., 1987), etc. The other one, CH_2D^+ (is a tracer of the important ion CH_3^+, which is one of the main reactants of the

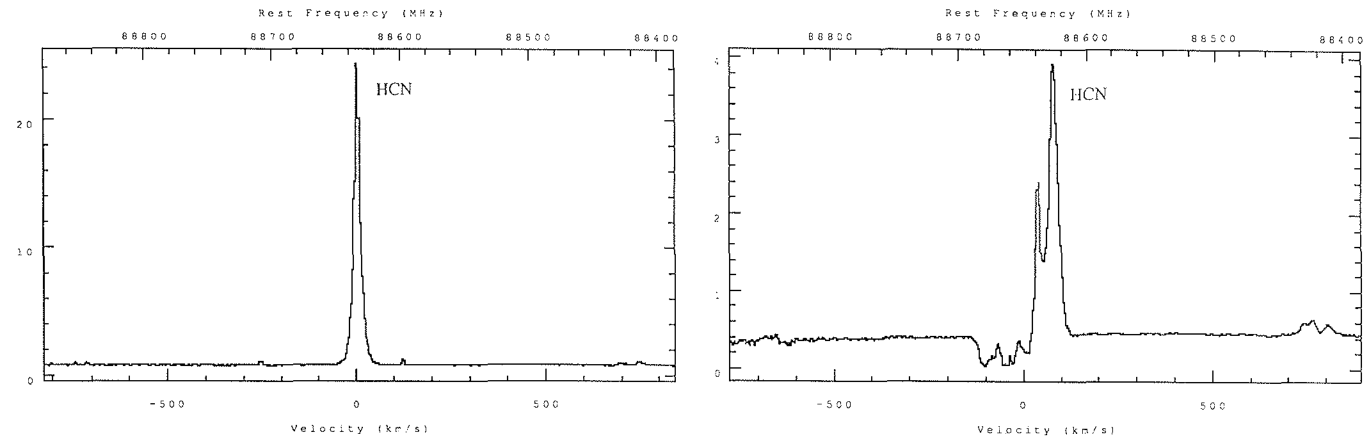


Figure 1: *Raw spectra taken towards IRc2 in Orion (a) and SgrB2(s) (b) with the SEST; central frequency 88631.8 GHz, the HCN (J = –0) line σ = 10 and 9 mK.*

chemical reactions forming complex hydrocarbons. Quantum mechanical calculations have been done by F. Pauzat (private communication), which gave the dipole moment (0.3 D) and the molecular constants with an accuracy of a few per cent. Spectroscopic work was then done at Lille, but did not succeed in detecting a line (the line is very faint and somewhat below the detection limit since the production of CH_2D^+ is very difficult, and the frequency range of the expected line quite large). To pursue their work, J.L. Destombes and his colleagues need better estimates of the molecular constants, which may be provided by infrared spectroscopy of the vibrational lines.

We decided to observe HCOCN and another molecule whose rotational constants were just measured by G. Wlodarczak at the "Laboratoire de Spectroscopie Hertzienne" of the Lille University (private communication), cyclopropenone c-C_3H_2O, the cyclic isomer of propynal which was recently detected by Irvine et al. (1988) in TMC1. These two molecules are asymmetric tops, with a dipole moment on the two principal axes A and B for HCOCN, and A only for c-C_3H_2O. We searched for several lines in the two molecular sources Orion-IRc2 and SgrB2(S).

2. The Observations

The observations were done from March 6 to 10, 1989, under clear sky conditions with the Swedish-ESO Submillimetre Telescope (SEST) at La Silla. It has been described by Booth et al. (1987). The antenna parameters at 2.6 mm are: HBPW = 43″, beam efficiency 0.78, aperture efficiency: 0.67, moon efficiency > 0.85. At the front-end, a dual polarization 80–115 GHz receiver with two cooled Schottky diode mixers was available, providing SSB noise temperature ranging from 280 K to 400 K. The side band rejection was always better than 10 dB, more often around 20 dB. At the back-end, we used a wide-band Acousto-Optic Spectrometer (AOS) with 2000 channels spaced by 690 kHz. The receiver temperature was measured by observing two loads at about 273 and 320 K. The results reported here are in units of T_A^*, the antenna temperature outside the atmosphere. Since the correction factor to get T_R^* (η_{fss}) is close to 1 and changes with frequency, we prefer to quote the result in the unit given by the chopper wheel method, T_A^*. The observed line intensities have been compared with existing frequency surveys of the same sources (Turner (1989), Cummins et al. (1986)) with similar angular resolution and are in reasonable agreement.

The spectra were saved on tape with FITS format, then read and converted to CLASS format read on the Vax computer at La Silla, and in Meudon. We used CLASS to correct the baselines, identify the line frequencies, fit gaussian profiles and do Hanning smoothing. Due to the line blending problem, the rms noise was difficult to estimate in the spectra (we have to find a frequency range without lines), but ranges from 8 to 40 mK depending on the time spent and the observing mode.

We observed two well-known molecular sources: the infrared source in the Orion Molecular Cloud IRc2 at α (1950) = 5h32m47.0s, δ (1950) = $-5°24'22.0''$, V_{LSR} = 9 km s^{-1}, and the southern H II region in the SgrB2 molecular cloud at α (1950) = 17h44m11.0s, δ (1950) = $-28°22'30''$, V_{LSR} = 60 km s^{-1}. For the first source, the reference was done switching the beam to a position 12′ from the source every 1 or 2 minutes. For the second, the emission is more extended than 12′, so we had to move the antenna to a reference position located 30′ north and 30′ west. This observing mode has two main disadvantages: (1) the antenna moves slowly, and the efficiency of the observations is lower than in the beam switch mode; (2) we had sometimes a very bad baseline with strong ripples extending through part or all of the frequency range. These ripples diminished or disappeared when the switch in position was done in azimuth instead of elevation and if the reference position was close to the observing position. However, at some frequencies the ripples were in every scan, so we chose to also observe this source in beam switch mode, since any emission in the reference position should anyhow be much weaker than in the "on" position. The absorption features on the strong HCN line at 88 GHz show the maximum level of contamination, since some are due to absorbing gas on the same line of sight, as shown by the comparison of this spectrum and that taken by Turner (1989) with the 12 m NRAO antenna with another reference position.

3. The Results

Figure 1 presents two of the spectra obtained with the SEST, and Figure 2 shows enlargements of some of them, after baseline subtraction and sometimes Hanning smoothing. For the spectra obtained towards IRc2 in Orion, the offset level is very stable from one scan to the other, and measures the continuum emission of the H II region in front of the molecular cloud. It should be accurate to about 0.1 K (about 10%).

The line confusion limit is reached in most of the spectra as shown by the numerous faint features at the 10 mK level. The frequency of the expected lines is indicated by arrows; we sometimes observe a line at the right position, but not always! Therefore, we conclude

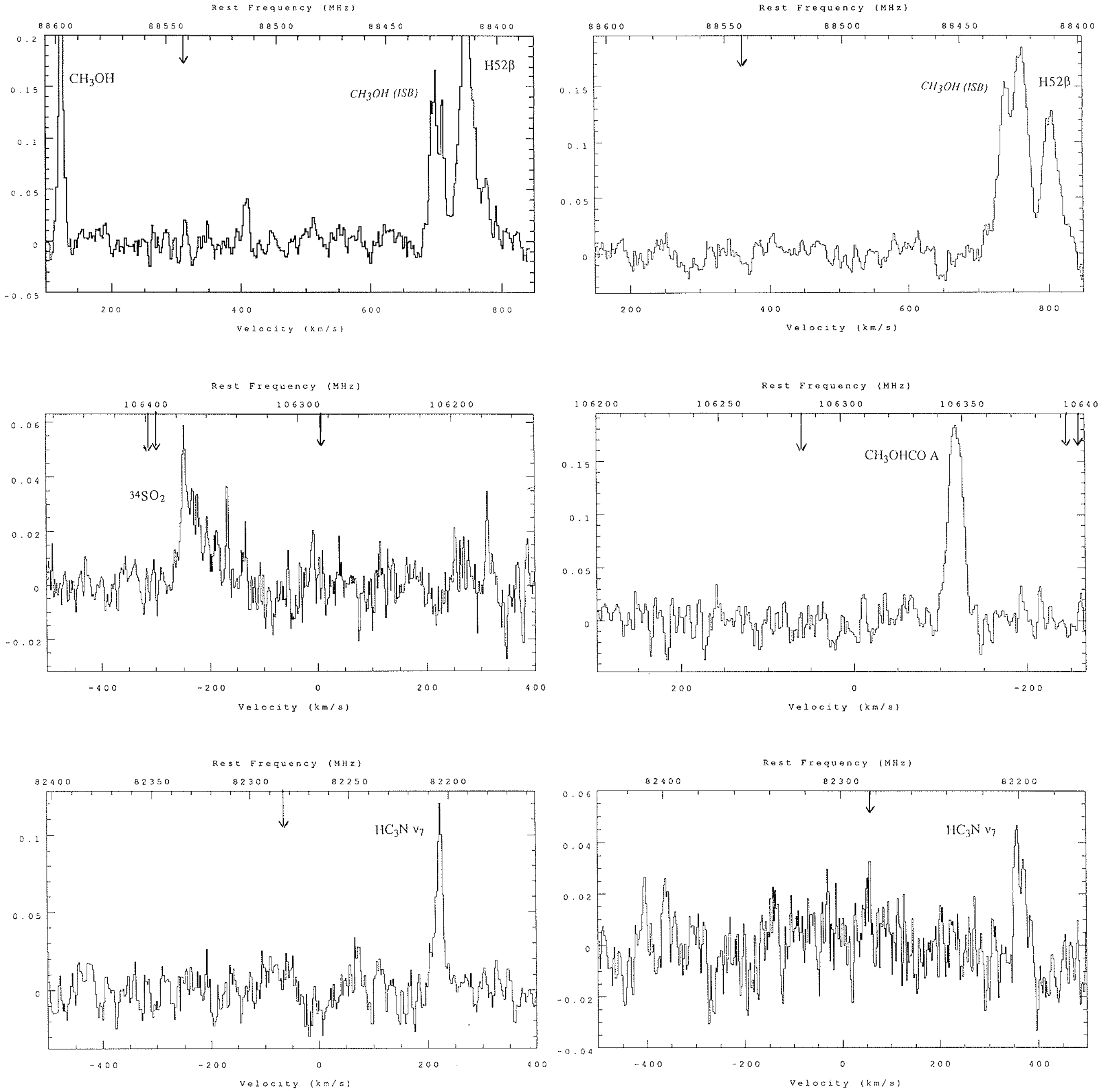


Figure 2: *Enlargements of some of the spectra. Expected line frequencies are shown by arrows.*

that neither HCOCN nor c-C_3H_2O were detected during this run. Taking the observed line intensities or a 3σ limit, we can construct for HCOCN a rotational diagram in the two sources. Typical rotational temperatures range from 50 to 200 K in Orion, and 10–30 K in SgrB2. This seems to be the case for both molecules. Assuming T_{ROT} = 100 K, $N(H_2) = 3\ 10^{23}$ cm^{-2} in Orion and T_{ROT} = 20 K, $N(H_2) = 10^{24}$ cm^{-2} in SgrB2(S) (Irvine et al., 1987), we obtain upper limits for the column density of HCOCN and its abundance relative to H_2: towards IRc2 in Orion N(HCOCN) $< 2\ 10^{13}$ cm^{-2} and [HCOCN] $< 7\ 10^{-11}$; towards SgrB2(S) N(HCOCN) $< 5\ 10^{13}$ cm^{-2}, and [HCOCN] $< 5\ 10^{-11}$. These values are similar to or lower than the abundances of other complex molecules with four heavy atoms in SgrB2: HC_3N ($2\ 10^{-9}$), $HCOOCH_3$ ($2\ 10^{-9}$) (Irvine et al., 1987), acetone ($5\ 10^{-11}$, Combes et al., 1987), H_2C_3O ($4\ 10^{-11}$, Irvine et al., 1988).

A line might be present at the expected frequency of the $6_{(0,6)}$–$5_{(0,5)}$ transition of cyclopropenone near 82.3 GHz, but we detected nothing at the frequency of the $8_{(0,8)}$–$7_{(0,7)}$ transition near 107 GHz. If the line at 82.3 GHz is due to cyclopropenone, we can explain the non-detection at 107 GHz by excitation effects: due to the high dipole moment of 4.4 D, the rotational temperature of this species could be around 10 K, although the kinetic temperature is much larger in both sources. In this case, the upper energy level of the second line is too high to be populated at this temperature, explaining the non-detection. The other possibility is of course a chance coincidence with a transition of another species. More observations of other lines of cyclopropenone of low excitation (less than 15 K), and in other sources should be done before this question can be definitively settled.

These observations with the SEST have not added new species to the already long list of interstellar molecules, but have demonstrated that more work can be done with this instrument: the 3 mm mixers are very easy to tune at nearly any frequency between 80 and 115 GHz and are stable, permitting long integration times on the same position. In the beam switching mode, the baselines are very flat over the whole frequency range; this observing mode is the best to use in the line search. Finally the southern position of the La Silla observatory allows one to track these molecular sources 10 hours per day above 30° elevation. The elevation of SgrB2 rises to more than 80°, where we had to stop the tracking (this is the telescope limit), while from the northern hemisphere we can observe it only 4 hours per day at elevations between 20° and 28°!

Acknowledgements

We are grateful to the whole SEST team, who kindly informed us about the telescope, and helped the observers at any hour of the day or night.

References

Booth, R.S., De Jonge, M.J., Shaver, P.A.: 1987, *The Messenger* **48,** 2.

Cummins, S.E., Linke, R.A., Thaddeus, P.: 1986, *Astrophys. J. Suppl.* **60,** 819.

Combes, F., Boulanger, F., Encrenaz, P.J., Gerin, M., Bogey, M., Demuynck, C., Destombes, J.L.: 1985, *Astron. Astrophys.* Letters **147,** L25.

Combes, F., Gerin, M., Wootten, A., Wlodarczak, G., Clausset, F., Encrenaz, P.J.: 1987, *Astron. Astrophys.* Letters **180,** L13.

Gerin, M., Wootten, H.A., Combes, F., Boulanger, F., Peters, W.L., Kuiper, T.B.H., G., Encrenaz, P.J., Bogey, M.: 1987, *Astron. Astrophys.* Letters **173,** L1.

Guelin, M.: 1989, Proceedings of the symposium "Molecules in Physics, Chemistry and Biology".

Hollis, J.M., Snyder, L.E., Lovas, F.J., Ulich, B.L.: 1980, *Astrophys. J.* **241,** 158.

Irvine, W.M., Goldsmith, P.F., Hjalmarson, A.: 1987, in *Interstellar Processes,* D. Hollenbach and H.A. Thronson ed., Reidel.

Irvine, W.M., Brown, R.D., Cragg, D.M., Friberg, P., Godfrey, P.D., Kaifu, N., Mathews, H.E., Ohishi, M., Suzuki, H., Takeo, H.: 1988, *Astrophys. J.* Letters **335,** L89.

Turner, B.E.: 1989, *Astrophys. J. Suppl.* in press.

The Arc in Cl 0500-24

E. GIRAUD, ESO

P. SCHNEIDER and J. WAMBSGANSS, Max-Planck-Institut für Physik und Astrophysik, Garching, F.R. Germany

In 1986, luminous arcs in two clusters of galaxies were detected; their highly elongated unusual morphology posed a problem to the nature of their origin. Whereas several interpretations have been suggested, it soon became clear that they may be the result of gravitational lensing of a background galaxy by the cluster. The gravitational lens hypothesis was confirmed for the arc in A 370 when its spectrum was measured; the redshift is about 0.724, i.e. roughly twice that of the cluster, which also is close to the ideal redshift for efficient lensing. The nature of the arc in Cl 2244 is less clear, but from the similarity of the morphology and colour of

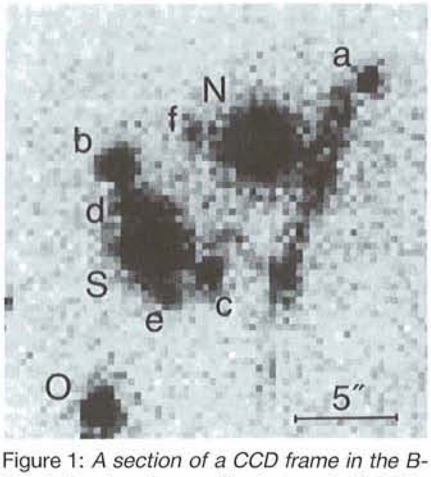


Figure 1: *A section of a CCD frame in the B-band showing the arc-like feature in Cl 0500-24 (exposure time: 56 min). North is up and east is to the left. On this image, taken with a seeing of 0.9 arcsec, the arc-like feature and galaxy N are well separated. Contrary to other arcs it appears nearly straight. However, its shape and the varying width can be well explained by a lens model. On the other hand, galaxies N and S have the same redshift. Thus we cannot exclude the hypothesis of tidal interaction.*

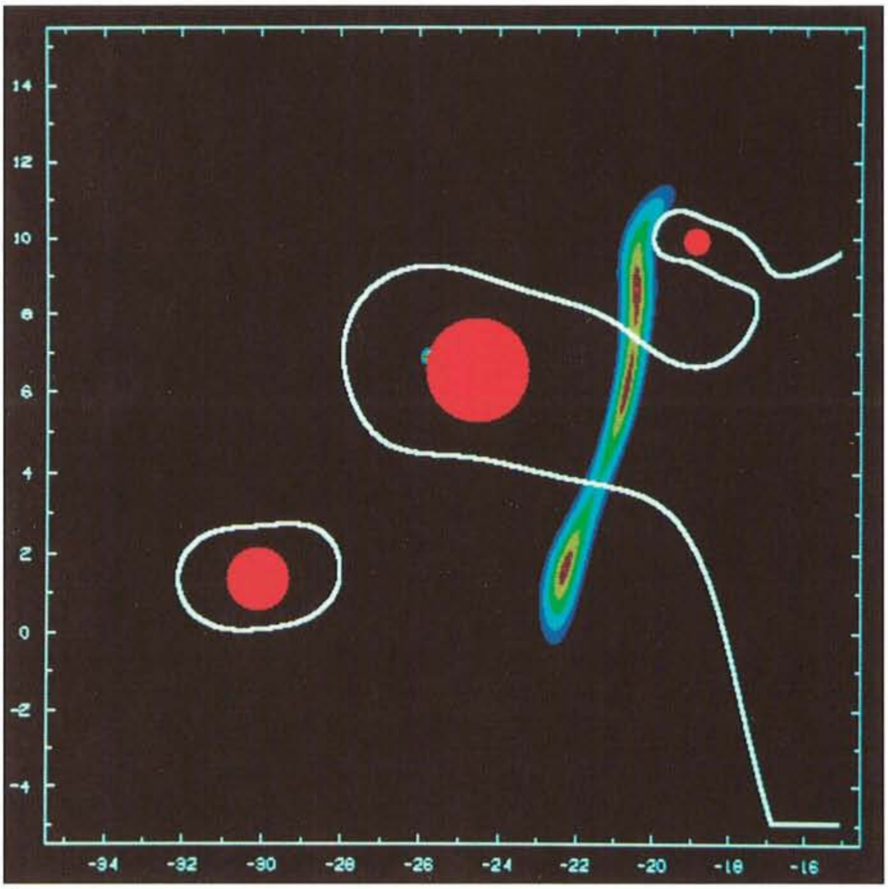


Figure 2: *A gravitational lens model of the observed arc in Figure 1. In this model we used an isothermal sphere for the cluster potential and three point masses for the three galaxies N, S, and a. We used a circular source of radius 0.6 arcsec. The different colours of the arc correspond to images of concentric rings of the extended circular source. The white lines are "critical lines" of the lens. The scale is in arcsec.*

this arc, it is usually assumed that this is also due to lensing of a background galaxy.

The arc-like feature detected in Cl 0500-24, a rich and compact southern cluster at z = 0.32 (Giraud, 1988), is different from the two other cases in several respects. First it is nearly straight, whereas the others are clearly curved toward the centre of the cluster. Secondly, the arc is shorter than in the other cases. Finally, the arc lies very close to a pair of bright galaxies which have the same redshift (z = 0.328). It is thus not clear whether this arc is also due to lensing or the result of the tidal interaction of the two interacting galaxies.

In a recent paper, we pointed out the attractiveness of the lensing hypothesis (Wambsganss et al., 1989). In particular, using a simple lensing model which incorporates only the cluster mass and the two interacting galaxies close to the arc, we were able to show that at the observed position it is reasonable to expect an arc. In other words: if a background source (with redshift in excess of 0.5) is seen at this position in the cluster, it is unavoidable, given the richness and compactness of the cluster as observed, that the image will be highly distorted. In addition, the distorsion will act in such a way that the image must be elongated in the direction perpendicular to that of the centre of the cluster.

New images have been obtained in January 1989 with the 2.2 m ESO-MPI telescope at La Silla under very good seeing conditions (0.9 arcsec). We used CCD No. 8 which has low noise (30 e^{-1} rms) and high quantum efficiency. These observations have revealed that the arc-like feature has three components, which are seen as varying width and surface brightness along the arc (Fig. 1). When we tried to understand these new observations with a simple lens model, we were unexpectedly successful. An image of one of our models is shown in Figure 2. Not only are we able to understand the multicomponent nature of the arc, but also their relative size and orientation. These models, however, have shown that the arc is of a different nature concerning its lensing origin. The two other arcs are well understood as a source being close to the cusp point on the caustic of the lens. In the present case, the critical line intersects the arc twice, namely there where the arc is thinnest. In order to achieve this kind of configuration, the mass parameter of the cluster must be very well tuned. If it varies, either the arc becomes too short, or its multiple nature vanishes. If the redshift of the arc can be measured, the mass parameter of the cluster can be rather well determined.

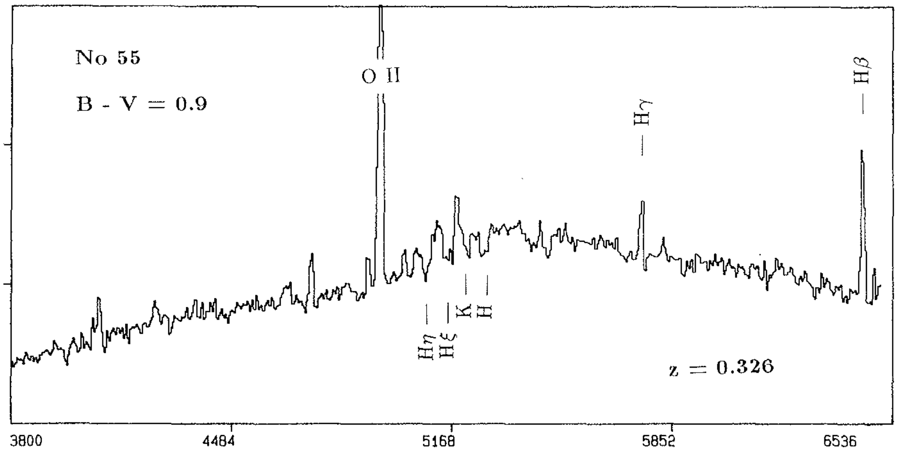


Figure 3: *A spectrum of a galaxy in Cl 0500-24 having colours similar to those of the arc. This spectrum was obtained in multislit spectroscopy with EFOSC at the 3.6 m telescope at La Silla (Giraud, 1989).*

On the other hand, while our photometry (in B, V, R, I) has shown that the arc is very blue and may have the colours of a very distant object, its colours are also compatible with those of intrinsically blue galaxies, at the redshift of the cluster, for which we have spectra. These very blue objects are emission-line galaxies (Fig. 3). Thus the presence of a blue population in the cluster did not allow us to prove without ambiguity that the arc-like feature is the image of a distant galaxy. Finally if we look at the photometry without theoretical prejudice, we cannot even be sure that the object is not foreground. If the arc is the result of the tidal interaction of the two galaxies, and the arc-like feature is a star-forming region, it seems reasonable to expect a well visible O II emission as in blue galaxies. A measurement of the arc spectrum may confirm the lensing nature of this object, and in that case will provide an independent measurement of the mass parameter of the cluster.

E. G. expresses his thanks to all the ESO and MPI staff members for their hospitality.

References

Giraud, E., 1988 *Ap. J.,* **334,** L69.

Wambsganss, J., Giraud, E., Schneider, P., and Weiss A., 1989, *Ap. J.,* **337,** L73.

Giraud, E., 1989, Galaxy populations in medium distant clusters: the data in Cl 0500-24, *Astron. Astrophys. Suppl.,* in press.

A First Glimpse of the Spectrum of 3 C 255

E. GIRAUD, ESO

The radio source 3C 255 was identified by Spinrad et al. (1988) with a faint object having a complex, multimodal structure. The object was resolved in four components on CCD frames taken in good seeing conditions with the 2.2 m ESO-MPI telescope on La Silla (Giraud, *The Messenger* **55,** 60). This image also suggested that the main object itself, which is probably the radio source, might be multiple (on 1 arcsec scale).

The radio source and fainter components may constitute a distant aggregate of galaxies, the radio galaxy being the first ranked object. Obtaining a low resolution spectrum of a 23rd magnitude object such as 3C 255, in a reasonable amount of telescope time, is still a rather uncertain adventure which requires very good observing conditions. Fortunately, distant radio galaxies are known to show moderately strong emission-line spectra. It was thus assumed that our task would be greatly simplified by the presence of these emission features. The exposure time was estimated from two 90-min exposures of a 21st magnitude emission-line galaxy, obtained with EFOSC, which was degraded down to a level that still permits distinguishing emission from noise. It was found that an acceptable spectrum would be obtained in

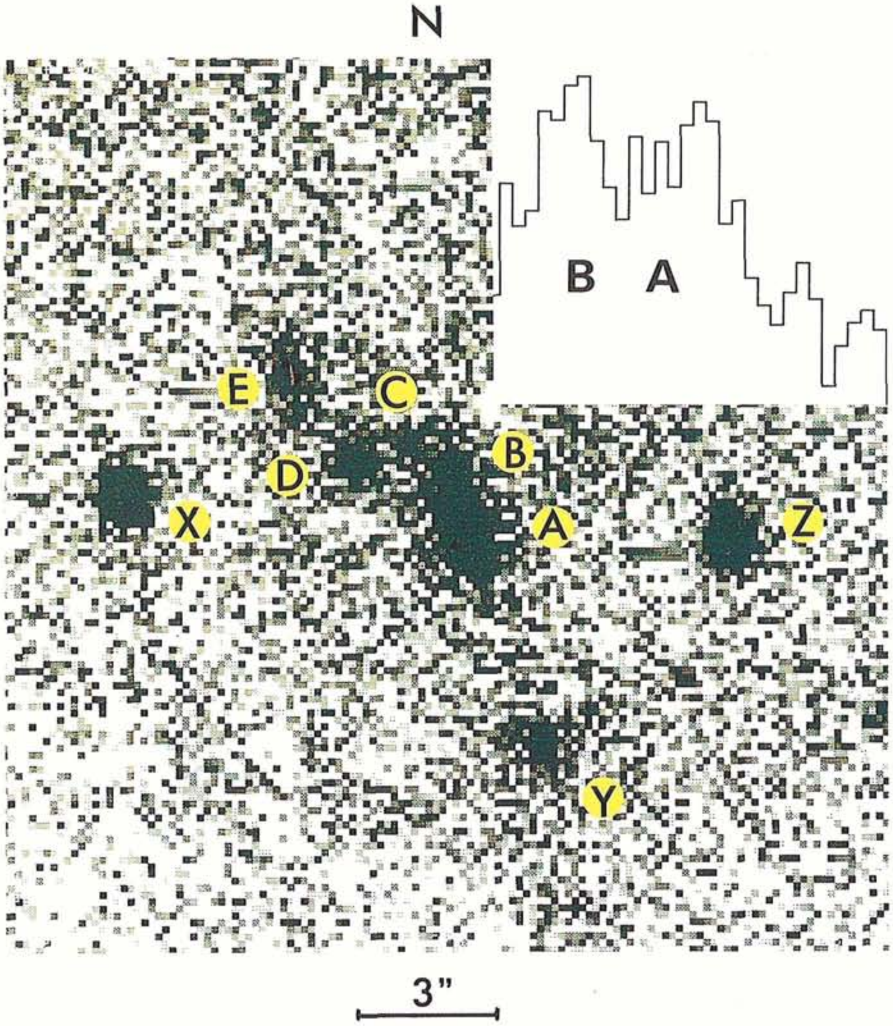


Figure 1: *A spatially resolved image of the radio source 3C 255 obtained with the 2.2 m telescope on La Silla. Exposure time: 2 × 3600 s in R (seeing 0.85 arcsec). Objects A and B were not separated on the image shown in the* Messenger *No. 55 where objects C, D, E could already be resolved. Object B is slightly redder than A. Magnitudes of the objects range between V = 23.4 and V = 24.9. The separation of objects A and B is shown in the upper right corner. North is up and east is to the right.*

3 × 150 min, if the emission lines were rather strong. In the present case the best grism would be a visible-red, i.e. covering approximately the range 4000–8000 Å, where the detector (RCA CCD No. 8 or No. 11) is the most efficient, and a dispersion of about 300 Å/mm. This is an intermediate value between the B 300 and B 1000 grisms currently used with EFOSC.

Just before the off-schedule night allocated to this programme, high resolution CCD frames could be obtained at the 2.2 m telescope under excellent seeing conditions. The image shown in Figure 1 is a stack of 2 × 1 h exposures in the R-band. The seeing measured on that frame is 0.85 arcsec. The main object appears elongated and a new component (marked B) is found. It could be only marginally seen on the previous frames due to poorer seeing. The V magnitudes and V-R colours of the objects in Figure 1, measured within disks of radius r, are as follows:

A: r = 6 pix, V = 23.4, V-R = 0.5; B: r = 4 pix, V = 24.3, V-R = 0.6

C: r = 4 pix, V = 24.9, V-R = 0.5; D: r = 5 pix, V = 24.2, V-R = 0.6

E: r = 6 pix, V = 24.1, V-R = 0.7; X: r = 6 pix, V = 24.1, V-R = 1.4

Y: r = 6 pix, V = 23.9, V-R = 0.6; Z: r = 6 pix, V = 23.4, V-R = 0.8

Galaxy X has the V-R colour index of an early-type galaxy at z ~ 0.6–0.8. The magnitudes and colours of objects A to E and Y are consistent with those expected for galaxies at z ≥ 1. Object Z might be foreground.

Spectra were obtained during the night on April 12–13 (first quarter moon). The night was clear and dry, the seeing measured when refocusing was between 0.9 and 1 arcsec. The CCD mounted on EFOSC was No. 8, a RCA CCD with a readout noise of 30 e^{-1} rms and high quantum efficiency. Two exposures (2 h and 2 h 10) were recorded. The pointing for the first exposure was facilitated by calculated offsets.

A calibrated spectrum of 3C 255 is shown in Figure 2. It is of course very noisy, but some possible emission features can be seen, namely at 4494 Å, (4770 Å), 5484 Å, 6588 Å and (7043 Å). An identification of C III 1909, C II 2326, and Mg II 2799 with the lines that seem to be the most robust gives a redshift of z = 1.355 (C III, z = 1.354; C II, z = 1.357; Mg II, z = 1.354). We also tried a redshift of z = 1.9. In that case the feature at 6588 Å would be ignored and the identification would be C IV (z = 1.901), He II (z = 1.908), C III (z = 1.873), Ne IV (z = 1.905). The weakness of this system is the discrepancy between the redshifts of C IV and C III. Also, the V-R colour index would be very red for objects at such a high redshift. In contrast, the observed colours would agree quite well with a redshift of 1.3.

Finally, this observing test has shown that it is possible to obtain spectra of 23rd magnitude emission-line galaxies in 6–8 h under favourable weather conditions.

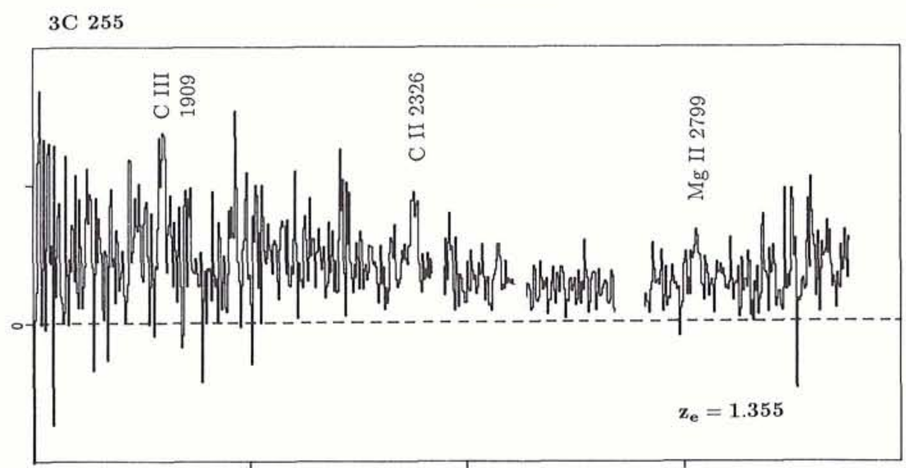


Figure 2: *The spectrum of the very faint galaxy at z = 1.355 associated with 3C 255. The emission features are quite narrow and suggest rather low ionization. The spectrum is similar to that of 3C 241. Regions of the spectrum corresponding to intense sky lines have been deleted.*

Deep images of extremely distant radio galaxies such as 3C 255 (and 3C 300.1 observed during the same run) taken in excellent seeing conditions, show that these objects do not look like nearby giant elliptical radio galaxies. Evolutionary links between these objects and nearby giant elliptical radio galaxies are still speculative. They may well constitute a different population.

The presence of very faint objects near 3C 255, having similar colours, speaks in favour of a very distant aggregate of galaxies. It might be a cluster core in the process of formation as 3C 326.1 (McCarthy et al., 1987) or 3C 294 (Spinrad et al., 1988) could also be.

I express my thanks to Professor H. van der Laan for the observing time allocated to this project, and to J. Breysacher and D. Hofstadt. This work was greatly helped by information on the seeing coming from Vizcachas. In particular, it was extremely important to know that before and when I was taking long exposures at the 2.2 m telescope, the seeing was constant and near 0.65 arcsec. It is a pleasure to thank M. Sarazin and the team at the seeing monitor for making these data available. I am grateful to all the ESO staff at La Silla who made these observations possible, in particlar P. Le Saux and C. Gouiffes (resident astronomers), E. Barrios and L. Baudet (setting of the instrument), Bahamontes (assistance at the telescope), and S. Vidal (data retrieval).

References

MacCarthy et al., 1987, *Ap. J.* Letters, **319,** L39.

H. Spinrad et al., 1988, *A. J.*, **96,** 836 (previous references therein).

A New and Improved Camera for the 1.5 m B & C Spectrograph

B. JARVIS and D. HUTSEMÉKERS, ESO

A new dioptric camera was installed on the Boller and Chivens spectrograph at the ESO 1.52 m telescope in February 1989 to replace the old Schmidt camera. This allowed the removal of a focal reducing lens in front of the spectrograph slit designed to match the f/15 beam of the telescope to the f/8 focal ratio input of the spectrograph. The focal length of the new camera is 127.0 mm compared with 143.5 mm for the old camera. This means that the effective dispersions of all gratings as found in the recently published Boller and Chivens manual must be multiplied by 1.13 (= 143.5/127) when used at the 1.52 m telescope. The new slit scale is 9.2 arcsec mm^{-1} (compared to 19.4 arcsec mm^{-1} before) and the detector scale along the slit is 0.68 arcsec $pixel^{-1}$ (with 15 μm pixels, compared to 1.28 arcsec $pixel^{-1}$ before). Note also that the new TV slit-viewing field is now reduced by a factor of 2 giving a new field of about 1.5′ × 1.1′. The Nyquist sampling criterion is satisfied with a slit-width of 1.5 arcsecs (15 μm pixels and a small grating angle). For larger grating angles (say 10° or more), the grating demagnification must be considered (see Users' Manual).

Observers should also note that, like the old camera, a ghost spectrum will appear on the detector when the grating angle is between 21.5° and 29°. This will occur for all gratings. The ghost spectrum appears (at much reduced intensity) parallel to the real spectrum but displaced symmetrically with respect to the real spectrum about the optical axis of the spectrograph. This poses a problem for long-slit spectroscopy.

A major advantage of the new camera is that observers now have an almost unvignetted field along the spectrograph slit. Also, a three times improvement in efficiency over the old camera is obtained from 4000 Å up to at least 10000 Å (the longest wavelength measured). Using CCD # 13 (RCA) with grating # 13 (508 Å mm^{-1}), the absolute efficiency of the system (telescope + spectrograph + CCD) was measured to be 18% at 5445 Å. Figure 1 shows the total system efficiency from 4000 Å to 10000 Å for CCD # 13 and this grating and CCD combination.

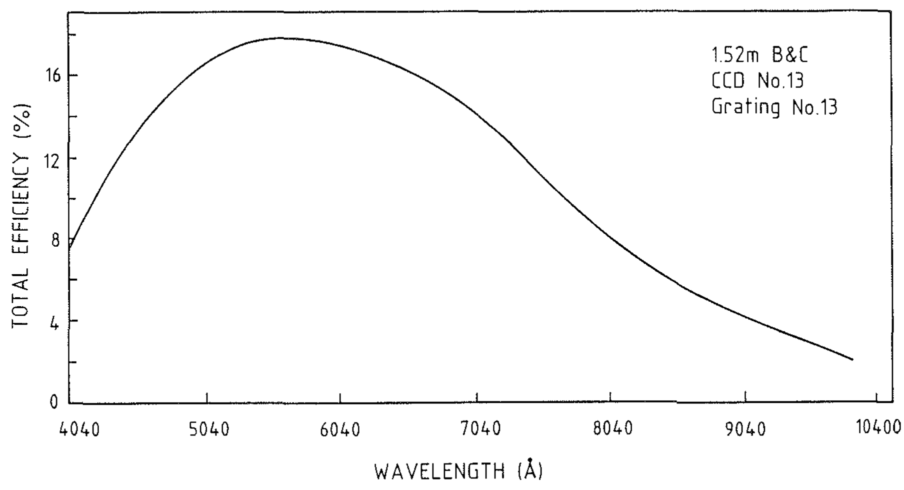


Figure 1: *Total system efficiency of the 1.52 m telescope and Boller & Chivens spectrograph fitted with the new camera.*

MIDAS Memo

ESO Image Processing Group

1. Application Developments

The echelle package for reduction of CASPEC spectra has now been ported to the new MIDAS. This new version is basically compatible with the previous one, with minor modifications to support other instrument formats like ECHELEC and EFOSC in echelle mode.

The Table File Editor has been significantly improved. The new editor uses the Term Window package in such a way that it is device independent, using a terminal definition file which also supports X11 Window systems. The editor incorporates a large number of commands that can be executed directly (in command mode) or by using keypad and function keys (keypad and function key modes).

2. Data Analysis Workshop

The annual ESO/ST-ECF Data Analysis Workshop took place April 18–20. It consisted of 1½ day scientific meeting centred on reduction software for direct imaging followed by one day with user meetings for both MIDAS and ST-ECF. Approximately 100 people participated in the meeting where more than 15 papers were presented. Proceedings of the scientific session will be published.

The next Data Analysis Workshop is expected to take place in the week April 23–27, 1990, with emphasis on reduction procedures for spectral data.

3. Support of X11 Window Systems

The portable MIDAS has now a full set of graphics and image display facilities. To provide these capabilities for a majority of workstations, major emphasis was placed on the X11 Window Manager implementation. The X11 system, being the industrial standard for window display systems, will be offered by almost all vendors making workstations. The MIDAS implementation image display with X11 was developed partly in collaboration with Trieste Observatory where much of the initial work was done. The MIDAS Display routines were tested successfully on workstations from DEC, HP, Stellar and SUN. Of special interest is the verification for DEC windows which also will be offered with VAX/VMS on VAX stations.

4. MIDAS on New Systems

Two new systems were tested and benchmarked with MIDAS, namely: DEC station 3100 and IBM 6150 systems. The DEC station 3100 uses a R2000 MIPS processor and was tested with Ultrix 3.0 while the IBM 6150 has a ROMP RISC processor running under AIX 2.2. *Please note that the mentioning or testing of specific computer systems is not in any way an endorsement.*

5. Portable MIDAS

As of the 89 MAY release, the portable version of MIDAS is the only official version of MIDAS being maintained and developed. The portable MIDAS can be used on both UNIX and VAX/VMS systems. Only the lowest level of routines differs from system to system while all user interfaces and application programmes are identical, no matter which type of system is used.

The START and STEP descriptors in MIDAS images have in the portable version been changed from single to double precision in order to provide sufficient accuracy for spectral reductions. For people working on VAX/VMS systems, this modification is transparent since the new version can also read the old single precision descriptors; the opposite is *not* true. In general, data files in the internal MIDAS format cannot be used on other systems due to differences in the binary formats. Thus, it is strongly recommended to store data in the FITS formats which is computer independent.

The 89MAY release contains the vast majority of applications available in old VMS-MIDAS including full support of graphics and image display. The major exceptions are the CCD and Long-Slit packages which both are being improved to provide better support of ESO instruments. The final testing and verification of these package will be done in the coming months with an expected release in the 89NOV version.

6. 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.: 528282 22 eod, 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.

Test Images for Two-dimensional Photometry Software

F. MURTAGH, ST-ECF, ESO; affiliated to Astrophysics Division, Space Science Department, European Space Agency, and R. WARMELS, ESO

A collection of test images was the focus of a satellite workshop of the recent Data Analysis Workshop. It was held on Monday, April 17, and provided an opportunity for the participants to compare analyses carried out with a wide range of 2-dimensional photometry packages.

The analyses carried out on the test images include the following: S. Ortolani (Padua Observatory) looked at the globular cluster 47 Tuc and NGC 3210 using DAOPHOT (P. Stetson, Dominion Astrophysical Observatory), INVENTORY (A. Kruszewski, Warsaw Observatory), and ROMAFOT (R. Buonanno et al., Rome Observatory). The last two packages have been incorporated into ESO's image processing system MIDAS, and are extensively documented in its user manual. F. Valdes (Kitt Peak National Observatory) carried out analyses on almost all test images using the FOCAS system (F. Valdes, KPNO). This UNIX-based package is available both as a stand-alone system or under Kitt Peak's IRAF image processing. A range of the test images was also investigated by M. Mateo (Mount Wilson and Las Campanas Observatories) using the DoPHOT package. D. Koo (Lick Observatory) studied the SA68 galaxy field images using a wide range of packages. These were APEX (Anglo-Australian Observatory), APM (Cambridge, England), COSMOS (Royal Observatory, Edinburgh), CURRIE (Rutherford-Appleton Laboratories), FOCAS, GROTH (Princeton University) and VIC (University of Victoria, British Colombia). Other analyses were carried out by A. Penny (Rutherford Appleton Laboratories), A. Kruszewski, N. Eaton (University of Durham), and M. Aurière (Observatoire du Pic-du-Midi). Results are also available for the CAPELLA package, which were obtained by A. Llebaria (LAS, Marseilles) and B. Debray (ESTEC).

Together with results of the Data Analysis Workshop, the results of the analyses will be published in an ESO Workshop and Conference Proceedings volume. It is foreseen that these pro-

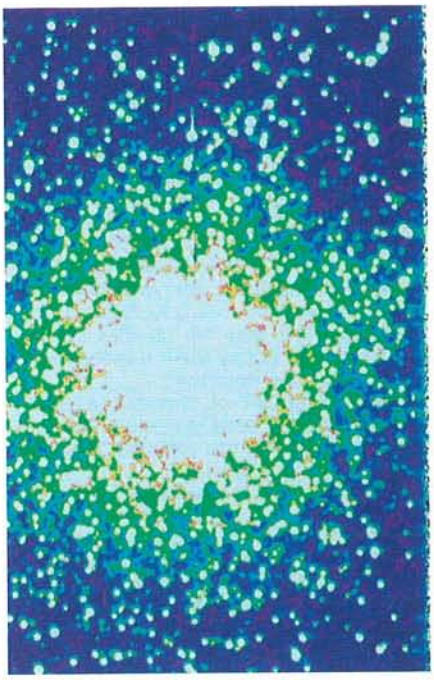


Figure 1: *Globular cluster: 47 Tuc, V, very crowded field with charge transfer problems; 15 sec. CCD (ESO No. 1) exposure taken with the Danish 1.5 m at La Silla. (S. Ortolani, Padua Observatory.)*

ceedings will appear later in 1989. Results of the analyses are also contained in the form of catalogues and other files in directory MISC$DISK:[TESTIMAGES] on ESO's VAX system. Together with the test images themselves, this information will be made available to the general public on magnetic tape by the authors of this report. Copies of the tape can be obtained upon request.

Two of the test images are shown in the figures. They will be of particular interest to those investigating globular clusters and faint galaxy fields. Images with different exposure times are included. A few further images will be included in the future. These include simulated Hubble Space Telescope Wide Field/Planetary Camera (WF/PC) images – a typical globular cluster at distance 1 Mpc with an exposure of 300 seconds as seen using different filters.

The advantages of using this set of test images are two-fold. They provide a set of results which can be used for benchmarking future software packages and alternative algorithms devised by anyone working in this field. They also provide a common point of interest for those who develop 2-dimensional software for stellar and galaxy photometry. One hopes that such systems can be used as building-blocks for systems of the future rather than the all-too-common restarting from first principles.

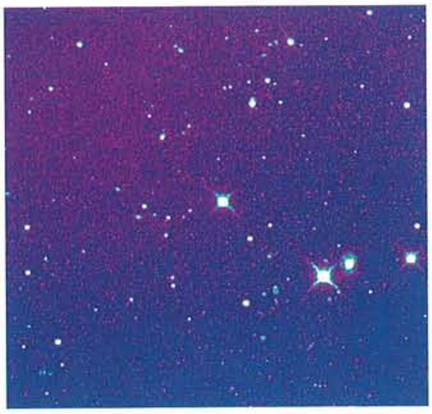


Figure 2: *Faint galaxy field: SA 68, contains very faint BV standards; 75 min. J. plate taken with Kitt Peak National Observatory 4 m. (D. Koo, Lick Observatory.)*

TEX and MATHOR 3-TEX for Astronomy and Astrophysics Journal and Supplement Series

Main Journal

H.-U. DANIEL

Springer-Verlag is pleased to announce an important development which will bring "Astronomy and Astrophysics" to the absolute forefront of scientific publication technology: In addition to the traditional route of manuscript processing and in response to the growing number of authors using TEX, such authors have now the opportunity to submit their papers to the journal editors on disk or tape. Springer-Verlag has developed a style template for "Astronomy and Astrophysics" contributors using PLAIN-TEX, the Springer-Verlag A+A macro package 1988.

The A+A macro package is designed to achieve two goals:

1. TEX-contributions coded only with the A+A macros will comply in width, height, title head, headings, fonts, captions, etc. with the regular layout of the journal.
2. Having reformatted the TEX input file using the M-TEX format file, the resulting DVI file will be run directly into the monotype typesetting machine. As the print-out with the M-TEX fonts will look exactly like the usual page proofs, there will be no need for checking page proofs. Authors using TEX and the layout macros but not the M-TEX fonts will still receive page proofs as usual.

The Springer-Verlag A+A macro package 1988 (including the M-TEX software) can be obtained from the editors. Disks and tapes (format 5.25 inches or 1,600 bpi) together with instructions have also been given to the directors of the following institutions; authors working here are encouraged to make use of this possibility:

Observatoire de Paris, Meudon; MPI für Astrophysik, Garching; MPI für Radioastronomie, Bonn; Institut du CNRS, Paris; Kapteyn Astronomical Institute, Groningen; Laboratory for Space Research, Utrecht; Landessternwarte Königstuhl, Heidelberg; Observatoire de Genève, Sauverny; Astronomical Institute, Amsterdam; Sterrewacht Leiden; Osservatorio Astronomico di Trieste; Osservatorio Astrofisico di Arcetri, Firenze; Astronomisches Institut, Tübingen; ESO, Garching.

The instructions for TEX-authors will also appear in the journal "Astronomy and Astrophysics".

In order to minimize the loss in style uniformity of the journal, authors are urgently requested to follow the special instructions given on the disk or tape. The editors of the journal may return accepted contributions, should they fail to comply with the A+A style.

We, the authors, editors and publisher, are entering an interesting time of innovation. continuing, patient cooperation will be necessary until the usual smooth processing of manuscripts at Springer-Verlag has been extended to "electronic" manuscripts.

Supplement Series

J. BERGER and D. SAVARY

Les Editions de Physique are pleased to announce that the A+A Supplements Series is now produced using MATHOR 3-TEX. This went into effect, beginning with the January 1989 issue.

For all subsequent issues authors themselves may send submissions to the series in either MATHOR 3 or TEX format. Les Editions de Physique will provide the appropriate "Supplements Series Macro Package" to any authors who wish to use plain TEX for the preparation of their articles. Additionally, a special version of the MATHOR 3-TEX software package is now available to help authors and their staff who are not "TEXperts".

What are TEX, MATHOR 3-TEX and MACROS?

TEX is a powerful text formatting programme designed specifially for scientific texts. TEX macros are programme routines which can "automate" or control the style of the pages which TEX produces, for example to ensure than they conform to the house style of a journal. You can create TEX documents in one of two ways:

The first way is to learn how to code your text using the special description language which TEX requires and then to create the necessary code using a standard text editor. You should bear in mind that TEX is not a word processor.

The second, much easier, way is to use MATHOR 3-TEX which is a full feature "WYSIWYG" (What You See Is What You Get) scientific word processor and interactive preprocessor for TEX. What that means in plain English is that you have all the power of a word processor available to you and that you

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.

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

EUROPEAN
SOUTHERN OBSERVATORY
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München
Fed. Rep. of Germany
Tel. (089) 32006-0
Telex 5-28282-0 eo d
Telefax: (089) 3202362
Bitnet address: IPS@DGAESO51

The ESO Messenger:
Editor: Richard M. West
Technical editor: Kurt Kjär

Printed by Universitäts-Druckerei
Dr. C. Wolf & Sohn
Heidemannstraße 166
8000 München 45
Fed. Rep. of Germany

ISSN 0722-6691

see your document on-screen in readable (rather than coded) form. Once you have completed your document MATHOR3-T$_E$X will then translate it into the special T$_E$X code automatically, including the appropriate macro package at the same time. In this way you can produce T$_E$X documents without ever needing to get involved with the intricacies of T$_E$X, in fact you don't even need to own a copy of the T$_E$X software.

What you Need to Do

In addition to traditional manuscripts you may submit articles to the supplement series in one of three ways:

1. Write your document using MATHOR3, without worrying about its final appearance. You should then send your MATHOR3 text, on IBM 360K or 1·2M format 5 1/4″ floppy disks, together with a printout of the document. We will then handle the T$_E$X side of things.
2. Write your document using MATHOR3, incorporating the T$_E$X commands defined in the A&A SUPPLEMENTS SERIES MACRO PACKAGE. This package is available from us, together with appropriate Instructions for Authors. The "MATHOR3-T$_E$X Translation" function will then allow you to obtain a T$_E$X version of the document. Once you have completed your document you should send us the MATHOR3 version on IBM 360K or 1.2M format 5 1/4″ floppy disks together with a printout of the document.
3. Finally, if you are a T$_E$X enthusiast and enjoy doing things the hard way, you may write your document as a T$_E$X source file using the A&A SUPPLEMENTS SERIES MACRO PACKAGE. Ask us for this package and our Instructions for Authors. Send us your T$_E$X data file on IBM 360K or 1.2M 5 1/4″ floppy disks together with a printout of the document.

Whichever option you choose Les Editions de Physique will send you page proofs as usual so that you can see the final page layout of your submission.

We will be providing evaluation copies of the MATHOR3-T$_E$X package to the ESO pilot centres; for further information you may contact them or contact us directly at: **Les Editions de Physique** 7 avenue du Hoggar, Z.I. de Courtaboeuf, B.P. 112, 91944 LES ULIS Cedex FRANCE Tel. (1) 69.07.36.88, Fax (1) 69.28.84.91, Telex 602321 F

Contents