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# Europe Decides to Build the World's Largest Optical Telescope

On December 8, 1987, the ESO Council gave the green light to the ESO 16-metre Very Large Telescope (VLT), an extraordinary astronomers' dream and an amazing engineering challenge. The VLT is to be the largest telescope in the world and Europe's superior eye to the Universe.

The representatives of the eight member states (Belgium, Denmark, the Federal Republic of Germany, France, Italy, the Netherlands, Sweden and Switzerland) agreed that the European Southern Observatory shall embark upon the realization of this marvellous instrument. This decision expresses Europe's confidence in the ambition of her astronomical community and the ingenuity of her high-tech industry; together they will ensure that Europe will be second to none in the exploration of the Universe for a long time to come. The VLT is an essential complement of Europe's astronomical research activities from space vehicles.

Further information about the VLT will be found on pages 28–32 and 53–55.

# ESO's Directors General: Retrospect and Prospect

## *PROF. LODEWIJK WOLTJER*

Now that my thirteen years as Director General of ESO are coming to a close, I wish to briefly review where the Organization stands today and what the outlook for the future is.

ESO has experienced a great expansion: upon the realization of the 3.6 m, CAT and 1.5 m Danish telescopes, several new projects were started. The installation of the 2.2 m telescope on loan from the Max-Planck-Gesellschaft and of the 15 m SEST has been accomplished, while the 3.5 m NTT is approaching completion. As major instruments CES, CASPEC, IRSPEC and EFOSC have been built, while EMMI, DISCO and IRAC are on their way. With regard to the present class of telescopes and instruments, ESO is therefore in good shape and in a very competitive position internationally. The construction of the VLT will ensure that this remains so in the future.

The idea of the VLT arose in 1977, a bit before the first ESO large telescope conference in Geneva. The next year, various

## *PROF. HARRY VAN DER LAAN*

In the June 1987 issue of the *Messenger*, Professor Lodewijk Woltjer wrote the leading article under the heading: A Time for Change. Now, six months later, he passes the ESO reins to me, just when a new milestone has been firmly anchored, a milestone to mark the beginning of a new chapter in European astronomy. In a parallel article, Lo Woltjer summarizes what ESO has become and to whose key contributions we owe its present state and its perspectives.

In a broad discussion with Council before my appointment, we agreed that ESO's assignment in the next ten years is threefold: (i) to operate the La Silla Observatory; (ii) to further develop ESO as a meeting place and communications centre for astronomical research in Europe; (iii) to build the Very Large Telescope. Clearly these tasks are interdependent and if carefully managed, each of them will help the others. It is also not farfetched to imagine that the engineering design and construction of the VLT could so dominate ESO's next

*Prof. L. Woltjer (continued from p. 1)*

internal working groups were given the task to evaluate the relative merits of a single dish 16 m or arrays of four 8 m or sixteen 4 m telescopes. Not surprisingly, the conclusion after a number of years of study was that the middle option avoided a number of the difficulties of the others and was to be preferred for both scientific and technical reasons. Subsequent more detailed studies during the last four years have transformed these early projections into a solidly based project, which will be the centrepiece of ESO's activities for many years to come.

To deal with the results obtained by the telescopes and instruments, much data and image processing is needed. With the development of IHAP and MIDAS and the acquisition of the necessary hardware, also in this domain a satisfactory situation has been achieved. Future developments will lead to further increases in speed and ease of use – essential with the increased data flows from ground- and space-based telescopes.

While the development of advanced instrumentation is ESO's primary mission, perhaps equally important is the role that ESO has begun to fulfill as a scientific centre for the European astronomical community. Every day one may find at ESO in Garching some 40–50 associates, fellows, facility users and visitors from different institutes. Similarly, at La Silla numerous Visiting Astronomers meet while executing their observing programmes. In this way and also through the many workshops and conferences, ESO has become an essential catalyst in the creation of a European astronomical community.

European cooperation is viable only if it leads to results which are superior to what could be achieved by a simple superposition of national efforts. An organization like ESO, therefore, has an absolute need for an ambitious programme, an economical management and a staff dedicated to cooperate rather than to compete with the institutes in the member countries. The VLT is a fitting measure of its ambition; the fact that its inflation adjusted budget did not change in a decade of growth is an indication of its economical management, and the support it receives in the community is ample proof of an effective cooperation.

While I cannot thank here all ESO's staff members individually, I would like to acknowledge in particular the following persons: Ray Wilson who conceived active optics and the NTT, Massimo Tarenghi who made the NTT a reality, Daniel Enard who transformed the vague VLT ideas into a real project, and Jean-Pierre Swings who assured the liaison between the VLT and the community; Manfred Ziebell and Daniel Hofstadt who not only developed the electronics so essential in all modern telescopes and instruments, but who also enforced an effective cooperation between La Silla and Garching; Alan Moorwood who conceived and built the IR instrumentation and Sandro D'Odorico who pushed the performance limits of optical instrumentation further; Klaus Banse, Philippe Crane and Preben Grosbøl who created MIDAS, and the late Frank Middelburg who thought of image processing and IHAP before anyone else; Franco Pacini, Per Olof Lindblad and Giancarlo Setti who made the Scientific Division a central element in European cooperation and who gave me friendly advice on many matters, and Piero Benvenuti who made the ST-ECF a success; Arne Ardeberg who directed La Silla with enthusiasm, and Hans-Emil Schuster whose long experience of La Silla and its population has served ESO well; Peter de Jonge who created the TRS which has become the centrepiece of the La Silla activities and who from Grenoble provided the SEST, and Wolfgang Bauersachs who assured the infrastructure on which everything else at La Silla rests; Gerhard Bachmann who has directed the administration with competence, flexibility and diplomacy, Robert Fischer who has assured the optimization of ESO contracts – which will become of even greater importance in the VLT era, and Inge Meinen who for a decade administered La Silla in her dignified way; Philippe Véron and Richard West who brought the "Messenger" to its present distinction, and Jacques Breysacher who has developed the art of scheduling a dozen telescopes to perfection; and last but not least Ulla Demierre who has run my office with efficiency, optimism and tact. To them and to their collaborators my profound thanks. The best wish I can give my successor Harry van der Laan is to have as distinguished a set of collaborators as I have had the good fortune to work with.

A Director General can only function effectively if he enjoys the confidence of Council, Finance Committee and the other advisory bodies. I wish to my successor that his relations with these will be as positive, cooperative and smooth as I have experienced them to be. To all members of these and to all others in the European community who have contributed to the success of ESO my deepest thanks.

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*Prof. H. van der Laan (continued from p. 1)*

decade that both La Silla's observing quality and ESO's communications function might suffer as a result. A large fraction of all ESO resources will somehow be drawn upon to achieve VLT performance goals. Aware of the risks, we will guard against them with persistent care.

La Silla remains Europe's major observatory for the years to come. With the telescopes and their instrumentation as they are now and as they will be by mid-1989, when the NTT is operational and a number of instruments now in the pipeline have been commissioned, the ESO community is as well equipped as any. Developments will from then on focus on VLT systems, but no doubt ways will be found to turn VLT instrumentation ideas into working prototypes for real life trials on La Silla. One must optimistically expect the VLT to be good for La Silla and vice versa. This is equally true for new observing modes and scheduling methods. Service observations, remote control and top priorities guarded against the fatalism of meteorology will all move through experimental phases into optimized routines. La Silla will be the community's and ESO's proving ground for exploiting the full potential of the VLT. It will be an even more interesting place to work: young astronomers and engineers, mark this opportunity!

There is no need to dwell on ESO's role as a meeting place: the series of symposium and workshop publications as well as the constant stream of working visitors to Headquarters and to La Silla provide ample evidence. There is an additional goal ESO may pursue and indeed will have to in preparation for the VLT. That is to map the technical as well as astronomical talent in the member states and to bring that talent into a coherent collaborating pattern. I envisage more and more intensive working visits to ESO by astronomers, established as well as post- and pre-docs. Doing research on La Silla and in Garching, they will more readily collaborate across national boundaries once backe home. Technical scientists, instrumentalists and systems engineers, will also be welcome as we try to determine with whom to conceive and build the VLT's instrumentation. It is my ambition to make it as easy and as natural for institutes and individuals from, say France, Switzerland and Sweden to form a team or consortium as it is for such relations to arise between California, Massachusetts and New Jersey, at least in astronomy.

ESO's new assignment, designing and constructing the VLT, is a task at once exciting and daunting. During the past ten years, our user community has engaged in intense discussion with our staff, searching for the most attractive instrumental deployment of hoped-for resources for a scientifically fruitful, technically innovating future. The VLT concept now approved by Council and funded by the member states originated in that structured community-wide consultation. Heated debate as well as numerous studies, crossing all sorts of boundaries, of both nations and of disciplines, stimulated the emergence of countless ideas, new problems and original solutions. In spite of great diversity, in starting positions, national astronomy cultures and engineering traditions, a consensus formed that culminated in the momentous decision by the ESO Council on December 8, 1987.

The ESO community owes much to the leadership and foresight of two key people: Lo Woltjer, ESO's Director General, who orchestrated both the scientific discussion and the political process towards this ambitious goal; and to Daniel Enard, the gifted engineering scientist who led the evolution of the conceptual design and will now play a central role in its engineering realization.

It is a privilege as well as a challenge to succeed Lo Woltjer at just this juncture. European astronomy is deeply indebted to him for the depth and persistence of his efforts. We wish him well and look forward to his further contributions to ESO and to astronomy.

*The ESO Council in session on December 8, 1987.*

# About "The Messenger – El Mensajero"

You have the 50th issue of the ESO *Messenger* in your hands.

It all began in the early 1970's with a growing ESO staff in Chile and in Europe. The Director General of ESO, Professor A. Blaauw, felt there was a need for increased communication between the ESO communities in Hamburg, Geneva, Santiago, La Serena and La Silla, not to forget the individuals in other places who were in some way connected to ESO. In May 1974, the first issue of the new ESO journal was launched with a total of 6 pages. After somewhat irregular publication dates during the first two years, a quarterly schedule has been adhered to since issue No. 4 in March 1976. As the readers will have noticed, the scope of the ESO *Messenger* has become broader and it has grown, culminating with a 60-page issue in March 1987 that included the first news about SN 1987A.

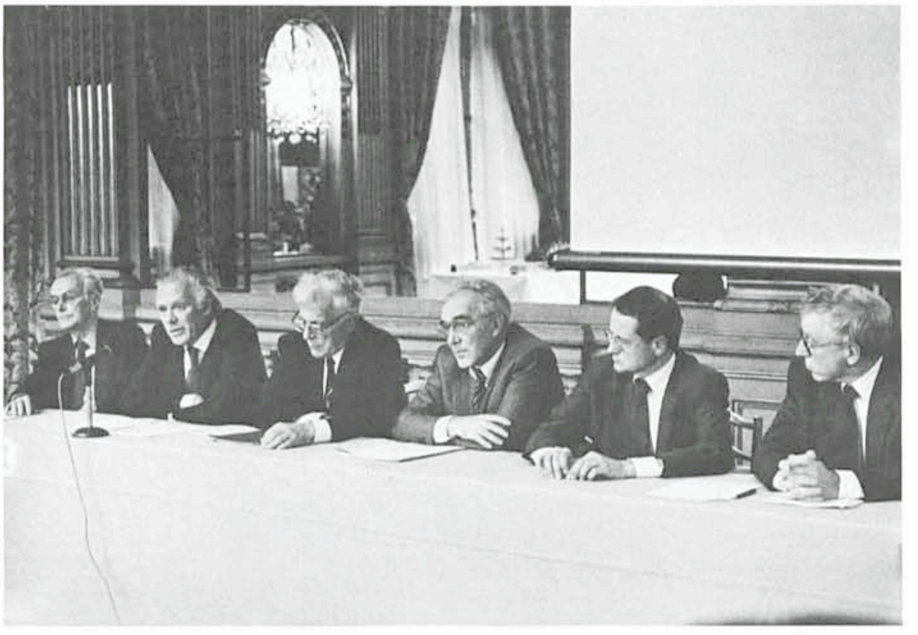
Although the first 50 issues together have brought 1,500 pages, other semipopular journals have published many more during the same time. And although some colour pictures have been brought in the more recent issues, there are other journals which by far surpass the *Messenger* with glossy views of the sky. Scientific articles abound in the professional journals, so why the *Messenger?*

Because it brings the latest news from ESO, the main organization for astronomy in Europe. As the astronomical research at La Silla and in Garching reflects an increasingly broader section of front-line astronomy, so the *Messenger* has become a multi-faceted mirror of modern astronomy and astrophysics. The articles are mostly written while the research is still underway and frequently convey the thrill of discovery. Although the guidelines to authors indicate that contributions in general should be written for a wide audience, we do not attempt to edit everything into a uniform format. The articles and news reflect the style of their authors and by difference in level and form, they enliven and bring variety to the *Messenger* issues. We do not expect that every reader will read everything, but there should be something for everybody.

With a circulation of more than 4,000, the *Messenger* reaches a wide audience, in the ESO member countries and elsewhere, including professional and amateur astronomers, as well as other groups like teachers and decision makers. For some years now it has been indexed in the semi-annual volumes of "Astronomy and Astrophysics Abstracts", and a growing number of references in the professional literature to *Messenger* articles indicate increased awareness in many places.

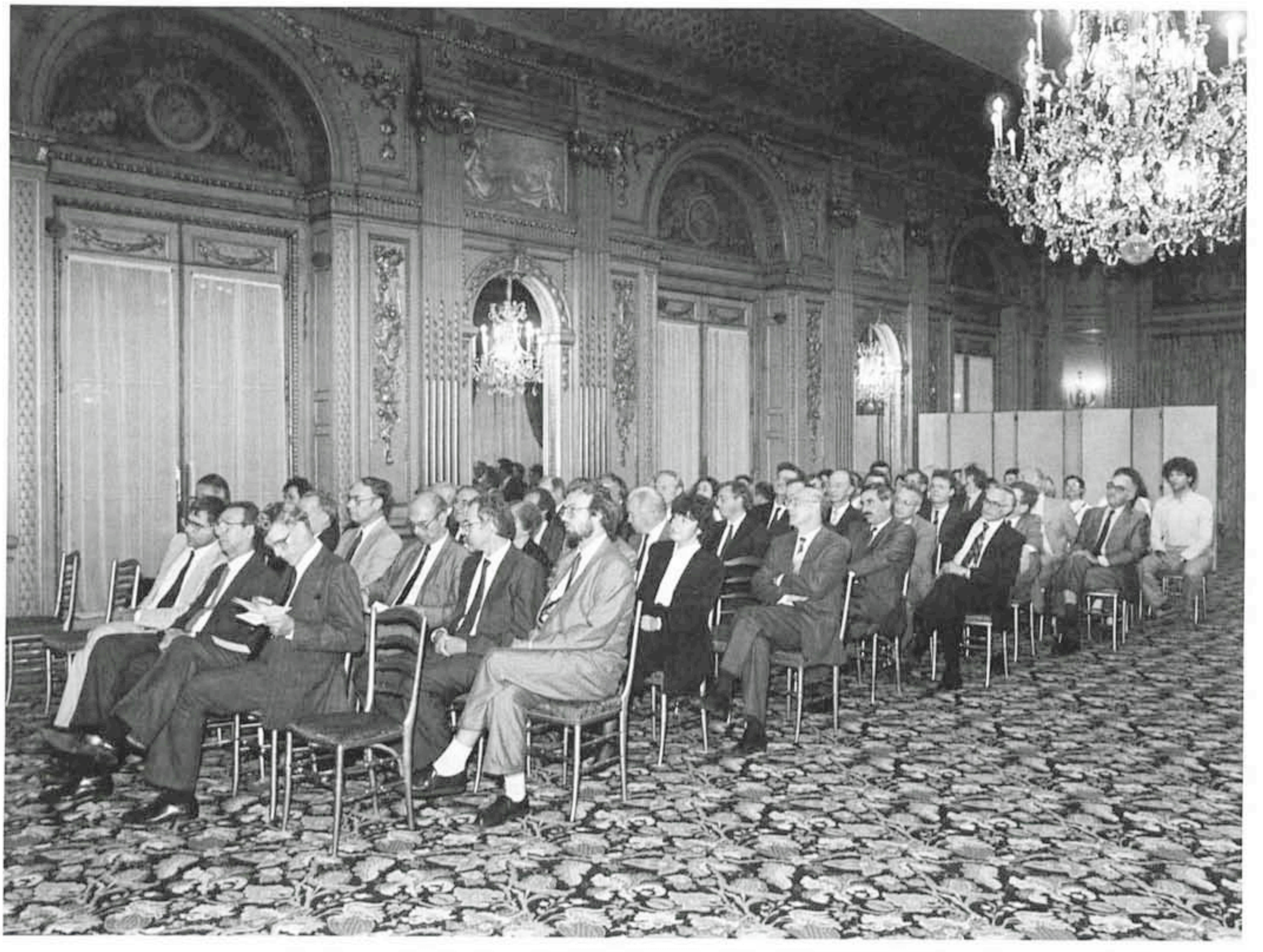
On the occasion of the "golden" jubilee, we wish to thank all authors for many excellent contributions. In return, we shall continue to publish the ESO *Messenger* rapidly and efficiently so that their achievements will become better known to more people. *The Editors*

# Where ESO was Born . . .



On October 5, 1987, a brief ceremony was held at the Centre de Conférences Internationales in Paris. Members of the ESO Council and some invited guests commemorated the signing of the ESO Convention which took place in the same room exactly 25 years earlier.

The first speech was delivered by Prof. J.F. Denisse, former President of the ESO Council and a Member of the Académie des Sciences, who recalled early ESO history and the development during the past 25 years. He was followed by M. J. Laureau, Directeur de la Coopération Scientifique, Technique et du Développement (Ministère des Affaires Etrangères), who spoke on behalf of M.J.-P. Angremy, Directeur Général des Relations Culturelles Scientifiques et Techniques. The President of the ESO Council, Prof. K. Hunger, and the Director General of ESO, Prof. L. Woltjer, surveyed ESO's position in European astronomy and plans for the future. M. André Berroir, Directeur de l'Institut National des Sciences de l'Univers (Centre National de la Recherche Scientifique), spoke for M.S. Feneuille, Directeur Général du CNRS, and was followed by M. Claude Frejacques, from the Académie des Sciences, Conseiller spécial du Ministre de la Recherche et de l'Enseignement Supérieur, M.J. Valade, speaking on his behalf.



# Discovery of the First Gravitational Einstein Ring: the Luminous Arc in Abell 370

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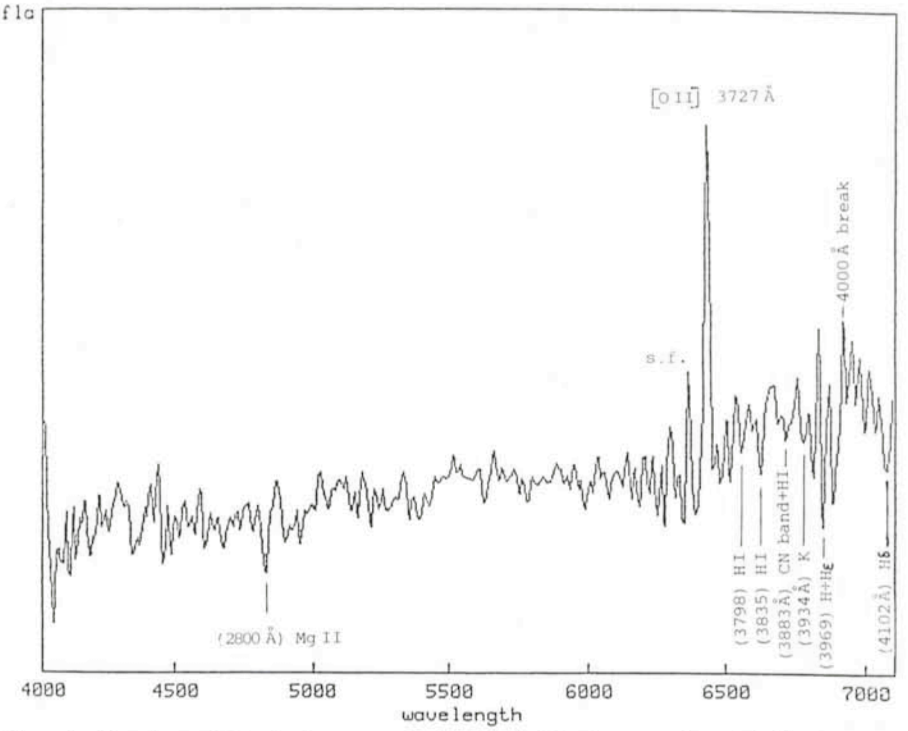


Figure 1: *Spectrum of the luminous arc in Abell 370. The lines mentioned in the text are indicated. ESO 3.6 m + EFOSC, 6 hours integration.*

Since the discovery of the first luminous arcs in rich clusters of galaxies (Soucail et al., 1987a, Lynds and Petrossian 1987), several hypotheses were suggested to explain their nature and origin. One of them is the gravitational lensing of a background galaxy nearly perfectly aligned with the deflector (in this case the cluster core) and the observer. A piece of evidence for this effect comes from our observations of such a structure in the distant cluster Abell 370 ($z = 0.374$). We first attempted to get a spectrum of the eastern end of the arc in this cluster during an observing run at ESO in November 1986 (Soucail et al., 1987b). In fact, bad weather conditions only allowed a one-hour exposure on this object leading to a poor S/N spectrum. Nevertheless, in view of the spectral energy distribution we suggested that this could result from a background galaxy at a redshift of 0.6. Moreover, our recent spectroscopic data on the quite similar blue arc in the cluster Cl 2244-02 ($z = 0.329$) have shown that the spectral energy distribution is flat and consistent with the one of a distant object (galaxy or quasar). This is also in favour of the gravitational lensing model.

Even though the gravitational lensing appeared to be a very attractive model this had to be confirmed with better data than the one obtained in A370 for two reasons:

(1) the spectrum we obtained is very faint and the redshift had to be confirmed;

(2) some astronomers were not convinced that the eastern part of the structure really belongs to the arc, in spite of a similar surface brightness in each bandpass.

This is the reason why we reobserved intensively the arc of A 370 on October 18-22, 1987 at ESO with EFOSC/PUMA 2 at the 3.6-m telescope.

For this peculiar object we used a long slit but we also used the PUMA 2 system (Fort et al., 1986) to punch curved slits well suited to the geometry of the arc. This has the advantage of collecting the maximum of energy through the aperture plate and to obtain at the same time the redshifts of the galaxies located near the ring structure. Sky subtraction was ensured by using a duplicate curved slit punched on the same mask close to the arc. The B 300 grism used gave a resolution of 15 Å over a spectral range from 3800 Å to 7500 Å. Several 90-min. exposures were made leading to a total integration time of 4h30 with the curved slit and 1h30 with the long slit. We then compensated the rather high read-out noise of the RCA CCD (60 $e^-$ r.m.s.) by co-adding the total 6 hours exposures. Thanks to these data we can now con-

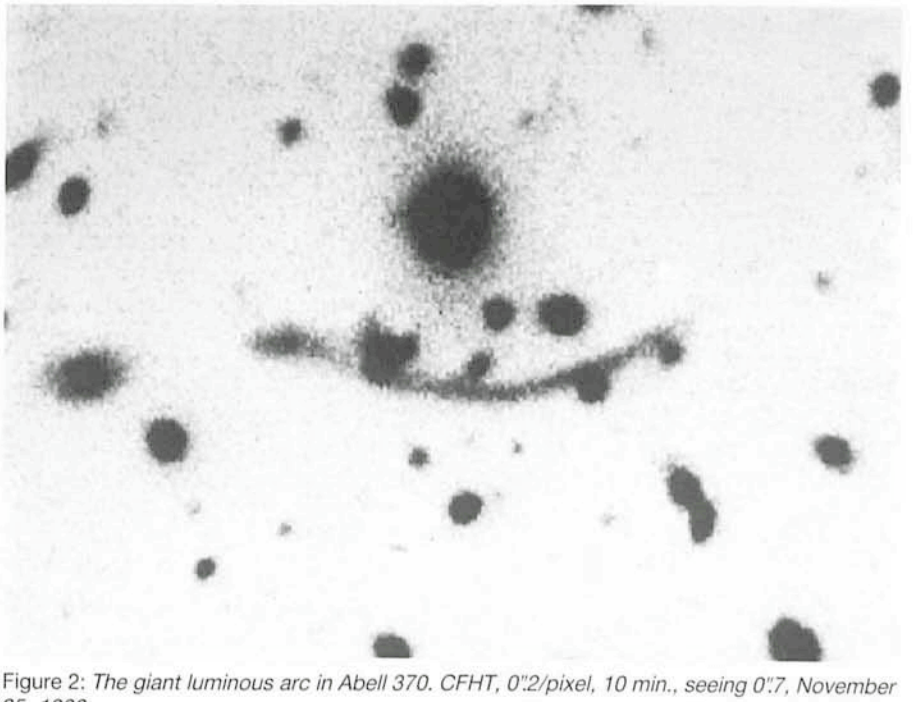

Figure 2: *The giant luminous arc in Abell 370. CFHT, 0".2/pixel, 10 min., seeing 0".7, November 25, 1986.*

firm that both the central and the eastern parts of the arc really present the same spectral energy distribution: therefore it is now proved that the eastern end of the structure belongs to the arc!

Moreover, a narrow emission line is clearly observed at 6427 Å all along the arc spectrum. The assumption that it is the [OII] λ 3727 line leads to a redshift z = 0.724, a value confirmed by the detection of absorption features corresponding to the CaII λλ 3933, 3968 Å and the 4000 Å break, the CN band at 3883 Å, the MgII λ 2800 Å line and several Balmer lines, all at the same redshift. These features are typical of a blue galaxy, redshifted at z = 0.724.

A complete discussion of these data is out of the scope of this paper and will be presented in a letter to *Astronomy and Astrophysics*. Nevertheless it is obvious now that all these results confirm that the arc in A 370 does result from the gravitational lensing of a background galaxy at a redshift of 0.724. With respect to the model presented by Soucail et al., (1987b) the only difference is that the mass of the lens is lowered by a factor of 1.30.

It is clear that the observations of such giant arcs in distant clusters of galaxies will open new fields of investigation for gravitational lensing phenomena with probably important consequences on observational cosmology to study the distribution of dark matter in the universe.

In particular, one can imagine to use the rich clusters of galaxies as "gravitational telescopes" to search for more distant objects in the universe (Nottale and Hammer, 1984).

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# Lunar Occultations at La Silla

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## 1. Introduction

Lunar occultations provide the means to obtain high angular resolution down to the milliarcsecond level in the optical and near infrared spectral regions, by analysing the diffraction pattern produced when a source disappears behind (or reappears from) the limb of the Moon. This technique has its main application in the measurement of angular diameters of stars. In particular, it is noteworthy to stress that the majority of all known angular diameters have been measured in this way – see for instance the reviews by McAlister, 1985 and White and Feierman, 1987. In fact, a resolution of one milliarcsecond (mas) at $\lambda = 1 \div 3$ μm is far beyond the possibilities of any other available technique, at present and what can be foreseen in the immediate future (with the possible exception of future long-baseline Michelson interferometry).

In June 1987, observations in the near infrared of lunar occultations were performed at La Silla. The programme – proposed by A. Richichi (ESO), F. Lisi and P. Salinari (Arcetri Observatory, Italy) – had several goals. First of all, our knowlege of the relation between temperature (easily obtained if the diameter and the total flux are known) and spectral type for cool stars is still largely unsatisfactory. According to a review by J. Davis until 1984 there were only 32 stars with a diameter known at the 5% level or better – the minimum for a useful check of current theories with observations – and many of them were early-type stars or cool supergiants. Therefore, we felt that if observations with the instrumentation at La Silla proved feasible, one could hope to significantly improve in the set of measured diameters by observations of occultations in the low-declination portion of the zodiacal belt. This area is very rich of cool giants, especially in the Sagittarius-Scorpius region. In addition, preceding work at the Infrared Telescope of the Gornergrat Observatory (TIRGO), had shown that occultations could also lead to the discovery of compact circumstellar structures (Richichi et al., 1987); therefore many objects in our sample were selected with this aim. Finally, the high resolution provided could lead to serendipitous discoveries, such as the detection of close binaries.

## 2. The Observations

We travelled to La Silla with a set of about 30 sources that were due to be occulted in a three-night period (10–12 June 1987). They had been selected, not only on the basis of their expected angular diameter being at reach of the technique, but also because of their visual and infrared colours indicating the possible presence of circumstellar dust. They included sources from the SAO, TMSS, IRAS, AFGL catalogues and others. Since most of them had no published data regarding their near-infrared fluxes and/or are strongly variable, we did photometry in the standard J, H, K, L, M broad band filters and in some cases also with the narrow-band circular variable filters (CVF) and in the 10 μm spectral region with the bolometer. Also, for many of the sources it was necessary to determine an accurate position because the error on the given coordinates was often too large. All these preliminary observations were accomplished during a preceding 6-night period at the 1.0-m telescope. They allowed us to move to the 3.6-m for the occultation period with a selected list of "best objects", but they also produced data on many poorly studied objects and revealed some interesting peculiarities.

The observations were carried out at the 3.6-m, using the infrared speckle detector and the Fast Photometry data acquisition programme. This configuration has several advantages: it allows to perform observations at 1 kHz rates with a relatively strong signal, to use the near-infrared filters, and finally to perform also speckle interferometry during the intervals between successive occultations. The fast sampling is necessary because typically all of the critical information is encoded in the central 0.1 ÷ 0.3 seconds of an occultation event. Also the advantage of operating in the near infrared, rather than in the optical, is crucial; the event is slower (roughly by a factor of two), the sources often have their peak emission at wavelengths around 1 μm, and – last but not least – the background level is much lower, because it is mainly composed of scattered sunlight ($\lambda^{-4}$ law).

Finally, we also had the possibility of a quick switch from Fast Photometry mode to Speckle mode, allowing to collect interferometric data on the same sources that were to be occulted: this means to merge information at the 1-50 mas angular scale of the occultation technique with that at the 0.1-1 arc-

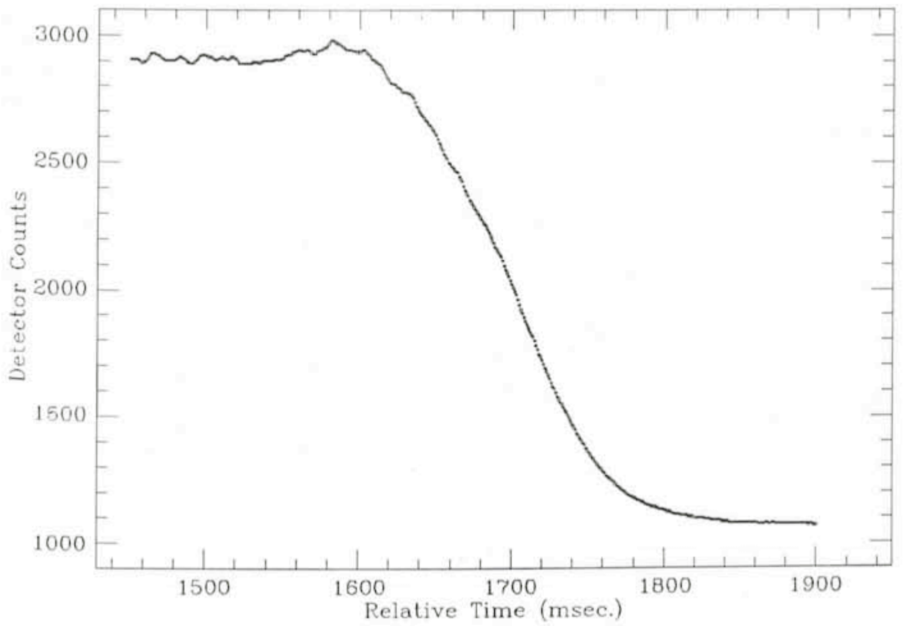


Figure 1.

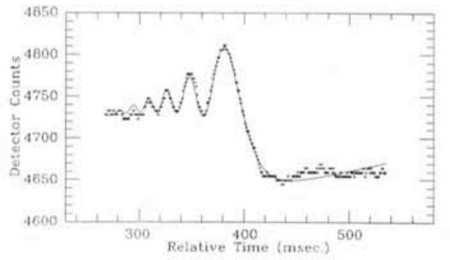


Figure 3.

second scale of speckle interferometry, providing a deeper insight into possible compact circumstellar features.

## 3. The Results

We attempted to record about a dozen events in two nights (the events occurring during the first night could not be observed due to technical problems). While we succeeded in observing all of the disappearances, the following night we lost many reappearances because it was not possible to use the autoguider of the 3.6-m telescope. Nevertheless, we ended up with at least 4 recorded events. We believe this is a satisfactory result, if we consider that the technique was being tested for the first time and that the observing conditions were less than optimal. In particular, the phase of the Moon was full during our observations, then hampering many procedures such as direct guiding on the monitor or off-axis guiding and giving rise to an extremely high background level.

A detailed analysis of the occultation data is still in programme, and therefore we cannot give the final conclusions. In any case, the most interesting results are surely those concerning the occultations of Antares ($\alpha$ Sco) and SAO 185573. In the first case, we observed an immersion of the bright M 1.5 Ib supergiant through a CVF filter, and the lightcurve is shown in Figure 1. It can be seen that, due to the large angular diameter of the source, almost all fringes in the diffraction pattern are smoothed out, and only a small bump just before the rapid fall is left. We are not yet able to give a definite value for the angular diameter, because we still have to perform detailed calculations. There is evidence of values around or maybe slightly less than the 40 mas given in the literature which is the average of measurements obtained using different techniques (Michelson interferometry, speckle interferometry and lunar occultations) at different wavelengths.

We would like to remark that the signal-to-noise ratio is very good, of the order of 100 in the portion of the lightcurve before the occultation and of the order of 500 after the event. Therefore, it will be possible to determine, in addition to the diameter, other fundamental parameters such as the limb darkening coefficient or (eventually) any significant departure from the expected spherical geometry.

The occultation curve (a reappearance) for the K 5 giant SAO 185573 is shown in Figure 2, together with a preliminary best fit to the data. The diameter of this bright star (V = 6.8, K = 1.7) had never been measured before: it is an example of how the southern part of the zodiacal belt is still largely unexplored from this point of view. Also in this case the S/N ratio is excellent, and we are confident that the final error on the diameter – which by a first estimate is found to be in the 4.0–4.5 mas range – will probably be of the order of 1 %.

The other two occultations that have been detected so far in the data (there may possibly be others) are those of the variable star WX Sco (V ~ 12 – 13, K = 3.0) and the weak SAO 184535 (V = 8.0, K = 5.1). A first analysis of the lightcurve of WX Sco (shown in Figure 3 together with a preliminary fit) indicates that the source is unresolved and yields thus an estimate of the "maximum resolution" of the 3.6-m under the given observing conditions: this limit is about 2.0 mas, and is determined mainly by the broad bandpass of the K filter ($\Delta\lambda$ = 0.4 $\mu$m).

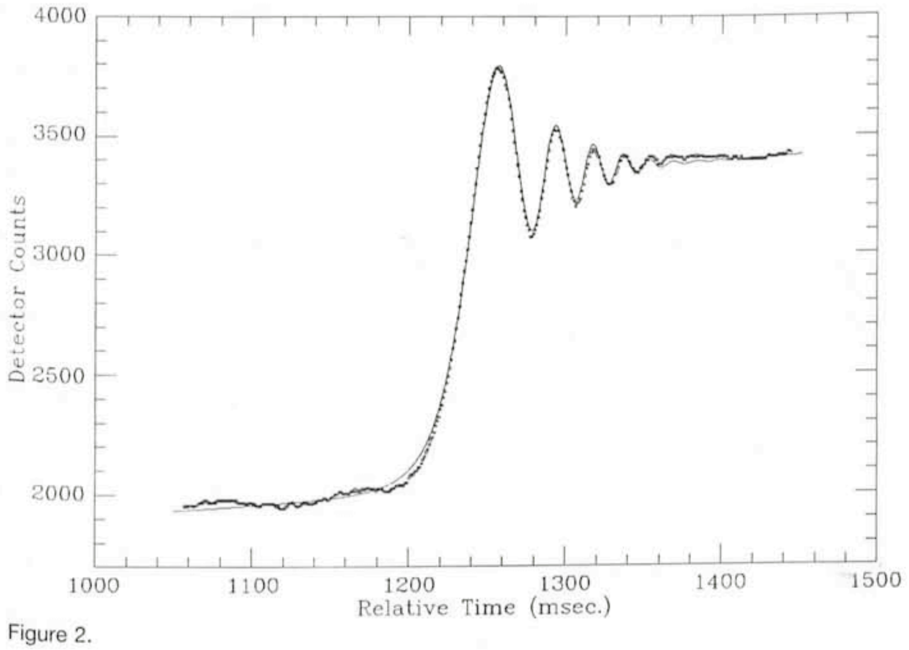


Figure 2.

## 4. Conclusion

In the first ever observed lunar occultations at La Silla, we measured for the first time the angular diameter of SAO 185573 with very high accuracy. We also recorded the occultation of Antares ($\alpha$ Sco) with very good S/N ratio, and this will allow a detailed study of the outer layers of this bright supergiant. Other occultations were recorded, showing the possibilities and the limits of the 3.6-m telescope in this mode of operation.

But what seems more important to us is the fact that the feasibility of lunar occultations at La Silla has now been demonstrated, and that the results are of the best quality. If lunar occultations were observed on a routine basis at La Silla, maybe taking advantage of future developments of the remote-control facility, a relatively large number of new diameter determinations could be easily collected. This would help to gain new knowledge about the calibration of fundamental quantitities of cool stars and probably lead to the discovery and the study of circumstellar dust shells and binary systems. There is no doubt that the angular resolution of the present method is superior to all other techniques at least in the infrared.

## 5. Acknowledgements

Our work would not have been possible without the help of many people before, during and even after the observations. In particular, we are grateful to P. Bouchet, U. Weilenmann and the infrared technical staff at La Silla, to C. Perrier for his help during one whole night with the specklegraph, to F. Gutierrez and S. Vidal for their help with the Fast Photometry software, to the night assistants R. Vega and H. Herborn.

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# The Large Intractable Nova Shells

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Despite the fact that nova outbursts seem to be well understood – at least in principle –, the fine structures of the eruptions remain enigmatic. Novae are believed to be binary stars, composed of a white dwarf and a tightly bound cool dwarf secondary which dumps unprocessed material onto the surface of the primary at a rate of $10^{-8}$ $M_\odot$ per year, i.e. 600,000 million tons per second. After perhaps thousands of years – the order of magnitude is still uncertain – enough material has accumulated on the surface of the white dwarf to give rise to a thermonuclear runaway in the electron-degenerate, hydrogen-rich layer. The accreted matter plus some carbon-oxygen-rich white dwarf material, which was mixed into it during the accretion process, is partially processed in the CNO cycle, and, over a time interval of weeks to years, ejected into space with a speed of several hundred to a few thousand km/s. Thus the nova shell is formed.

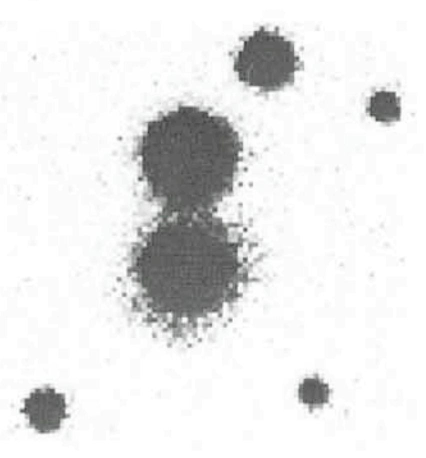

Figure 1: *The shell surrounding nova BT Mon, taken through an Hα filter.*

Faithfull readers of the *Messenger* may still remember the report on the discovery of shells around southern novae *The Messenger* No. 17, June 1979, page 1). In that article, photographs of the shells of RR Pic, CP Pup and T Pyx, taken at the prime focus of the ESO 3.6-m telescope, were presented. In early 1987 a combined study, based on imaging and spectroscopy with the ESO 2.2-m telescope, helped to illuminate more facets of nova remnants and their evolution. We even added a new nova nebula to the small list of known objects. The shell of BT Mon, which erupted in 1939, was first postulated from spectroscopic evidence (Marsh et al. 1983). Now it is seen in Figure 1, very weak and with a nearly circular outline.

The determination of shell properties of novae: geometry, kinematics, temperature, density, and chemical composition as functions of space and time is a largely unsolved task. The variety of light curve types for different nova outbursts reflects to some degree the temporal behaviour of mass ejection. However, almost nothing is known about the late phases of the outburst and the transition to a quiescent wind from the central object.

Spectra taken during the nova outburst display emission lines whose structures indicate that matter is generally not ejected in simple spherical shells. The absorption lines show that gas clouds given off at later times have higher velocities than those of the principal mass ejection. The high velocity material must interact with the previously ejected clouds. Estimates of the times, after which clouds of different velocities meet, agree well with the times at which certain ionized species are first observed in the spectra. The kinetic energies which might be transferred during inelastic collisions have just the right values to account for the observed ionization stages. The appearance of high excitation ("coronal") emission lines in the spectra of some novae during late stages might be attributed to the interaction of the highest velocity material with the principal shell. But is all high-velocity material decelerated by collisions, or can we still observe some of it?

Combining several CCD frames of a

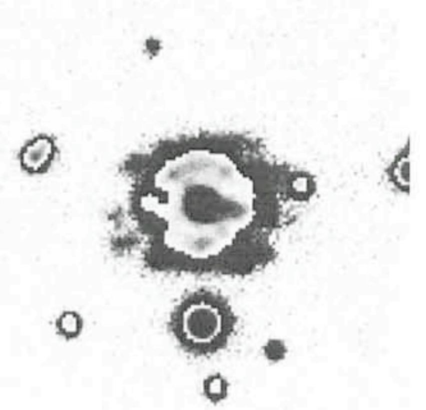

Figure 2: *The shells surrounding the recurrent nova T Pyx, taken through an Hα filter. For this composite, the central section of the highly amplified picture was set to zero, then a lower amplification image of the well-known central nebula was inserted.*

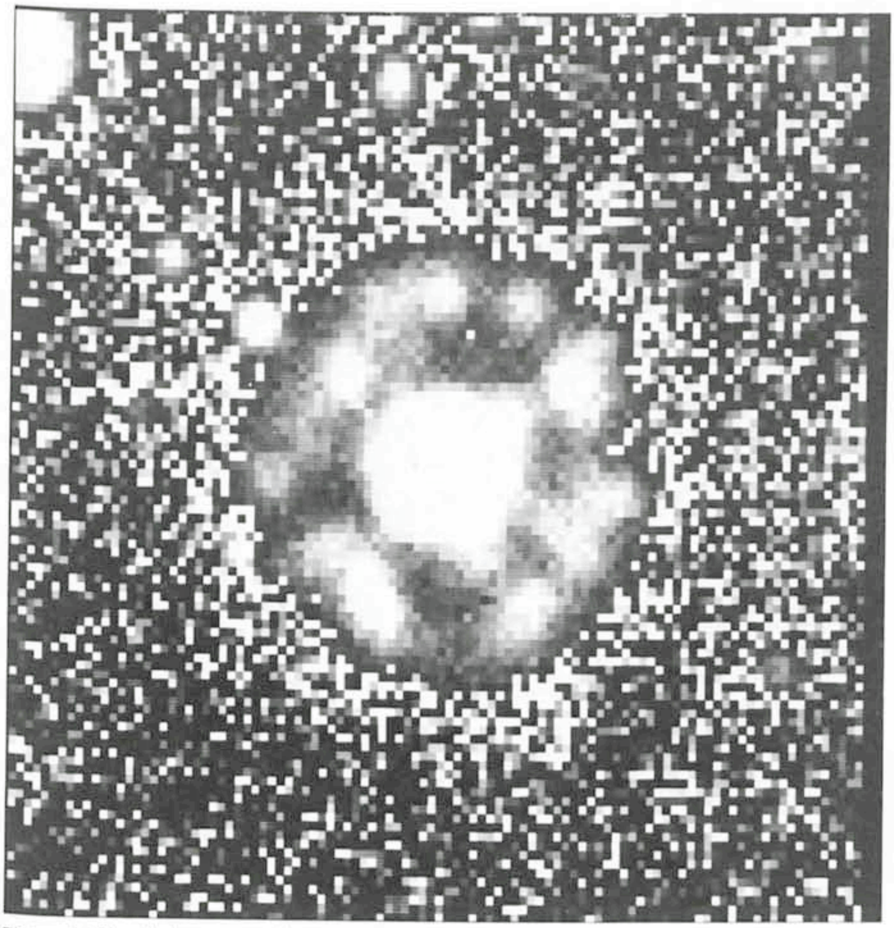

Figure 3: *The shells surrounding nova CP Pup, taken through an Hα filter. Composite picture as in Figure 2.*

nova shell is a powerful tool to make faint nebulosities clearly visible. Before turning to the questions asked above, we present an object, where we expect a superposition of shells: the recurrent nova T Pyx. This slowest one of the few known recurrent novae (V 394 CrA, T CrB, RS Oph, T Pyx, U Sco, V 1017 Sgr) had recorded outbursts in 1890, 1902, 1920, 1944 and 1966/67, the frequency of which lets us expect a new eruption very soon.

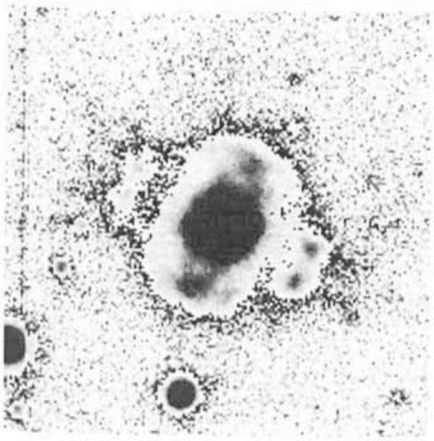

Figure 4: *The shells surrounding nova RR Pic, taken through an Hα filter. Composite picture as in Figure 2.*

Faint shells are barely apparent on a single CCD exposure (Seitter 1987). A clearly visible secondary shell was found on several superimposed images. In Figure 2, the central section of the highly amplified picture was set to zero, then a lower amplification image of the well-known central nebula was inserted. The tenuous outer shell can be attributed to the 1920 outburst, the central shell to that of 1944 while the shell of 1966/67 is still too close to the star to be resolved.

In contrast to the multiple shells from multiple events, secondary shells around classical novae must be attributed to different phases of a single event. The fast nova CP Pup, which erupted in 1942, exhibits a halo of weakly glowing gas around a stronger inner nebulosity (Fig. 3). So does the slow nova RR Pic, which appeared in 1925 (Fig. 4). In both cases the outer structures have some resemblence with the inner ones. In CP Pup both shells are circular, the ratio of their radii is 1.7. In RR Pic the outer shell is by factors 1.6 to 1.9 larger than the nebulosity found earlier and depicted in the photographs of Messenger No. 17. Interaction of the halo material with the "polar blobs" is suggested by long filaments apparently originating in the blobs and extending outward in radial directions.

From the absorption spectra of RR Pic observed during outburst it is known that the ejection velocities of the "diffuse enhanced stage" are 1.5 to 2.2 times larger than those of the earlier principal ejection. Material lost during

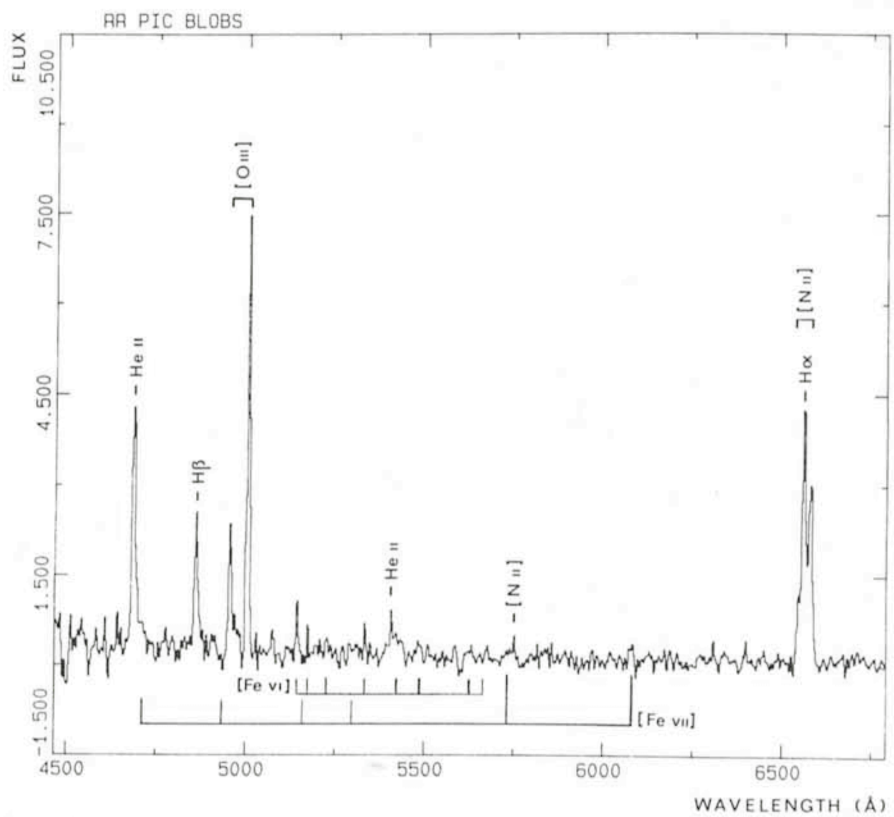


Figure 5: *The spectrum of the "polar blobs" of nova RR Pic.*

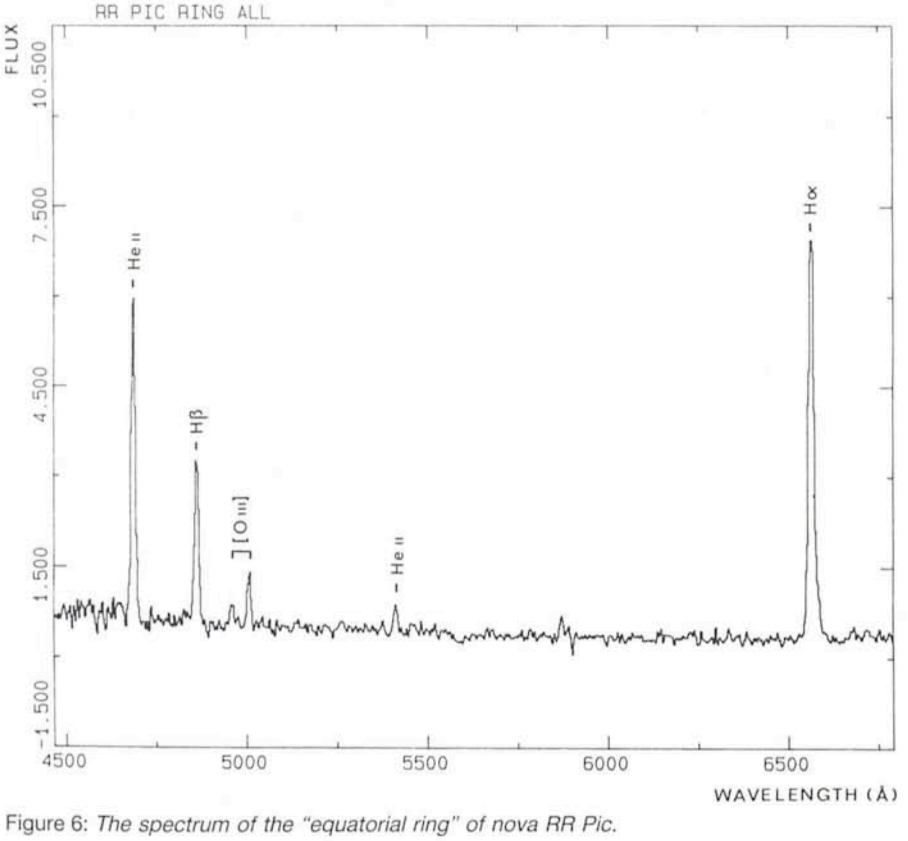


Figure 6: *The spectrum of the "equatorial ring" of nova RR Pic.*

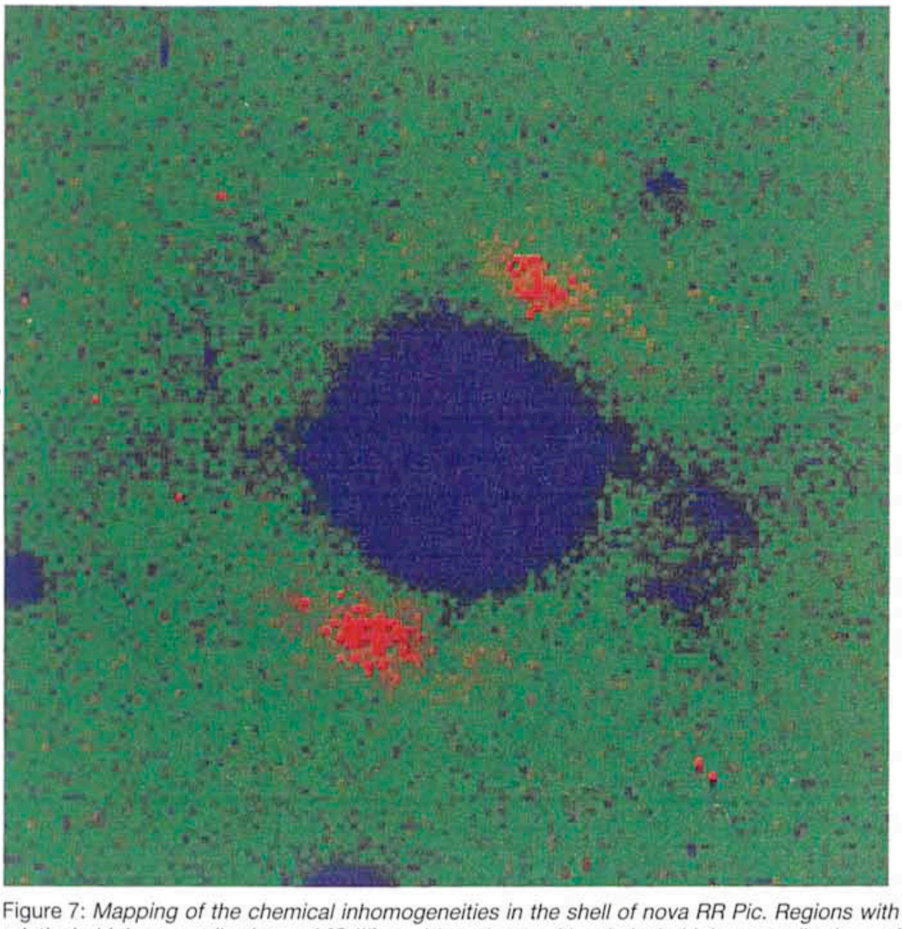

Figure 7: *Mapping of the chemical inhomogeneities in the shell of nova RR Pic. Regions with relatively higher contributions of [O III] are blue, those with relatively higher contributions of [N II] + Hα are red. The stellar colours are determined by continuum radiation and are not correctly shown in the chosen colour table.*

the still later "Orion stage" is 3.5 times faster. As a working hypothesis, we adopt the notion that the halo is made of diffuse enhanced material, which penetrated the principal shell and whose interaction with gas condensations in the principal shell led to its present filamentary appearance.

In CP Pup the ratio of the diffuse enhanced to the principal velocity is 1.2 to 1.6, but since the velocity of the principal absorption increased noticeably during the early stages of the outburst, it is not clear whether the diffuse enhanced mass outflow or the material ejected during the late stages of the principal phase is responsible for the halo.

In order to obtain information on local physical parameters, spectra taken in different parts of a shell are required. The CCD spectra of RR Pic from the recent observing run have considerably higher S/N ratio than earlier IDS spectra. They reveal more lines so that the parameters can be determined with better confidence (Figs. 5, 6). Even lines from the inner regions of the outer shell are visible in the CCD frames. These lines suggest that the physical conditions are similar to those in the inner shell, except for the density.

Newly found features are several weak lines of [Fe VI] and [Fe VII], found only in the polar blobs. Lines of [Fe V] were reported in the blue spectra of the blobs by Williams and Gallagher (1979). The same highly ionized iron lines were observed in the late decline from outburst (1926–1934) where we consider them to be the spectral tracers of ionizing collisions between high velocity particles and low velocity shells. In the well developed shells tens of years after outburst, the source of excitation could be a hot wind. Coming from the accretion disk, it streams mainly vertically away from the disk which is assumed to lie in the plane of the "equatorial ring".

In the spectra of two polar blobs, the electron temperature derived from the strength of [N II] lines is 35000 K. The ratio He II/Hβ is the same in the polar blobs and in the equatorial ring, suggesting similar temperatures for the two regions. In the spectra of the equatorial ring, marginal [S II] lines give values for the electron density of 10 to 100 $cm^{-3}$. These lines are not visible in the polar blobs. Because of the brightness of the blobs it is, however, hard to assume that the electron densities are much lower. Finally, the ratio of line strengths [O III]/[N II] is 2.5 in the blobs and approximately 1 in the rings. This strongly suggests a difference in chemical composition of the two regions. At first sight, it seems more likely that the enhancement

Figure 8: *Mapping of the chemical inhomogeneities in the shell of the recurrent nova T Pyx. Colour coding as in Figure 7.*

of oxygen in the polar blobs is due to meridional circulation of white dwarf material at the onset of the outburst (Kippenhahn and Thomas 1978) than to differences in the ashes of nuclear burning.

The apparent abundance inhomogeneities can be mapped by combining pictures taken through interference filters isolating the radiation of [O III] and [N II] + Hα, respectively. In the colour plots, regions with relatively higher contributions of [O III] are blue, those with relatively higher contributions of [N II] + Hα are red (Figs. 7, 8).

Aside from their physical meaning, which must still be better substantiated, the colour plots help to determine the symmetry axes in nova shells. This was already shown for the northern nova GK Per (Duerbeck and Seitter 1987) which until then was considered irregular. The shell of RR Pic is shown in Figure 7. The colour method is particularly useful for shells which appear in nearly spherical projection, such as T Pyx (Fig. 8).

This ends our present report on nova shells. With a plethora of novae and nova remnants still awaiting their observational share, the field of stellar cataclysms appears to be as attractive as ever.

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# Internal Dynamics of the Gum Nebula


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## Introduction

Among the many large and spectacular objects of the southern sky, the Gum nebula with an angular diameter of 36 degrees in the sky is the object with the largest known apparent dimensions. Unlike the other large objects like the Large Magellanic Cloud (diameter $\simeq 8°$) and the Small Magellanic Cloud (diameter $\simeq 3°$) which clearly stand out as highly luminous regions in the night sky, the Gum nebula, however, is extremely faint and is not visible to the naked eye. The only way to see this nebula is to look at the photographs taken in emission lines like $H_\alpha$ λ 6563 Å and [NII] λ 6584 Å lines since the entire visible radiation from the nebula is confined to a few such emission lines. But the extent of the nebula is so large that it fills the conventional Schmidt photographs and can be detected only from a mosaic of Schmidt photographs. In fact, the nebula was first detected this way in 1953 by Colin S. Gum, who made a mosaic of several long exposure Schmidt plates of this region, each with an 11° field, taken in the $H_\alpha$ + [N II] lines. It is befitting that the nebula now bears the name of its discoverer, C.S. Gum, who was unfortunately killed in a skiing accident in Switzerland in 1960, at a relatively young age of 36.

The central region of the Gum nebula contains Zeta Puppis (O4f), the brightest O-type star in the sky, and Gamma Velorum (WC 8 + 09 I). From the ESO IIa-O and the SERC IIIa-J plates of the region of the Gum nebula, about 29 cometary globules (CGs) and 7 dark clouds have been identified (Hawarden and Brand, 1976, Sandqvist, 1976, Zealey, 1979, and Reipurth, 1983). Cometary globules are dark clouds which have dark, dense heads which are completely opaque to the background starlight, and faint, luminous tails through which background stars can be seen. The heads often have bright rims on the side that points towards the centre of the Gum nebula complex while the tails, in general, point away from this central region. To date, a total of about 38 CGs have been noted and catalogued of which 29 lie in the Gum nebula region. Several of these

CGS show signs of star formation. Reipurth (1983), Brand et al. (1983) and Pettersson (1987) have conclusively shown that CG 1 and CG 30 are sites of star formation. We have carried out a study of CGs and dark clouds in the Gum nebula using IRAS and other optical data (Srinivasan et al., 1987) where we find the dust to be concentrated and compressed on the side of the head that faces the central region of the Gum nebula complex. Our study also shows that there is evidence for the presence of point sources in the heads of a few CGs indicating that star formation is current in these globules. Hence from the morphology of the CGs in the IR it seems that the internal dynamics of the Gum nebula has played an important part in their formation and in triggering a series of star forming events in the heads of the CGs.

## Previous Studies

Earlier work on the internal dynamics of the Gum nebula have clearly suggested the need for further work. There have been three attempts in this direction. They are listed below with the methods and essential results.

(1) The earliest attempt to study the internal dynamics of the Gum nebula was made by Hippelein and Weinberger (1975) where they used a photographic Fabry-Perot interferometer and detected no systematic expansion. Since their actual interferograms are not published, it is difficult to judge the errors and the reliability of the results. But the velocity resolution in this study seems rather poor and the results seem uncertain due to the many problems associated with the difficulty in correcting for the background using the old photographic techniques, particularly when the object is faint.

(2) More accurate measurements were carried out by Reynolds (1976) where he used a twin-etalon Fabry-Perot spectrometer and a photo-electric detector to obtain line profiles in $H_\alpha$ $\lambda$ 6563 Å, [N II] $\lambda$ 6584 Å and [O III] $\lambda$ 5007 Å lines in 8 positions of the nebula. At a few positions, he detected expansion velocities as high as 20 km/s and less in a few other positions. The northern location of the telescope used in this study (the telescope used was the McMath telescope at KPNO) however forced the observations to be confined only to the northern parts of the nebula, leaving the southern regions of the nebula completely unexplored.

(3) Reynolds' results were contradicted by Wallerstein et al. (1980) where they studied optical and UV interstellar absorption line spectra of about 70 stars in the direction of the Gum nebula and concluded that the nebula undergoes no systematic expansion. Their analysis, however, involves the assumption that the Gum nebula is the cause of the observed absorption features, although it is not clear whether some other component of the ISM in the line of sight could also be the cause of these features.

Thus the need for further systematic observations to resolve the issue was clear and we have undertaken a study where high resolution (R ≅ 40,000) line profiles could be obtained at many points uniformly distributed throughout the nebula.

## Observations

The ESO 1.4-m telescope, which is equipped with a Coudé Echelle Spectrograph, a short camera and a CCD detector, is well suited to study such large and faint nebulae. Since the nebula is extremely large, high spatial resolution is not necessary and hence the short camera can be used advantageously to increase the field of view thereby increasing the light-gathering power of the spectrometer. Use of the CCD provides an extra advantage since it is possible, at the data reduction stage, to rebin the spectra in the direction perpendicular to the dispersion up to about 50 to 100 pixels thereby increasing the S/N by a large factor.

Observations were made in February and May 1987, in the $H_\alpha$ $\lambda$ 6563 Å, [N II] $\lambda$ 6584 Å and [O III] $\lambda$ 5007 Å lines at 14 positions well distributed in the nebula, with a resolution of R ≅ 40,000. Care was taken to include southern regions which were not included in the study of Reynolds. Three of our positions coincide with those of Reynolds and were taken for the sake of comparison. Figure 1 shows a photograph of the Gum nebula, with the approximate positions of Reynolds and our observation positions superposed on it. Typical exposure time for all the three lines was 1 hour. The data were reduced using MIDAS (Munich Image Data Analysis System) at ESO, Garching.

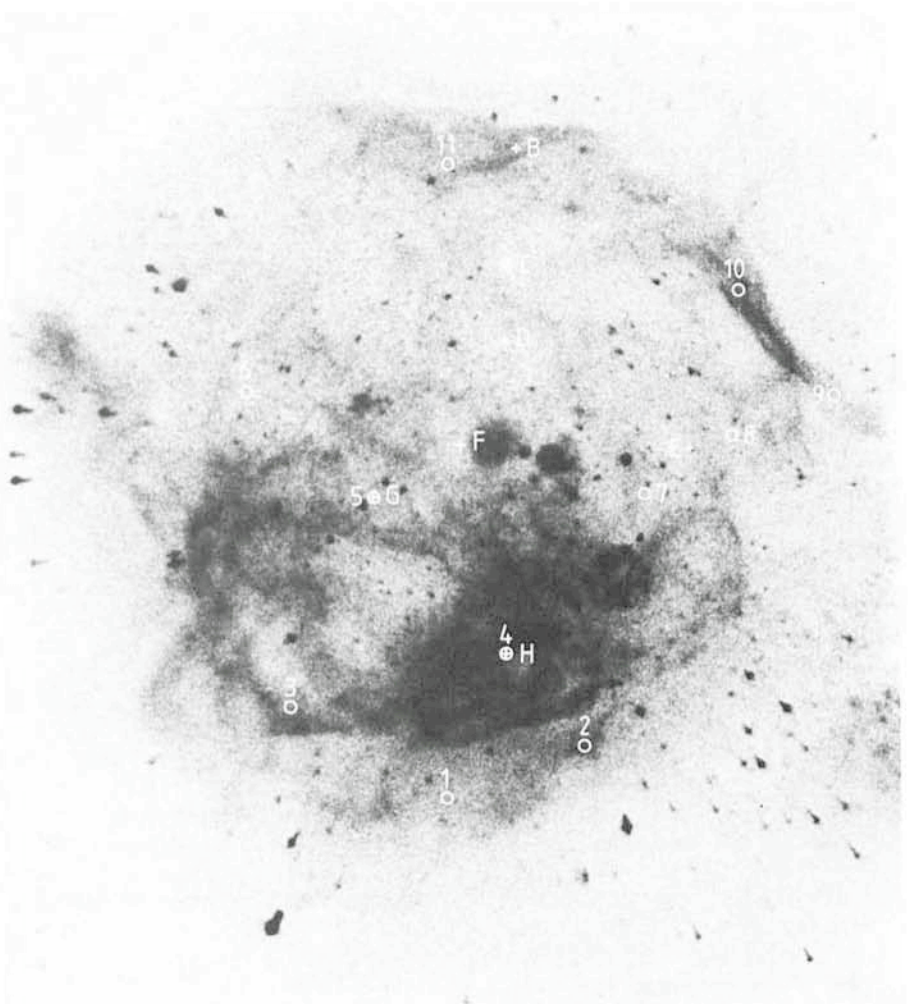


Figure 1: *This photograph of the Gum nebula was obtained by J.P. Sivan and has been reproduced from the ESO book "Exploring the Southern Sky", by S. Laustsen, C. Madsen and R.M. West. Superposed on the photograph are the approximate positions at which our observations are taken (indicated by O) and those of Reynolds (indicated by +).*

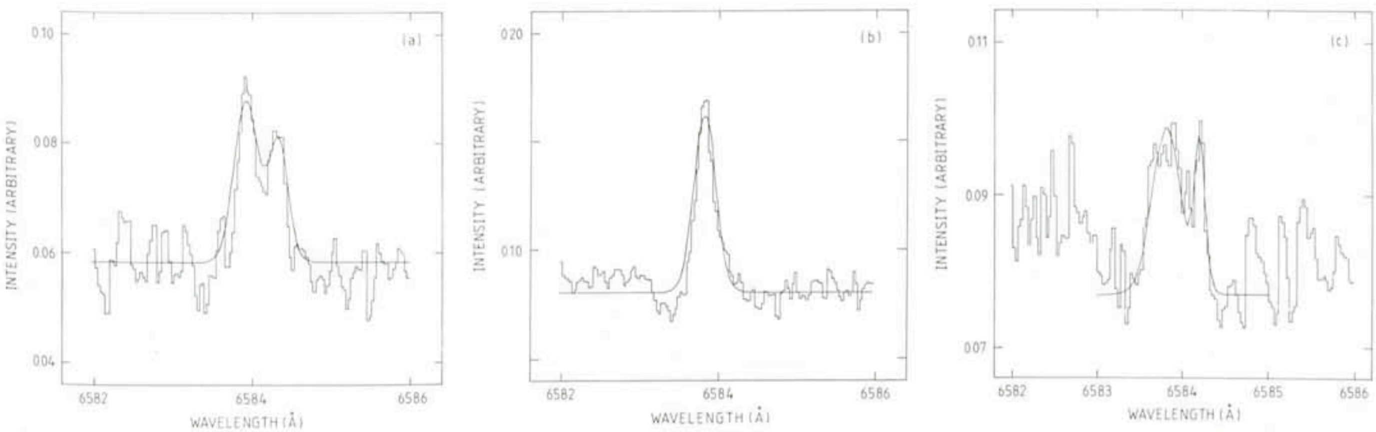


Figure 2: *(a, b, c): The observed [N II] λ 6584 Å profiles (histograms) obtained at positions 2, 1 and 4 respectively using the ESO 1.4-m CAT + Coudé Echelle Spectrograph + CCD, along with the Gaussian best fits (smooth curves). Position 4 corresponds to position H of Reynolds.*

## Results

Though the detailed analysis and modelling are in progress, some results can be stated here which are the following:

(1) To derive the true expansion velocity of the nebula, we have applied the geometric correction factors to the observed line of sight velocities and our observations are more consistent with an expansion velocity of Vexp = 10 km/s for the Gum nebula as obtained from the splitting of the [N II] line profiles. Figure 2 shows the [N II] line profiles obtained at positions 1, 2 and 4.

(2) We failed to detect [O III] emission in any of the 14 positions observed, in contradiction with the observations of Chanot and Sivan (1983) (who made spectrophotometric observations of the Gum nebula) and in agreement with the observations of Reynolds. In order to confirm our non-detection, we repeated exposures in the region near Gamma Velorum (position 4) where the [O III] emission was reported by Chanot and Sivan to be high. We failed to detect [O III] at this region in spite of integrating exposures of totally 2 hours and 20 minutes, which shows that the object is a low-excitation nebula.

(3) None of the $H_\alpha$ profiles showed any splitting. This is however not surprising because of the large thermal width of the $H_\alpha$ line (the expected FWHM of the $H_\alpha$ line is about 22 km/s at 10,000 K). The non splitting of the $H_\alpha$ line profiles shows the expansion velocity to be less than 10 km/s which is consistent with the results obtained from the [N II] profiles.

A comparison of our observations and results with those of the previous studies is shown in Table 1.

A physical model for the Gum nebula taking into account the observed geometry and the velocity structure is underway. We also plan to obtain high resolution spectra at many more positions in the nebula in different ionization lines for further study of the internal dynamics and the ionization structure of the nebula.

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TABLE 1.

| Studies | Telescope and instrument | Field of view | Resolution (km/s) | No. of positions | Line studied | Results |
|---|---|---|---|---|---|---|
| Hippelein and Weinberger (1975) | 16-cm telescope (Gamsberg, S. Africa) + photographic F.P. interferometer | 3°.5 | 19–28 | 2000 | Hα (em.) | no expansion |
| Reynolds (1976) | 60-cm McMath telescope (USA) + twin-etalon F.P. spectrometer | 5'.7 | 12 | 8 (northern regions) | Hα [N II] [O III] (em.) | Vexp = 20 km/s |
| Wallerstein et al. (1980) | 1.5-m CTIO (Chile) + Coudé spectrograph and Copernicus satellite results | not relevant | > 12 for (Ca II) and > 25 for (Na I) | 70 | Ca II Na I (abs.) | no expansion |
| Present study (1987) | 1.4-m ESO (Chile) + Coudé Echelle Spectrograph + CCD | 1' X 1".6 | 7.5 | 14 (including southern regions) | Hα [N II] [O III] (em.) | Vexp = 10 km/s |

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# V 605 Aquilae – a Star and a Nebula with No Hydrogen

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Three planetary nebulae are known with hydrogen-poor central nebulosities and WR-type central stars: A 30, A 78 and A 58. While the former have been discussed extensively in the literature, the latter remained spectroscopically unknown until 1983. Its story, however, begins much earlier.

In 1920 Max Wolf found a $10^{m}_{.}4$ star on photographic plates taken in 1919. The object had been invisible before 1917; it disappeared in 1923. In 1921, Lundmark took spectra of the suspected nova. These had no resemblance with spectra of any of the known evolutionary states of novae, they looked like those of carbon stars. Decades later, the region around the star, now designated V 605 Aql, was inspected. Abell (1966) found a faint old planetary nebula and entered it as number 58 into his catalogue, Herbig (1971) noticed a very faint starlike object near the centre of A 58 and suggested that this was the remnant star of V 605 Aql.

Our own story of V 605 Aql and A 58 starts in 1983, when I joined H. Duerbeck in his spectral survey of faint old novae with the Calar Alto 2.2-m telescope. The central star of A 58 was not visible on the telescope monitor. However, we had just recorded another unseen old nova, V Per, because it had appeared somewhere along the long slit with which the unwidened spectrum was taken. Thus, the long slit was placed across the planetary nebula in various positions. When it lay exactly across the centre, as deduced from the pattern of spectra from neighbouring stars, a central point-like emission spectrum appeared in addition to the emission lines of the extended planetary nebula. The central nebulosity showed no hydrogen, only strong [O III] and moderately strong [N II] lines, slightly blueshifted with respect to the planetary emission lines (Seitter 1985a).

An EFOSC spectrum taken for us with the ESO 3.6-m telescope by P. Angebault in 1986 shows the spectra of *three* objects: lines of the planetary nebula and the central nebula and stellar emission lines superimposed on a weak continuum of red magnitude 22.3 (Seitter 1987).

Follow-up observations were obtained on July 1/2, 1987, again with the EFOSC at the ESO 3.6-m telescope. A slit width of 1″ was chosen in order to clearly separate the [N II] 658.4, 654.8 nm lines at a dispersion of 23 nm/mm. The mean spectra obtained in the blue and red/near infrared regions are shown in Figures 1 to 4. In all spectra, contributions from the night sky and the planetary nebula are removed. The subtraction of the latter rests on the assumption that the strengths of the nebular lines towards the northern part of the PN do not differ from those superimposed on the central nebula. This seems to be justified from the appearance of the hydrogen lines in the two-dimensional spectra, where no differences are noticed between the two regions (see Figs. 2 and 3 in Seitter 1985b).

The result is striking as seen in Figure 4: no trace of Hα is found between the nitrogen lines. The central nebula of A 58, which also appears to be the remnant nebula of the nova-like outburst of the central star V 605 Aql in 1917, is the foremost candidate for a nebula entirely free of hydrogen.

The central star of the two nebulae exhibits a strong C IV 580.6 blend, besides marginal lines of He II 468.6, O V and O VI. The broad C IV feature with a FWHM of 2,300 km/s and a total width of 4,400 km/s suggests that this star is of WR type, as are the central stars in A 30 and A 78. An additional similarity of the three objects is the presence of cool dust. Extended dust shells of 140 K were derived for both A 30 and A 78 (Cohen and Barlow 1974) while the IRAS data indicate a point source of 170 K for A 58.

The central object of A 58 is interesting not only because of its extreme properties but also because the outburst was observed photometrically and spectroscopically. This puts severe constraints on any theory trying to explain the observed phenomena.

Following earlier suggestions (e.g. Iben et al. 1981 for A 30 and A 78, and Pottasch 1985 for A 58) the central stars of all three PNs are candidates for post helium shell flash evolution. The central nebulae in A 30 and A 78 have kinematic ages of a few thousand years. If the central stars reached their observed positions in the H-R diagram during the same time interval, one finds fair agreement with evolutionary computations. V 605 Aql, on the other hand, has reached a magnitude comparable to its pre-outburst brightness after less than 70 years.

Because the temperature determination is difficult for a star which displays just one well-defined line, the bolometric

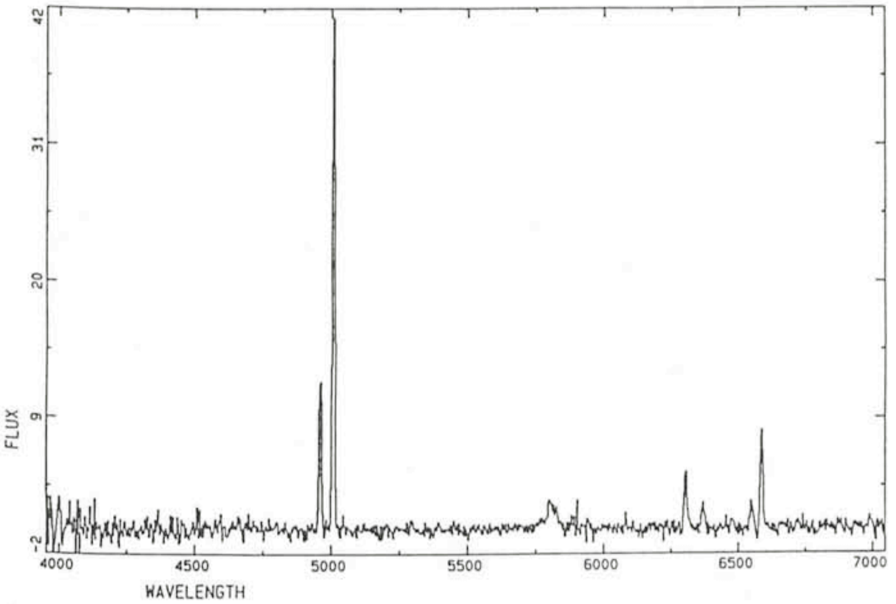


Figure 1: *The nebular remnant of V 605 Aql in the blue spectral region and the superimposed stellar C IV blend at 580.6 nm.*

correction for V 605 Aql remains doubtful. Similarly, any correction for dust absorption in the nebula is merely guesswork. With T = 100,000 K (70,000 K is the Zanstra temperature from the extremely weak He II 468.6 lines in both nebulae relative to the visual stellar continuum) and $A_v$ = 4 at the distance of 3.5 kpc, the luminosity obtained for the central star at its present stage is L = 300 $L_\odot$. It places the object in the H-R diagram in a position which central stars of 0.6 $M_\odot$ reach thousands of years after a late final helium shell flash (Iben et al. 1981). This is more than two orders of magnitude longer than the time which V 605 Aql has actually taken to reach the place computed with the above assumptions. Even a higher mass star would still need much longer than a few tens of years. Observationally, V 605 Aql is an explosive phenomenon, but dynamical evolution has so far not been included in the computations of final helium shell flashes (Schönberner 1987).

The measured radial velocity of the central nebula relative to the PN is 60 km/s, somewhat larger than the 25 km/s observed for the central blobs of A 30. In an explosive event, where the star had no time to adjust to a quasi-stable configuration and the ejected matter escaped directly from the high density central star, a low velocity indicates that the original velocity did not exceed the escape velocity very much and that only a small percentage of the total outburst energy went into kinetic energy. In this respect V 605 Aql differs from classical novae but resembles planetary nebulae (Seitter 1985b).

The C-type spectrum of V 605 Aql during outburst shows that the star was hydrogen-poor two years after light maximum. The extremely low temperature (other outburst objects, like novae or symbiotic stars, generally have A- to F-type spectra during their coolest stages) indicates a very large extent of the stellar quasi-photosphere (locus of optical depth = 1) and/or high opacity in the extended shell or wind. This is supported by the high mass found for the remnant nebulosity from the analysis of the nebular spectrum.

The remnant nebula shows strong lines only of heavy elements. Three ionization stages of oxygen are observed. The [O III] 500.7, 495.9 lines are the strongest lines found in the spectrum. The near infrared [O II] and the red [O I] lines are weaker. The [N II] 658.4, 654.8 lines are next in strength to [O III]. The auroral lines of both ions are very week so that the simultaneous solution for electron temperature and electron density is somewhat uncertain. [NE III] and [A III] lines are seen only in the 1986 spectrum.

The best results for the central nebula with the present data are $T_e$ = 14,000 K and $N_e = 5 \cdot 10^4$ cm$^{-3}$, those for the planetary nebula are $T_e$ = 12,800 K (derived from [N II]) and $N_e$ = 230 cm$^{-3}$ (derived from the radius/mass relation for PNs given by Pottasch, 1980, the volume and the mean ionic weight per electron). Direct determinations of electron densities from the [S II] lines yield contradictory results from the 1986 and the 1987 spectra. This is attributed to high noise, especially in the 1987 spectra. The results of 1986 also contradict those obtained from the 1987 simultaneous solution. In view of the very faint magnitude ($21^m$) of the unresolved central nebulosity only a series of long exposures can supply more reliable data. The mass of the central nebula derived from the above data is $M = 5 \cdot 10^{-2} M_\odot$ (upper limit, assuming a filling factor of 1), as compared to $M = 10^{-2} M_\odot$ derived from the light curve data.

Only coarse abundance estimates are possible at this time. This is largely due to the weakness of helium and other diagnostic lines.

The procedure to derive abundances is to first estimate the He/H ratio for the planetary nebula using the equations given by Miller (1987), then to determine the relative strengths of the heavy elements in both nebulae, taking into account the different column heights and filling factors of the central and the planetary nebula. Using for the column heights the ratio 1/10 as derived from the angular sizes (with an upper limit for the unresolved central nebula) and for the filling factors the ratio 10/1 (a guess as good as any other) no correction factor is needed. Then, adopting the

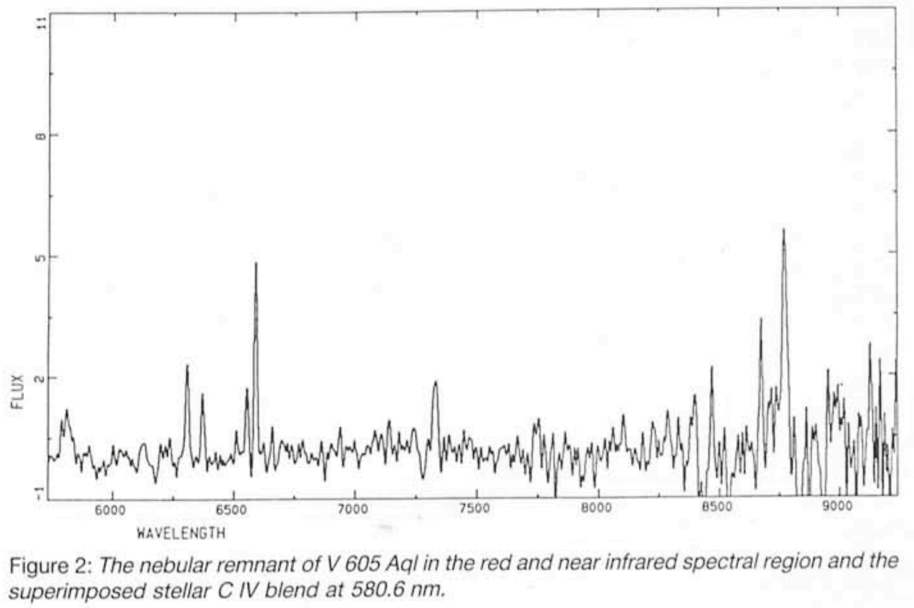


Figure 2: *The nebular remnant of V 605 Aql in the red and near infrared spectral region and the superimposed stellar C IV blend at 580.6 nm.*

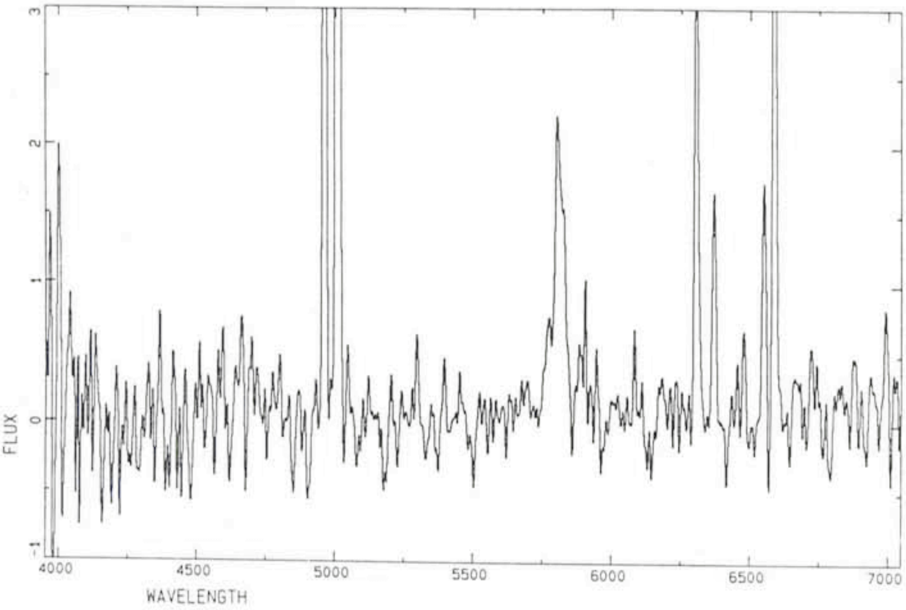


Figure 3: *The strongest feature of the central star, the C IV blend at 580.6 nm, seen as broad line near the centre of the spectrum.*

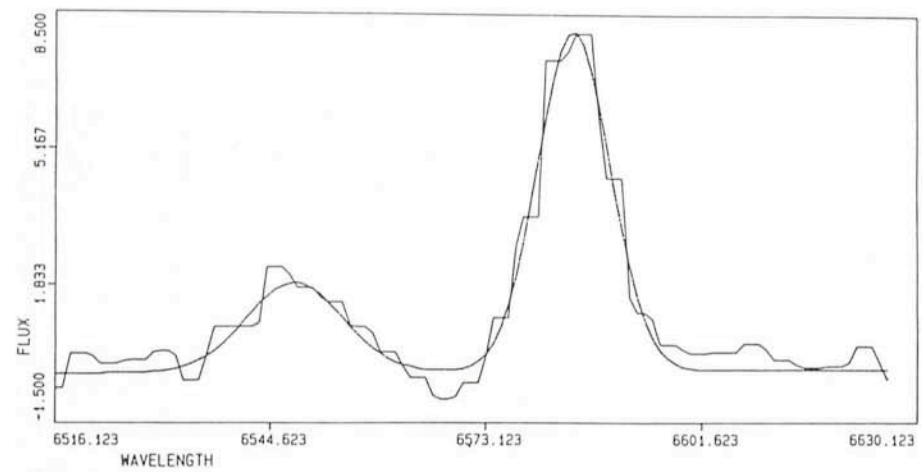


Figure 4: *Tracing and fitted Gaussian profiles to [N II] 658.4, 654.8 nm showing the complete absence of Hα.*

CNO abundance in the PN to be 1 % by number, all data are normalized to the data obtained for the PN. The results are given in Table 1.

The relatively strong nitrogen lines could be the result of incomplete hydrogen burning in the hot CNO cycle after mixing during the early phases of the helium shell flash. At the same time, the absence of hydrogen in both the stellar and the nebular remnant indicates that all H was consumed during this stage.

The large overabundance of oxygen would be the result of the triple alpha process, which is even more efficient in producing O than C as has been shown by Kettner et al. (1982). The abundance of carbon is uncertain because no line was clearly identified. A strong line in the near infrared could be [C I] 8727 but its wavelength is measured too large. Better calibrated spectra are needed to solve the problem. If the presence (and a possible overabundance) of neon can be verified, very hot He-burning is indicated.

Our conclusions are: If V 605 Aql is a final helium shell flash object, then:

- this stage was reached approximately 25,000 years (kinematic age of A 58) after formation of the planetary nebula;
- the time scale of evolution through the final helium shell flash and well back towards the pre-flash stage is of the order of tens of years indicating evolution on a dynamic time scale;
- incomplete CNO cycle- and (possibly hot) He-burning can account for the elemental abundances in the remnant star and the remnant nebula;
- the remnant star shows a strong WC-type wind, possibly instrumental in sustaining the cool dust shell;
- the apparent presence of hydrogen in the central nebula of A 58, as reported by Pottasch et al. (1985), must be attributed to the superimposed PN spectrum. It cannot be excluded from the observing modes described by Jacoby and Ford (1983) that this also accounts for the presence of hydrogen in the central objects of A 30 and A 78.

If there should be noticeable overall differences in the H- and He-contents of final helium shell flash objects as well as in their time scales, one will have to look for the parameters that determine whether a helium shell flash becomes eruptive or not. This might be important not only for the *final* helium shell flashes.

TABLE 1. *Abundance estimates, given in number percentages, for A 58 and for the nebular remnant of V 605 Aql*

| Object | H | He | CNO | C | N | O |
|---|---|---|---|---|---|---|
| A 58 | 79 | 20 | 1 | not specified | | |
| V 605 Aql | 0 | 93 | 7 | ? | ≤1 | ≤6 |

## Acknowledgements

Thanks go to P. Angebault and all those who helped me at La Silla, to H. Duerbeck for participation in all phases of this project, and to D. Schönberner for teaching me about the helium shell flashes.

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## ESO Book Presented to the Press

The ESO Book "Exploring the Southern Sky" (see the *Messenger* **49,** page 42) was presented to the Press in late September, in Copenhagen and at the ESO Headquarters. A reception was held at the Danish Academy of Sciences on September 21, with participation of representatives from the publisher, RHODOS, and the two foundations which supported the Danish edition, Urania Fonden and Knud Højgaards Fonds. On September 29, the English and German editions were presented by Springer and Birkhäuser Verlag, during a reception at ESO in Garching. On this day, the Press was also allowed to visit the "Remote Control Room" where Mira Véron (Observatoire de Haute-Provence) was observing with the 2.2-m telescope on La Silla.

## ESO Slide Sets

The following five Slide Sets are now available:

- Images of Comet Halley
- VLT: The ESO 16-m Optical Telescope
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## The Volcano and the Stars

This beautiful photo of the active Volcán Villarica in central Chile was obtained by ESO astronomer Bo Reipurth in March 1987. The photo was made in bright moonlight, illuminating the top glacier. The stars in the field are in the constellations of Ara and Pavo; η Pav is seen as bright trail near the right edge and η Ara is left of the fiery crater.

## SN 1987 A (continued)

The far southern declination of Supernova 1987 A (−69°.5) means that it is "circumpolar" – always above the horizon – at all of the major astronomical observatories in the southern hemisphere. Observations have therefore continued every night since the discovery in February.

Since the last reports about SN 1987 A in this journal (**49,** pages 25 and 32–34), the comprehensive Proceedings of the ESO Workshop on SN 1987 A have been published, giving an in-depth account of the first four months of intensive observations. Details about this king-size book and how to obtain a copy are given in the box.

Two contributions from ESO are included in this issue of the Messenger. The first concern observations of the infrared spectrum with the 3.6-m telescope and IRSPEC. These data are unique and it has therefore been decided to print the preliminary list of observed lines in its entity. Another contribution provides information about recent speckle observations.

Hard X-rays from SN 1987 A were detected already in August, but this was only announced in late September, because of problems in separating the SN signal from that of the nearby X-ray source, LMC X-1. X-rays in the 20–130 keV energy region were observed with HEXE, a German-built instrument on the Kvant module of the Soviet Mir station. The SN was also detected at energies up to 350 keV by the Soviet "Pulsar X-1" instrument, and also with the Japanese Ginga satellite. The observed spectrum was very hard; this explains why no radiation was registered by earlier experiments in the low-energy range. For instance, a rocket was launched on November 14 from Woomera, Australia, with a detector in the soft X-ray range from 0.75–2 keV, but no signal was detected.

It is not yet clear whether the observed hard X-rays originate in the expanding shell, as diffused emission from decaying Cobalt-56 atoms, or whether the source is a neutron star (pulsar) at the centre. Continued observations may be able to tell which of these two hypotheses is correct, since the flux from a neutron star is thought to remain largely constant, whereas radiation from Cobalt will slowly decrease.

The visual brightness continues to decrease slowly in an exponential way, and accurate measurements indicate that the corresponding "decay-time" lies between 106 and 115 days. This is very near the 111-day mean life of Cobalt-56 and is indicative of this radioactive element being the main source of energy during the present phase. It was thought in late October that a more linear decline in brightness might have begun, but this was soon refuted by continued, accurate photometry in South Africa and in Chile.

The magnitude in late November was about 6.0. This means that it is now becoming too faint to be seen with the unaided eye.

*The Editor* (November 30, 1987)



# A 1–5 μm Infrared Spectrum of SN 1987 A

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*A. F. M. MOORWOOD and I. J. DANZIGER, ESO*

An infrared spectrum of SN 1987 A covering the atmospheric windows between 1 μm and 5 μm was obtained at R = 1,500 with the IRSPEC spectrometer on the ESO 3.6-m telescope during the period 5–8 October 1987. Unfortunately, the observations had to be spread over several nights due to the presence of cirrus clouds which made it necessary to observe and calibrate separately at each of the ≃ 50 grating positions used. Nevertheless the result is instructive in demonstrating that, with the advent of array detectors, infrared observations do not necessarily have to stop as soon as the clouds appear!

The complete spectrum is reproduced in Figure 1 and, as three enlarged sections, in Figure 2 where the fainter lines are more visible and the main features are also identified. A strikingly large number of emission lines are now present and Table 1 represents our first attempt at identification. Many of these features have not previously been reported in astronomical spectra, several remain unidentified and some of the suggested identifications (mainly amongst the neutral atoms) must be considered uncertain. All the lines are broad, with typical FWHM ≃ 3,000 km $s^{-1}$. Their profiles range from highly symmetrical to pronounced P Cygni but, in all cases, the emission peaks are redshifted by 400–1,500 km $s^{-1}$ compared with the ≃ 270 km $s^{-1}$ expected for the LMC. Actual values for the "cleanest" and most securely identified lines are given in Table 1. Neither the "excess" redshifts nor their large spread can be attributed to wavelength measurement errors because the positions of H and CO lines in the observed comparison stars confirm the accuracy of the IRSPEC calibration (with a neon spectral line lamp) to better than one pixel (typically < 200 km $s^{-1}$). Within the observed velocity spread however there do not appear to be systematic differences between species or amongst lines with different optical depths. It should also be noted that visible spectra reveal the Hα emission to be redshifted by

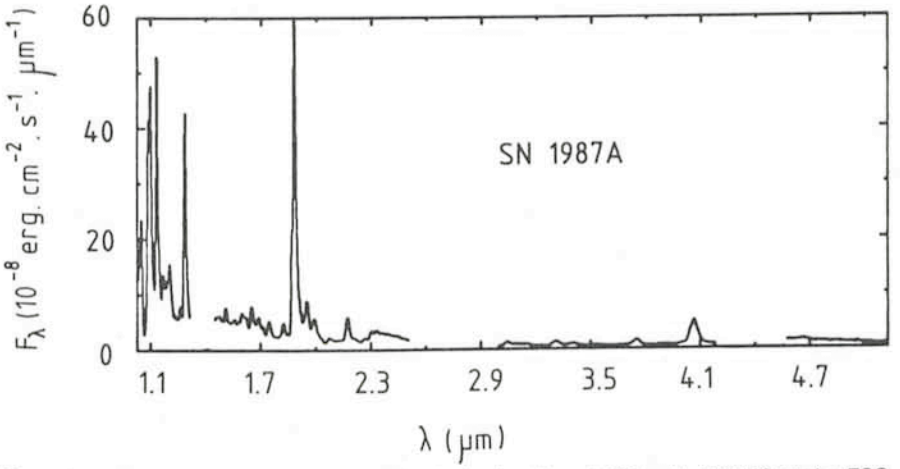



Figure 1: *1–5 µm spectrum of SN 1987 A obtained at R ≃ 1,500 with IRSPEC at the ESO 3.6-m telescope during the period 5–8 October 1987.*

the 1.257 µm line luminosity corresponds to an estimated $Fe^+$ mass of ≃ 0.04 $M_\odot$. Assuming all the Fe is singly ionized (L. Lucy, private communication), this implies an Fe mass function of ~ 0.004 for a 10 $M_\odot$ envelope. Given the uncertainties in this determination and in the expected LMC abundance, it is too early to claim that this is abnormally high.

## Neutral Atoms

The line at 1.132 µm is one of the brightest in the spectrum. Its identification with O I (1.1287 µm) is believed to be reasonably secure because the upper level of this transition has an energy

1,000 km $s^{-1}$ at this time. At present we do not know how to resolve this apparent contradiction between evidence for an expanding gas shell around the SN and a bulk motion along the line of sight away from us. As there has been very little time for interpretation between the data reduction and the deadline for this article, the other conclusions reached so far are also presented here somewhat tentatively.

## H and He

Around 20 hydrogen recombination lines are present and, allowing for possible flux errors estimated at ~ 20 % due to the clouds, the relative intensities of the 12 cleanest lines are close to those expected for a case B recombination spectrum. However, lines arising from levels n > 7 appear to be somewhat enhanced (~ 30 %) while Pfβ (H7-5 at 4.66 µm) is too faint by a factor ~ 3 – a result of particular significance because the CO fundamental band emission in this region appears to be similarly weak as discussed further below. Both the He lines detected at 1.083 µm and 2.058 µm have metastable lower levels, are the brightest lines expected and exhibit P Cygni profiles whereas the H lines do not (as observed also in some WR stars).

## Fe

In addition to the isolated [Fe II] (1.257 µm) line, the excess strength of the 1.644 µm feature relative to the neighbouring hydrogen Brackett lines is consistent with the presence of [Fe II] (1.6435 µm) blended with H 12-4. Two lines in the visible, at 5530 Å and 7160 Å, can also be identified with [Fe II]. Their line intensity ratios are consistent with thermal populations ($n_e \geqslant 10^7$ cm$^{-3}$) at $T_e$ ~ 4,000 K in which case

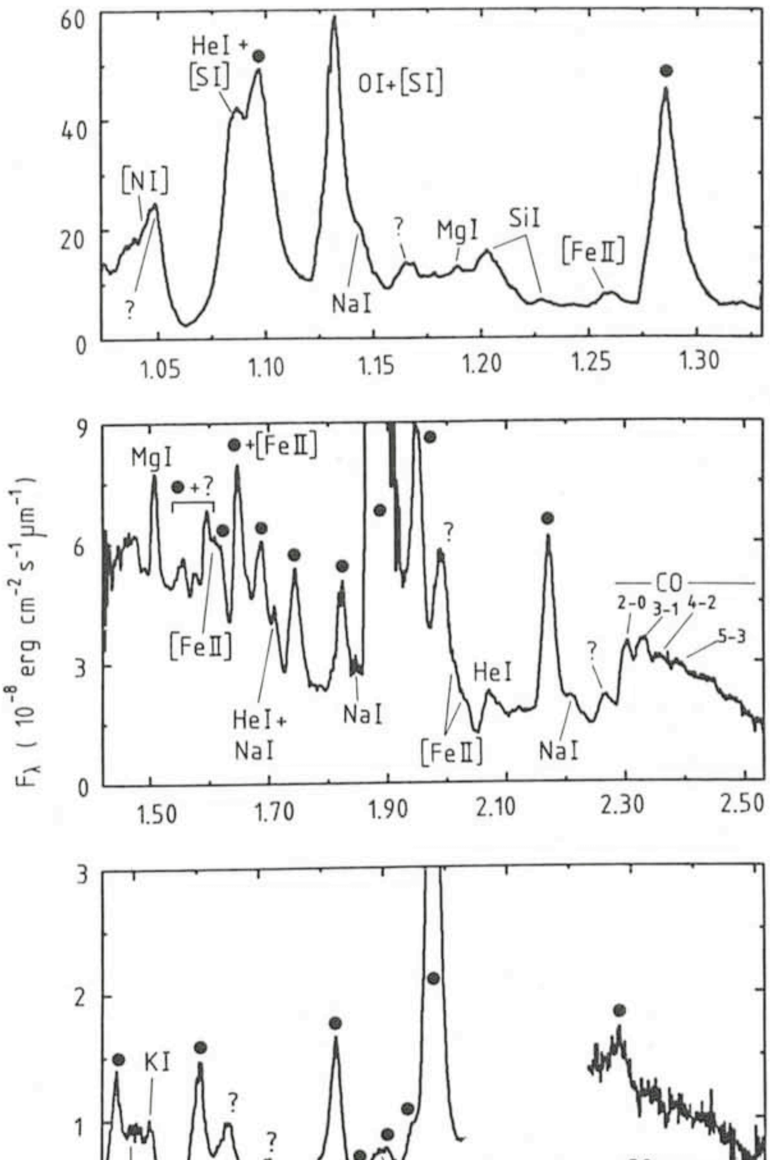



Figure 2: *As 1, but split into three ranges and expanded to show the fainter lines. Hydrogen lines (●) and other main features are identified.*

| $\lambda_{OBS}^{(1)}$ | $I^{(2)}$ | identification$^{(3)}$ | $\lambda_0^{(4)}$ | $\Delta v^{(5)}$ |
|---|---|---|---|---|
| 1.047 | ~20 | ? | | |
| | | [N I] $^2D^0 - {}^2P^0$ | 1.040 | |
| 1.086 | ~30 | He I $2s\,^3S - 2p\,^3P^0$ | 1.08294 | 800 |
| | | [S I] $^3P_2 - {}^1D_2$ | 1.08210 | |
| 1.096 | ~40 | H 6-3 | 1.09379 | 600 |
| | | ( [Si I] $^1D_2 - {}^1S_0$ ) | 1.09913 | |
| 1.132 | 53 | O I $3p\,^3P - 3d\,^3D^0$ | 1.1287 | 900 |
| | | [S I] $^3P_1 - {}^1D_2$ | 1.13058 | |
| 1.143 | | Na I $3p\,^2P^0 - 4s\,^2S$ | 1.139 | |
| 1.162 | ~3 | ? | | |
| 1.18 | ~5 | K I $4p\,^2P^0 - 3d\,^2D$ | 1.173 | |
| | | Mg I $3p\,^1P^0 - 4s\,^1S$ | 1.182818 | |
| | | Ca II $5s\,^2S - 5p\,^2P^0$ | 1.187 | |
| 1.202 | ~4 | Si I $4s\,^3P_1^0 - 4p\,^3D_2$ | 1.1984 | |
| | | Si I $4s\,^3P_0^0 - 4p\,^3D_1$ | 1.1991 | |
| | | Si I $4s\,^3P_2^0 - 4p\,^3D_3$ | 1.2032 | |
| 1.228 | 0.6 | Si I $4s\,^3P_1^0 - 4p\,^3D_1$ | 1.2104 | |
| | | Si I $4s\,^3P_2^0 - 4p\,^3D_2$ | 1.2227 | |
| 1.260 | 2.4 | [Fe II] $a\,^6D_{9/2} - a\,^4D_{7/2}$ | 1.25666 | 800 |
| | | ( K I $4p\,^2P^0 - 5s\,^2S$ ) | 1.248 | |
| 1.285 | 54 | H 5-3 | 1.28179 | 700 |
| 1.444 | 0.5 | [Fe I] $a\,^5D_4 - a\,^5F_5$ | 1.44294 | |
| 1.46 | ~2 | H n-4 (Bracket) limit | 1.45799 | |
| 1.488 | 0.1 | Mg I $3d\,^3D - 4f\,^3F^0$ | 1.487 | |
| 1.505 | 3.2 | Mg I $4s\,^3S - 4p\,^3P^0$ | 1.503 | 400 |
| | | ( [Fe I] $a\,^5D_2 - a\,^4F_4$ ) | 1.49820 | |
| 1.528 | 0.1 | H 19-4 | 1.52603 | |
| | | K I $3d\,^2D - 4f\,^2F^0$ | 1.5166 | |
| 1.55 | 1.4 | [Fe II] $a\,^4F_{9/2} - a\,^4D_{5/2}$ | 1.53345 | |
| | | H 18-4 | 1.53416 | |
| | | [Fe I] $a\,^5D_3 - a\,^5F_5$ | 1.53510 | |
| | | H 17-4 | 1.54387 | |
| | | H 16-4 | 1.55562 | |
| | | CO 3-0 band-head | 1.558 | |
| 1.573 | 0.5 | H 15-4 | 1.57004 | |
| | | Mg I $4p\,^3P^0 - 4d\,^3D$ | 1.575 | |
| | | CO 4-1 band-head | 1.578 | |
| 1.60 | 6.2 | H 14-4 | 1.58803 | |
| | | Mg I $3d\,^3D - 5p\,^3P^0$ | 1.5885 | |
| | | Si I $4s\,^1P^0 - 4p\,^1P$ | 1.58884 | |
| | | CO 5-3 band-head | 1.5990 | |
| | | [Fe II] $a\,^4F_{7/2} - a\,^4D_{3/2}$ | 1.59945 | |
| | | [Si I] $^3P_1 - {}^1D_2$ | 1.60679 | |
| | | H 13-4 | 1.61091 | |
| 1.644 | 6.5 | H 12-4 | 1.64070 | |
| | | [Fe II] $a\,^4F_{9/2} - a\,^4D_{7/2}$ | 1.64353 | |
| | | [Si I] $^3P_2 - {}^1D_2$ | 1.64453 | |
| 1.684 | 3.5 | H 11-4 | 1.68063 | 600 |
| 1.705 | 0.8 | He I $3\,^3P^0 - 4\,^3D$ | 1.70029 | |
| | | Na I $3d\,^2D - 5p\,^2P^0$ | 1.7031 | |
| | | Mg I $4s\,^1S - 4p\,^1P^0$ | 1.71087 | |
| 1.740 | 5.4 | H 10-4 | 1.73619 | 700 |
| 1.820 | 5.3 | H 9-4 | 1.81738 | 500 |
| 1.851 | 0.8 | Na I $3d\,^2D - 4f\,^2F^0$ | 1.847 | |
| 1.881 | 110. | H 4-3 | 1.87507 | 900 |
| 1.948 | 9.6 | H 8-4 | 1.94453 | 500 |
| | | ( Ca I $4p\,^3P_0^0 - 3d\,^3D_1$ ) | 1.93092 | |
| | | ( Ca I $4p\,^3P_1^0 - 3d\,^3D_2$ ) | 1.94530 | |
| | | ( Ca I $4p\,^3P_1^0 - 3d\,^3D_1$ ) | 1.95057 | |
| 1.989 | 6.0 | ? | | |
| | | ( Ca I $4p\,^3P_2^0 - 3d\,^3D_3$ ) | 1.97768 | |
| | | ( Ca I $4p\,^3P_2^0 - 3d\,^3D_2$ ) | 1.98622 | |
| | | ( [Fe I] $a\,^5F_5 - a\,^3F_4$ ) | 1.98045 | |
| 2.03 | | [Fe II] $a\,^4P_{1/2} - a\,^2P_{1/2}$ | 2.00667 | |
| | | [Fe II] $a\,^2G_{9/2} - a\,^2H_{9/2}$ | 2.01510 | |
| | | [Fe II] $a\,^4P_{5/2} - a\,^2P_{3/2}$ | 2.04598 | |
| 2.068 | 1 | He I $2s\,^1S - 2p\,^1P^0$ | 2.05810 | 1500 |
| 2.172 | 9.8 | H 7-4 | 2.16550 | 900 |
| 2.207 | 0.3 | Na I $4s\,^2D - 4p\,^2P^0$ | 2.207 | |
| 2.264 | 0.6 | ? | | |
| 2.303 | ~1 | CO 2-1 | 2.294* | 1100 |
| 2.330 | ~1 | CO 3-2 | 2.322* | 1000 |
| 2.36 | | CO 4-3 | 2.353* | 1000 |
| ~ 2.4 | 35* | CO first overtone band | | |
| 3.048 | 2.2 | H 10-5 | 3.03833 | 900 |
| 3.12 | 3.6 | ? | | |
| | | K I $3d\,^2D - 5p\,^2P^0$ | 3.149 | |
| 3.311 | 3.5 | H 9-5 | 3.29604 | 1400 |
| 3.402 | 2.1 | ? | | |
| | | ( Mg I $3d\,^1D - 4p\,^1P^0$ ) | 3.3963 | |
| 3.531 | 0.7 | ? | | |
| 3.659 | 0.2 | K I $5p\,^2P^0 - 6s\,^2S$ | 3.649 | |
| 3.747 | 4.5 | H 8-5 | 3.73948 | 600 |
| | | ( K I $5p\,^2P^0 - 4d\,^2D$ ) | 3.721 | |
| 3.827 | 0.1 | H 16-6 | 3.81836 | |
| 3.89 | 1.3 | ? | | |
| | | ( H 15-6 ) | 3.90643 | |
| 4.02 | | H 14-6 | 4.01971 | |
| | | K I $4f\,^2F^0 - 5g\,^2G$ | 4.01584 | |
| 4.064 | 25 | H 5-4 | 4.05109 | 1000 |
| 4.66 | ~2 | H 7-5 | 4.65244 | ~500 |
| ~4.7 | 50* | CO fundamental band | | |

TABLE 1. *Line identifications.*

Notes to table

(1) Observed wavelength in $\mu m$. The line center has been defined as the average of the 4 highest points. Center positions of broad features and lines in crowded regions are given with 2 significant digits.

(2) Observed line intensity, in units of $10^{-10}\ erg\,cm^{-2}s^{-1}$

(3) Identification. Transitions which are unlikely to give a substantial contribution to the observed feature are given within brackets.

(4) Rest wavelength of the identified transition. The number of significant digits is given according to the wavelength spread of the multiplet.

(5) Velocity shift in $km/s$ between the observed and the line rest wavelengths. Given only for bright and clearly identified lines. Positive values are for red shifts. Typical uncertainity is 200-300 $km/s$

coincident, within 15 km $s^{-1}$, with that of Lyβ and is connected to the ground state by a strong UV transition. A large fraction of the Lyβ photons can, therefore, be "transformed" into O I transitions (1.1287 μm + 8447 Å + 1304 Å) provided that the optical depth in Hα is large enough to inhibit the competitive process which transforms Lyβ photons into Hα + Lyα. It is not clear at present whether the observed line ratio Hα/Pβ can be accounted for by $\tau(H\alpha) \sim 500$, as required in the case of cosmic O I/H I abundance. Also, we cannot determine how much [S I] 1.1306 contributes to the observed 1.132 μm feature. We expect, however, that the O I line should vary more rapidly than the H lines due to its dependence on the optical depth of Hα and Lyβ. Future spectra should, hopefully, be able to confirm (or exclude) the O I identification and to determine the O I/H I abundance ratio.

Other lines have been identified on the basis of wavelength coincidence with atomic transitions between low lying states which may be collisionally populated at T ~ 5,000 K. Some of these identifications are further strengthened by the presence of several transitions (e.g. Na I, Mg I). In general, however, these identifications must be treated with caution at this stage.

### CO

The fundamental band of carbon monoxide at 4.6 μm appears to dominate the emission in the M window (4.5–5 μm) and its first overtone band the emission between 2.3 and 2.5 μm. As noted already, the CO emission is redshifted by the same amount as the atomic and ionic lines and is thus apparently associated with the SN ejecta rather than ambient material. Several of the individual $\Delta v = 2$ bands are resolved in the 2.3–2.4 μm region and their relative strengths lead to a crude temperature estimation of $T \simeq 2{,}000$ K and a CO mass of $\sim 4 \cdot 10^{-4} M_{\odot}$. Relative to the first overtone, however, the emission in the fundamental band is a factor ~ 3 too weak (the same as observed for Pfβ). This cannot be a calibration effect (because the flux levels in our spectrum are consistent with lower resolution CVF observations made slightly later by P. Bouchet) and therefore implies the importance of strong radiation transfer effects in the envelope. In this case the strength of the fundamental and first overtone bands can be expected to vary at different rates in the future.

### Summary

The infrared spectrum is dominated by emission lines from a gas of low ionization degree (including molecular CO) and, apparently, relatively normal abundances. Whereas the symmetry and widths of the lines are generally consistent with an envelope expanding at $\sim 1-2 \times 10^3$ km $s^{-1}$ however, the emission in virtually all lines appears to be dominated by gas receding along the line of sight at a few $\times 10^2$ km $s^{-1}$ relative to the systemic velocity of the LMC.

## IR Speckle Interferometry

Infrared (IR) speckle observations performed in early May and in June do not show the mystery spot – whose infrared detection has been erroneously mentioned in the summary of the ESO Workshop on SN 1987A. With the separation observed in visible light, the mystery spot must be, at 3.8 microns, at least 4 magnitudes fainter than the supernova to escape detection. But beginning from mid-June, our observations show a barely resolved structure appearing in this band and lying at the limit of detectability, thus either extremely small or extremely weak. Further observations carried out on August 6 confirm that the supernova is definitely resolved in IR. A weak oscillation shows up in all visibilities obtained from 2.2 to 4.6 microns. The actual structure causing this, accounting for 2.5 to 3 per cent of the total flux, cannot be unambiguously derived until now: the presence of one or several IR spots at 0.35 arcsecond, as measured on the N-S and E-W axis, is as plausible as that of a ring-like structure of 0.42 arcsecond diameter, although the latter seems physically more realistic. Whatever the correct model is, the projected velocity of about 0.4 c clearly points to a light echo.

A.A. Chalabaev, C. Perrier and J.-M. Mariotti (Observatoire de Lyon)

### Conference Report:

## Astronomy from Large Databases: Scientific Objectives and Methodological Approaches

The conference on Astronomy from Large Databases: Scientific Objectives and Methodological Approaches took place in Garching on 12–14 October 1987.

Approximately 150 attended. The projects and missions represented included, amongst others, HST, IUE, IRAS, ROSAT, EXOSAT, EUVE, and Hipparcos. In the three days of the conference, 74 presentations were discussed. These were organized in sessions on Astrophysics from Large Databases, Object Classification Problems, Statistics, Pattern Recognition and Expert Systems, and Databases – Current Trends.

Half of the presentations were in the latter category and hence a comprehensive view of work in progress in this area of astronomy can be gleaned from the papers. The diversity of approaches in this area (for example, the range of database systems in use, generally customized) points to the need for coordination. This conference provided a good start in this direction.

In other sessions, discussion took place on the applications of new technologies to stored astronomical data. Some of the papers on expert systems and statistics will provide useful reference material – not easily available elsewhere – when considering the application of methods in these fields.

The proceedings will be published by the European Southern Observatory and are expected to be available around the end of January 1988.

F. Murtagh (ST-ECF, ESO), affiliated to the Astrophysics Division, Space Science Dept., European Space Agency.


## "ESO Frontpages"

Pictures of Supernova 1987A were made available to the media in early March 1987, as soon as they arrived from La Silla. A colour photo of the supernova and the Tarantula Nebula, obtained with the ESO Schmidt telescope by H.-E. Schuster and Guido and Oscar Pizarro and prepared by C. Madsen was repeatedly requested and appeared in a large number of journals and newspapers. The ESO photos also "made it" to quite a few frontpages; here is a selection from various countries.

# List of ESO Preprints

### (September – November 1987)

529. D. Baade: (A) Doppler Imaging of Variable Early-Type Stars; (B) Nonradial Pulsations and the Be Phenomenon. Two invited talks presented at IAU Colloquium 132 "The Impact of Very High S/N Spectroscopy on Stellar Physics", Paris-Meudon, 29 June – 3 July 1987. September 1987.
530. G. Meylan: Internal Dynamics of Globular Clusters: From Our Galaxy to the Magellanic Clouds. Invited talk presented at the ESO Workshop on "Stellar Evolution and Dynamics in the Outer Halo of the Galaxy, Garching, 7–9 April 1987. September 1987.
531. R.A.E. Fosbury: Active Extragalactic Objects. Invited review talk at the Tenth European Regional Meeting of the IAU, Prague, 24–29 August 1987. September 1987.
532. M.H. Ulrich: Far Ultraviolet Absorption Lines in Active Galaxies. *Monthly Notices of the Royal Astronomical Society.* September 1987.
533. M.H. Ulrich: Galactic Nuclei and Quasars at High Angular Resolution. Invited paper prepared for the ESA Workshop on "Optical Interferometry in Space", Granada, Spain, 16–18 June 1987. September 1987.
534. P.A. Shaver: Quasar Clustering and the Evolution of Structure. Paper presented at IAU Symposium 130, June 1987, "Evolution of Large Scale Structures in the Universe". September 1987.
535. P.A. Shaver: Opacity of the Universe. Paper presented at the 3rd IAP Astrophysics Meeting, "High Redshift and Primeval Galaxies" (Paris, June 1987). September 1987.
536. E.J.A. Meurs et al.: (A) Observational Consequences of Precessing Relativistic Jets in Extragalactic Radio Sources; (B) [O III]-Line Emission Associated with Radio Structures in Seyfert Galaxies. Contributions presented at the 10th European Regional Astronomy Meeting of the IAU, 24–29 August 1987, Prague. September 1987.
537. E. Giraud: I. The Price of Keeping the Hubble Constant ... Constant (presented at the Symposium "New Ideas in Astronomy" celebrating the 60th birthday of Halton Arp, 5–8 May 1987, Venice, Italy); II. Dark Matter Around the Local Group?; III. Observed Distortions (from Linearity) of the Hubble Flow and Bias in the Data (contributions presented at the IAU Symposium No. 130 "Evolution of Large Scale Structures in the Universe", 15–20 June, 1987, Balatonfured, Hungary). October 1987.
538. E. Palazzi, N. Mandolesi and P. Crane: Interstellar CH Towards zeta Ophiuchi. *Astrophysical Journal.* October 1987.
539. J. Melnick, R. Terlevich and M. Moles: Giant H II Regions as Distance Indicators II. Application to H II Galaxies and the Value of the Hubble Constant. October 1987.
540. M. Heydari-Malayeri: Ionized Gas Properties of the Peculiar Southern H II Region RCW 34. *Astronomy and Astrophysics.* October 1987.
541. D. Baade and P. Magain: Very Low Upper Limits on the Strength of Interstellar Lithium Lines Towards SN 1987A. *Astronomy and Astrophysics.* October 1987.
542. M. Spite et al.: High Resolution Observations of Stars in the Peculiar Globular Cluster ω Cen. *Astronomy and Astrophysics Suppl.* November 1987.
543. P. François, M. Spite and F. Spite: High Resolution Study of Different Groups of Stars in the Peculiar Globular Cluster ω Cen. *Astronomy and Astrophysics.* November 1987.
544. J. Surdej et al.: Observations of the New Gravitational Lens System UM 673 = Q 0142-100. *Astronomy and Astrophysics.* November 1987.
545. P.A. Shaver: Quasar Clustering and Gravitational Lenses. Paper presented at the NATO ASI "The Post-Recombination Universe", Cambridge, July 1987. November 1987.
546. P. Magain: The Chemical Composition of the Extreme Halo Stars. I. Blue Spectra of 20 Dwarfs. *Astronomy and Astrophysics.* November 1987.
547. E.J.A. Meurs: Precessing Radio Jets in AGNs. Invited talk at the COSPAR/IAU

Symposium "The Physics of Compact Objects: Theory versus Observation", Sofia, Bulgaria, July 1987. November 1987.

548. B. Reipurth: Pre-Main Sequence Binaries. Review presented at the NATO ASI meeting "Formation and Evolution of Low Mass Stars", 21 Sept. – 2 Oct. 1987, Viano do Castelo, Portugal. November 1987.

549. E. Oliva and A. F. M. Moorwood: Detection of New, High Excitation, Emission Lines of $H_2$ in the 2.0–2.4 μm Spectrum of the Orion Nebula. *Astronomy and Astrophysics*. November 1987.

**NOTE TO OUR READERS**

When requesting ESO preprints, please do not forget to indicate the corresponding ESO preprint number. This will greatly facilitate our work. Thank you.

# A Timely Reminder

There has recently been much concern among astronomers about two proposed, commercial space projects. A "Ring of Light" would celebrate the 100th anniversary of the Eiffel Tower, and the Celestis capsule is supposed to carry the cremated remains of humans into space. The International Astronomical Union (IAU) has reacted strongly through its Commission 50 which deals with the safeguard of the best possible observing conditions. Whereas it now appears that the "Ring" will not materialize, less is known about the status of the Celestis project. In any case, there has been a renewed interest in "pollution" of the skies and the astronomers who work with the ESO Schmidt telescope were recently asked by the President of IAU Commission 50 to comment on the number of satellite trails they see on ESO Schmidt plates.

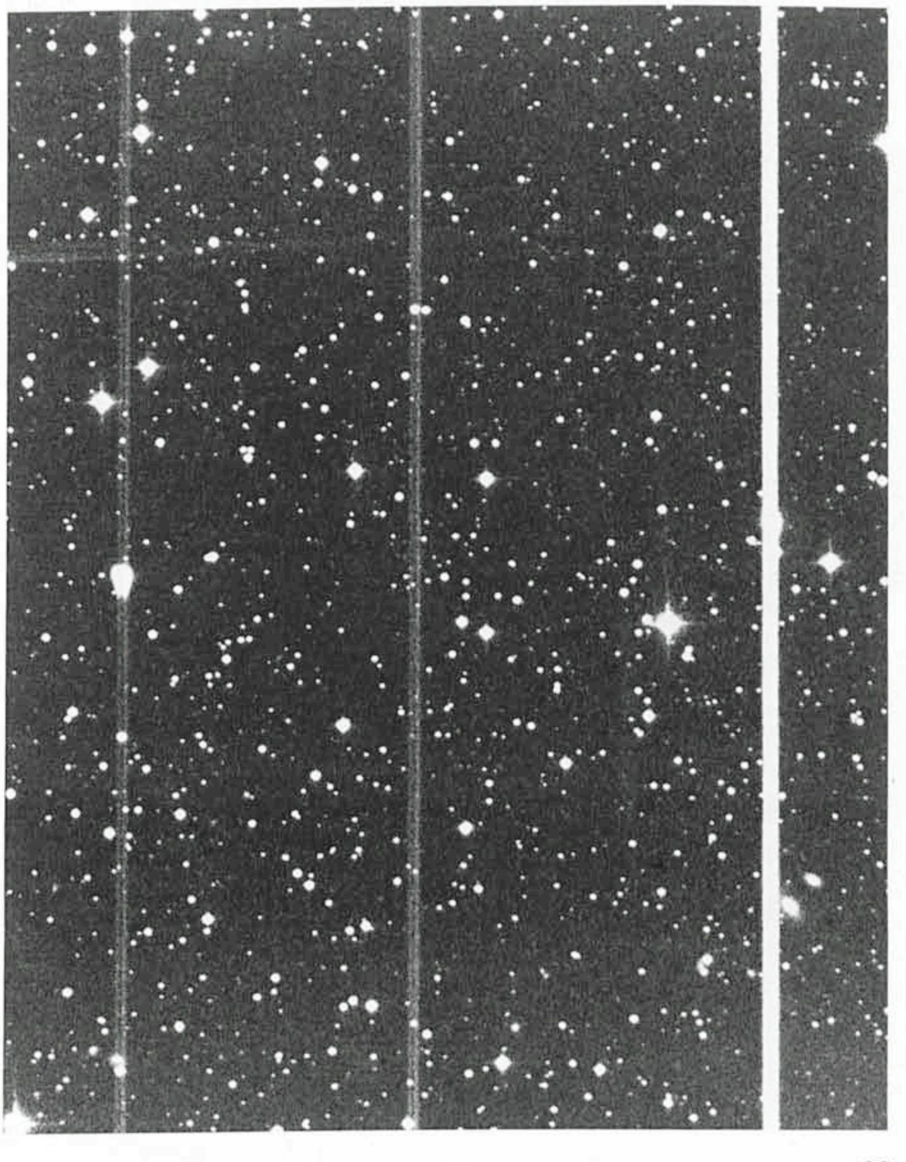
When the counting of satellite trails was nearly finished (Result: there is hardly any long-exposure plate without at least one trail, but since they are thin, they normally do not interfere with the measurements), the triple trail reproduced here was registered on a 2-hour Schmidt plate, exposed for the ESO(R) half of the joint ESO/SERC Atlas of the Southern Sky, now nearing completion. Nothing like it had ever been seen before on any plates obtained at La Silla. In particular, the multiple appearance was puzzling – each trail was double – which three (or six!) satellites were moving in such a perfect procession?

Thanks to the experience of ESO photographer Hans H. Heyer, who also experiments with astrophotography in his spare time and who lives near the Munich airport, the "mystery" was quickly solved. The triple trail was registered sometime between 19 : 47 and 21 : 47 (Chilean time) in the evening of Thursday, August 20, 1987, about 40° above the horizon, directly towards south. That evening, at about 19 : 10, flight PL 696 took off from the Santiago international airport and followed a northernly course towards Lima, Peru. The DC-8 jet with a wing-span of 43 metres flew through the Schmidt field-of-view less than an hour later.

Supposing that the speed was about 900 km/h and also that the plane passed almost directly over La Silla, the angular distances between the trails of the navigational lights on the wing tips and below the body indicate that the distance from the ESO telescope was about 13 km; this corresponds to a flight altitude of 11 km. The lights are double for safety reasons and the red lights on the left wing show up more strongly on the red-sensitive plate than the green lights on the right wing. In addition, the strobe lights, which are seen as bright spots at intervals of 0°.8 along the wing light trails, flash each 1.1 seconds during 8 milliseconds. The angular distance between the double lights is 7 arcseconds (projected distance 40 cm), illustrating in an unusual way the resolving power of astronomical instruments.

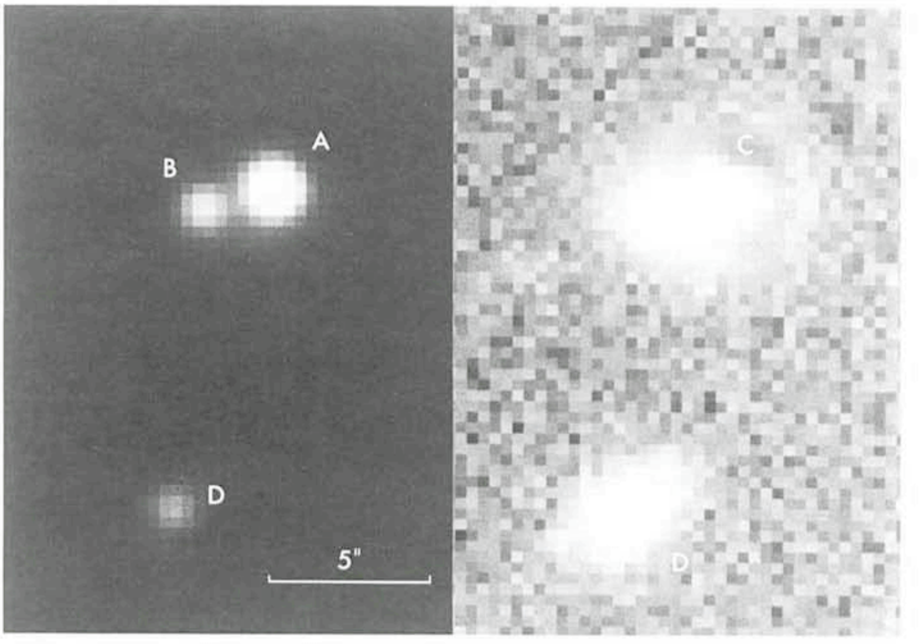
The loss of a plate for the Sky Survey due to a high flying aircraft is a pity, but not a disaster. However, the fact that this event is the first of its kind recorded at La Silla is a timely reminder. It underlines the nearly perfect "remoteness" of the ESO site, but it also demonstrates the need to preserve these optimal conditions by continued vigilance against all intrusions in space or closer to the ground.

*R. M. W.*



# Discovery of a New Gravitational Lens System

From detailed observations of several of the most luminous quasars, it has been found that the QSO UM 673 (z = 2.72) is a gravitational lens system (Surdej, J., Magain, P., Swings, J.-P., Borgeest, U., Courvoisier, T.J.-L., Kayser, R., Kellermann, K.I., Kuehr, H., and Refsdal, S., 1987, *Nature* **329,** 695; Surdej, J., Magain, P., Swings, J.-P., Borgeest, U., Courvoisier, T.J.-L., Kayser, R., Kellermann, K.I., Kuehr, H., and Refsdal, S., 1987, submitted to *Astronomy and Astrophysics*). This observational programme is designed to estimate how many of the highly luminous quasars are so luminous because of amplification effects by gravitational lensing. It is mostly conducted at ESO by the team who wrote the quoted papers.




Spectral and imaging observations of UM 673 were obtained at ESO in late 1986. They showed that both images have nearly the same spectra, and that the difference can be explained if the observed light from the fainter object is contaminated by an intervening galaxy at redshift z = 0.49. This finding considerably strengthens the identification of the double image of UM 673 as a new case of a gravitational lens system. The intervening galaxy can also be seen directly, when the two images of the QSO are removed by computer processing.

The left half of the figure shows the central part of an EFOSC CCD frame, exposed 2 min through a Bessel R filter. The two QSO images are marked A (mag. 17) and B (mag. 19); the separation is only 2.2 arcsec. The right half shows the same frame after the two point-like images have been removed and the intensity interval near the sky has been significantly stretched. The intervening 19th magnitude lensing galaxy is clearly visible as extended residual emission (C). The object D is another galaxy, possibly in the same cluster.

Modelling of the geometrical properties of the lens system allows to compute the mass of the galaxy ($\sim 2.4 \cdot 10^{11}$ solar masses), as well as the most probable time difference along the two light paths, $\sim$ 7 weeks (with $H_0$ = 75 km/s/Mpc and $q_0$ = 0). This time difference is short enough to be measured in one observing season, provided the QSO is cooperative and varies intrinsically on a sufficiently short time scale. Such measurements are particularly important, since they may give independent information about the absolute size of the system and therefore also about the Hubble parameter. A corresponding, observational campaign has already been started at ESO.

*T.J.-L. Courvoisier* (ST-ECF, affiliated to the Astrophysics Division, Space Science Department, European Space Agency)

# Deep LMC Images

One of the most observed objects in the southern sky is the Large Magellanic Cloud. It is easily seen as a naked-eye object near the southern celestial pole together with its less conspicuous neighbour, the Small Magellanic Cloud. Looking at the LMC, the casual observer discerns the elongated bar and the bright 30 Doradus nebula and, since February this year, the famous Supernova 1987 A.

We show here two unusual views of the LMC, obtained with special equipment at the ESO La Silla observatory, in the course of other observing programmes.

Figure 1 is a reproduction of two CCD frames, exposed at UT 08 : 06 to 08 : 39 on February 17, 1986, with the ESO Wide-Field CCD camera, while preparing to observe Comet Halley. The camera consisted of a Canon f : 2.8/100 mm objective at full aperture, with a RCA CCD 503 (high resolution, 640 × 1,024 pixels) behind a BG 39 filter. This corresponds to a very broad wavelength band, extending from the near UV to the CCD cut-off in the near IR. The exposure time was 15 minutes for each frame.

The pixel size is 31 arcseconds, corresponding to a field size of about $5^{\circ}\!.5 \times 9^{\circ}$. After cleaning with MIDAS software on La Silla, the full frames were recorded on 70 mm film at the ESO-Garching Dicomed facility and photographical copies were assembled to give the composite image in Figure 1. No flat-fielding was made, due to lack of adequate exposures, and the frames were not corrected for geometric distortion or vignetting. For these reasons, the two frames do not join perfectly.

The composite field size is $8^{\circ}\!.6 \times 9^{\circ}\!.6$ and north is up and east to the left. The two bright stars above the left centre are $\delta$ Dor (upper) and $\varepsilon$ Dor (lower), while the two in the lower right part are $\beta$ Dor (left) and $\mu$ Dor (right).

During the exposure, the minimum counts near the corners of the frames reached 1,500, still above the normal sky background. This indicates that the LMC halo extends beyond the field of

Figure 1.

the composite frame. In this reproduction, the intensity cuts were chosen to show the structure in the area north of the bar.

Figure 2 is a photographic print which has been subjected to diffuse light amplification. In order to show the LMC bar on the same photo, a high contrast positive copy film was sandwiched with a normal contrast negative and printed onto high contrast photographic paper. This photo was originally recorded on Kodak 153-01 emulsion (the on-glass version of TP-2415) with a Hasselblad SWC camera, equipped with a Carl Zeiss Biogon 1 : 4.5/38 mm objective. The plate, which measured 6 × 6 cm, was hypersensitized in 4 % forming gas at 65°C during 11 hours. The camera was attached to the ESO GPO double astrograph; the exposure lasted 90 minutes on March 27, 1985.

The original plate shows serious vignetting over the very large field (more

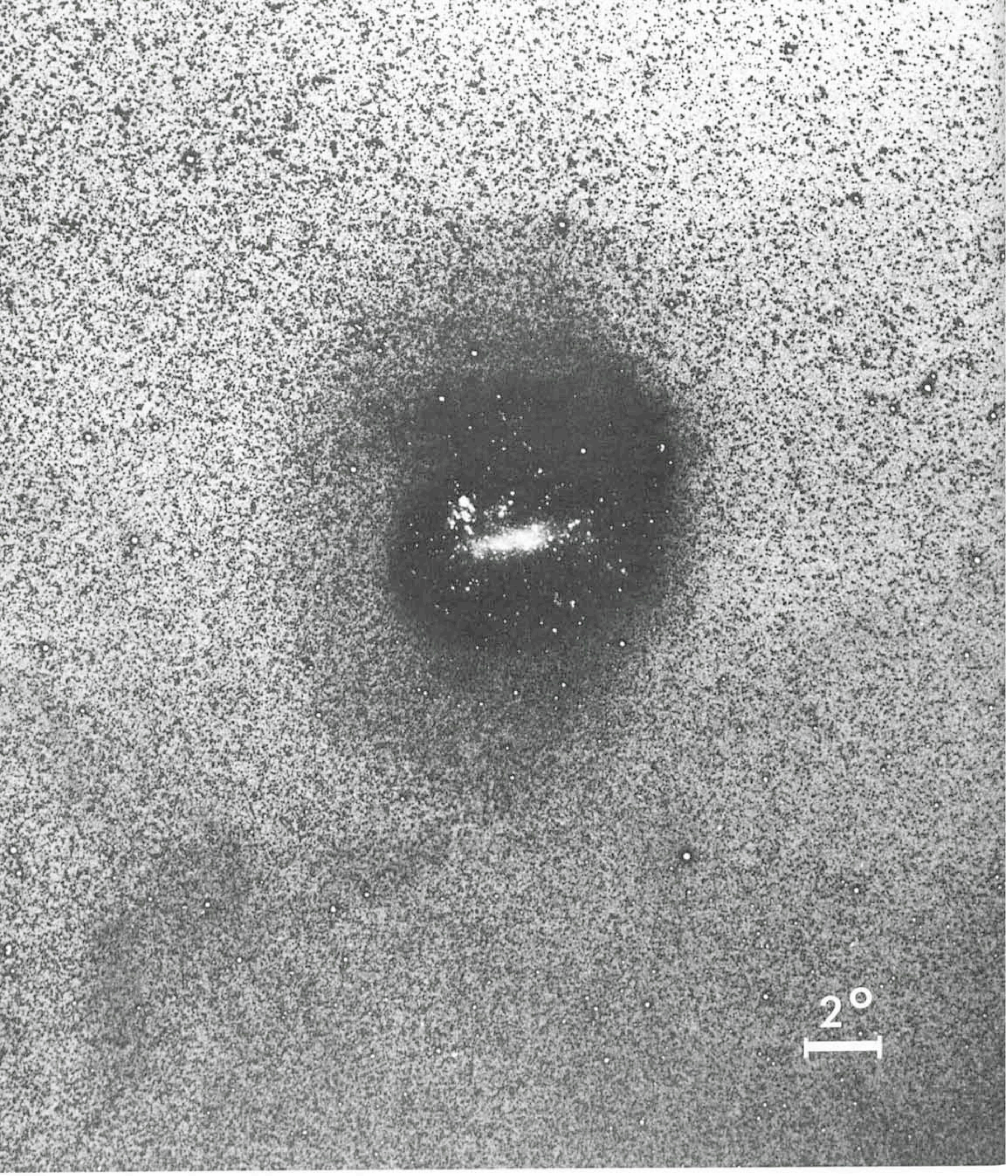



Figure 2.

than 70° × 70°), but part of this effect could be removed by masking. Moreover, the LMC and SMC were not very high in the sky at the time of the exposure; the plate includes part of the horizon. Normal reproductions of this picture have appeared in the ESO Annual Report 1984 (page 4) and also in the recently published ESO book "Exploring the Southern Sky" (see the *Messenger* **49,** 42). Note that Figure 2 is rotated ~ 20° towards East, as compared to Figure 1. The bright star (with white centre) between the LMC and the scale bar is $\gamma$ Hyi; the one of similar brightness in the upper left quadrant is $\alpha$ Pic.

The very deep print reaches a surface brightness around $26^{m}$(R) per square arcsecond and has a resolution slightly better than 1 arcmin. The LMC halo is well visible and measures about 15° (N-S) by 11° (E-W), corresponding to about 15 × 11 kpc. The overall structure shown here has been known for some time from the work of G. de Vaucouleurs (for a review, see de Vaucouleurs and Freeman, *Vistas in Astronomy,* **14,** 163, 1972). The outer "shells" are particularly well delineated north of the LMC; 4, perhaps 5 rather sharp borders are seen of which the outermost is just beyond the bright star β Dor (some astronomers think these are "spiral" features). Most of the halo light in this photograph is thought to come from a population of faint stars of intermediate age.

Note also how the giant H II region 30 Doradus, seen as the bright spot NE of the bar, on this picture is much closer to the geometric centre of the LMC than in less deep images. Whether or not it is indeed the "nucleus" of the LMC has been a matter of some debate (cf. Feitzinger, *Space Sci. Rev.* **27,** 35, 1980).

The straight shadow, which crosses the field south of the LMC, belongs to the Milky Way and is believed to be a "cirrus" cloud in the galactic halo. High-resolution Schmidt pictures of the SE part of this feature are shown in an article by Johnson and co-authors (*MNRAS,* **198,** 985, 1982).

Both of the prints shown here demonstrate the power of wide-field imaging to very-low surface brightness levels. Whereas the photographic image (Figure 2) has a wider field and can therefore show larger structures more easily, the CCD reaches fainter light levels, has a better resolution and can be well calibrated.

Wide-field imaging has also a potential for discovery of variable stars and moving objects, such as meteors or comets. The comparison CCD images taken at different epochs can be done by computer or by visual inspection.

*R. M. West, H. Pedersen and C. Madsen (ESO)*

## The 3rd ESO/CERN Symposium on Cosmology, Astronomy and Fundamental Physics

**will be held at the Palazzo Re Enzo, Bologna (Italy) from 16 to 20 May 1988**

The preliminary programme includes the following topics and invited speakers:

**Topics**

First results from new colliders – Ultrarelativistic nuclear collisions – Standard model of fundamental interactions – Supernova 1987A: observations and interpretations – Dark matter: evidence, candidates and detection – Large scale structure of the universe – Microwave background radiation – High redshift objects – Dynamical parameters of the universe – Underground laboratories – Perspectives for high energy physics – Beyond the standard model.

**Invited Speakers**

A. Dressler (MWLCO, Pasadena), M. Geller (CfA, Cambridge, MA), W. Hillebrandt (MPPA, Munich), M. Koshiba (CERN, Geneva), R.G. Kron (Yerkes Observ., Univ. of Chicago), L.M. Lederman (Fermilab, USA), D. Lynden-Bell (Univ. of Cambridge, UK), S. Ozaki* (KEK, Japan), F. Pacini (Univ. of Florence), R.B. Partridge (Haverford College, USA), R.D. Peccei (DESY, Hamburg), C. Rubbia (CERN, Geneva), M. Satz (Bielefeld University, FRG), Y. Tanaka* (ISAS, Tokio), M.S. Turner (Univ. of Chicago/Fermilab), N. Vittorio (Univ. of Rome "La Sapienza"), L. Woltjer (ESO), Ya.B. Zeldovich* (USSR Academy of Sciences, Moscow).

* Participation to be confirmed.

The aim of the symposium is to establish the status of our knowledge on the subject and to provide a forum for discussions among people from different disciplines. To this end about equal time will be dedicated to the formal lectures and to the general discussions on each topic. It is also foreseen to hold a poster session. The audience will be mainly composed of about equal numbers of astrophysicists and particle physicists and will be limited to approximately 250 participants.

The participation in the symposium is by invitation only. People who are definitely interested in participating in the symposium should write to the Scientific Secretariat at the address below prior to 31st January 1988:

Scientific Secretariat
3rd ESO/CERN Symposium
Istituto di Fisica "A. Righi"
Via Irnerio, 46
I-40126 Bologna, Italy

Tel. 051/244490 – Telex 520634 – Telefax 247244

# The ESO Exhibition

An ESO Exhibition was open to the public from October 10 to November 11, 1987, at Palais de la Découverte in Paris, France. The next stop will be in the capital of Austria where it opens on December 17, 1987 at the Vienna Planetarium. Negotiations are under way about some possible future exhibition sites, most in the ESO member countries.

With the addition of more panels that describe the newest research results at ESO, the Exhibition has grown during the past year and it has become necessary to put the letting of ESO material to exhibition organizers into system. For this reason, ESO has prepared a pamphlet "The ESO Exhibition – Instructions to Organizers" which gives useful information and serves as a basis for discussion about the details of individual exhibitions.

Potential organizers should contact the ESO Information Service, at least six months before the proposed opening date.

# STAFF MOVEMENTS

## Arrivals

**Europe:**

BÜTTINGHAUS, Ralf (D), Technician in Fine Mechanics/Instrument Maker
GOSSET, Eric (B), Fellow
SRINIVASAN, Ganesan (IND), Associate

**Chile:**

REMY, Marc (B), Associate

## Departures

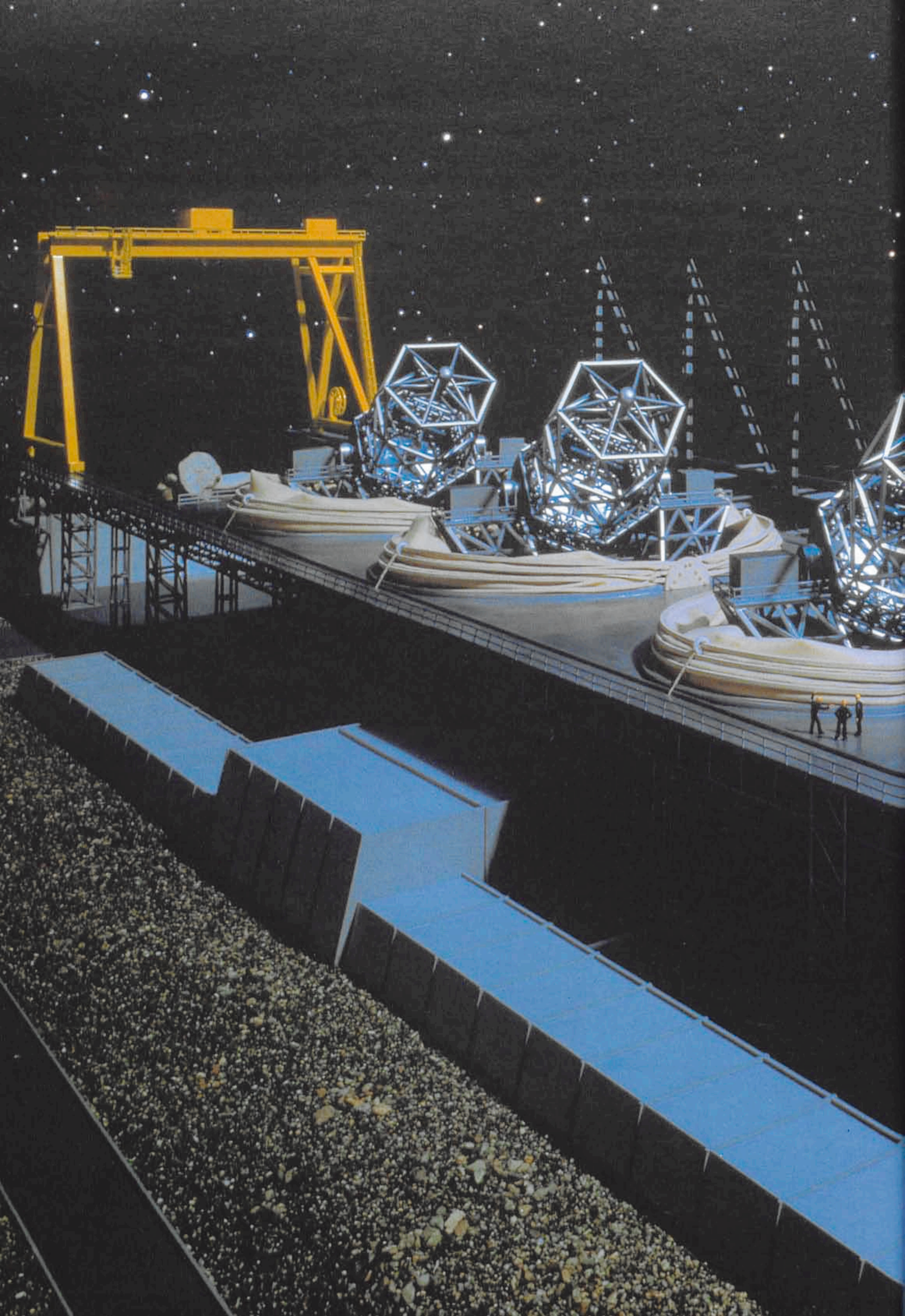
**Europe:**

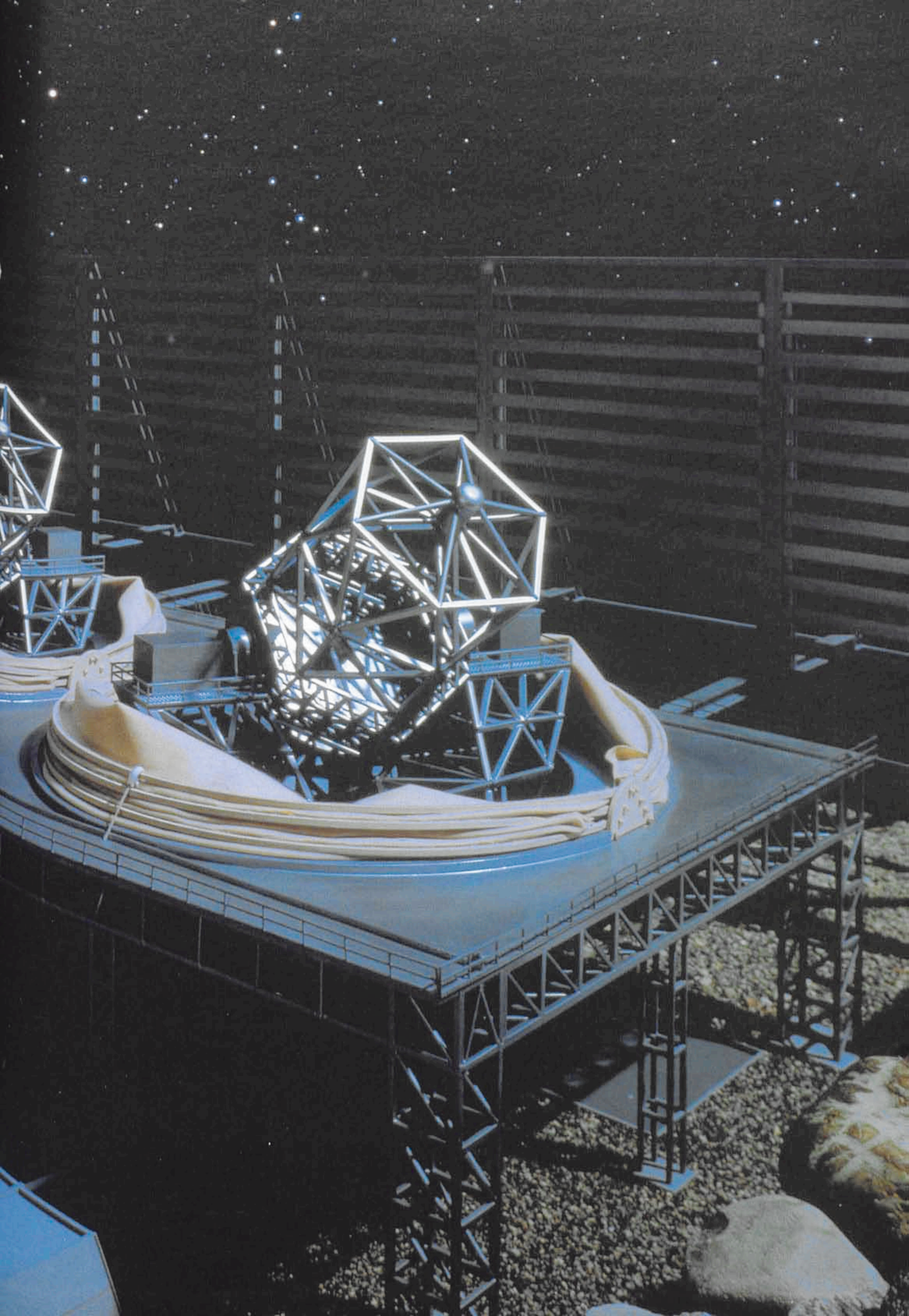
JAUCH, Christa (D), Draughtswoman (Graphics)

**Chile:**

MONDEREN, Peter (B), Student

*Model of the ESO VLT* ▶





# The VLT – Genesis of a Project

*D. ENARD, ESO*

Maybe it is not reasonable to write the history of a project before it even gets started. On the other hand, it is the common lot of the definition and pre-definition phases of projects to be rapidly forgotten. First of all, this is unfair to the people who have played a decisive role for the project to exist at all. Secondly, the choices made during this "pre-history" tend to survive the reasons which justified them at a certain moment. Tracing back the origin of the main trade-offs can later on prove to be quite useful. This is why a project such as the VLT should be well documented. It is the reason for this paper to be written now, before this part of the VLT history is completely forgotten.

Looking back to the genesis of any large project, one is amazed by the incredible long time ideas need to mature before they materialize into realistic proposals. This maturation time is usually comparable to, if not longer than the project duration. Telescopes and their instruments are no exception. Nor is the VLT: the very first discussions on an ESO 16-m VLT started more than 10 years ago!

The idea that giant telescopes would be needed did not originate only at ESO. Several astronomical organizations, after drawing the lessons from the 4-m class telescopes of the "Palomar generation" built in the 60's and 70's, saw clearly the need for a new generation of larger and more powerful telescopes. A first conference was held at ESO in 1977 (Optical Telescopes of the Future). At that time the ESO 3.6-m telescope was completed, the MMT was well on its way and J. Nelson presented the first description of the 10-m University of California telescope (now the Keck telescope). Interestingly enough, J. Nelson's paper was classified in the proceedings in the "conventional large telescopes" section! This gives an idea about the enthusiastic and somewhat surrealistic atmosphere of the time.

As a result of this conference, a study group chaired by Wolfgang Richter was created at ESO and a very preliminary analysis of three fundamental solutions carried out in 1978/79, a single 16-m telescope, four 8-m telescopes and sixteen 4-m telescopes. Though no real agreement as to which solution was preferable could be reached, at the end of this study some persons preferred a 16-m segmented telescope, but no real solution was proposed for manufacturing and controlling the segments. The main reason advanced for this preference was the expected lower cost of a single telescope compared to an array.

At the same epoch, an extensive study of all possible concepts applicable to a 25-m telescope was being conducted at Kitt Peak, and Soviet astronomers had also some plans for a monster 25-m telescope.

At the beginning of 1980, just at the time when concrete work could have started, ESO was shaken by its removal from Geneva to Garching. During this year ESO lost most of its technical staff and it became necessary to concentrate the efforts on current projects: essentially the CAT/CES, the CASPEC, the 3.6-m prime focus camera, I.R. photometer, etc. . . . New staff members were being hired, and the technical division was being reorganized at the very moment when 2 new projects were softly landing in. The 2.2-m telescope, which was offered in loan to ESO by the Max-Planck Society, but which nevertheless needed a building as well as an upgrading of its electronics, and a 3.5-m telescope which became necessary after Italy and Switzerland decided to join the organization. The ESO scientific community was becoming larger, and new observing facilities were necessary. Funds were available from the entrance fees of those 2 countries. Only the staff was missing.

The project started off effectively in 1981 under the leadership of Ray Wilson (and of Massimo Tarenghi from 1984). It took the name of New Technology Telescope (NTT).

The NTT concept laid down by Ray Wilson included two major new ideas: a thin metallic mirror substrate and an active support, which would correct for the thermal and gravity deformations as well as for some manufacturing errors. Because of scheduling problems, the metal option was abandoned but the active correction of a thin meniscus remains the fascinating part of this project.

A new VLT study group was set up in January 1981. It was chaired by R. Wilson and after April 1981 by Jean-Pierre Swings. The Cargèse workshop in May 1983 marked the end of this 2nd study phase.

This group consisted of a dozen of persons mainly from ESO. The fundamental question was again: which concept to select? To the 3 basic concepts investigated earlier in Geneva, the MMT was added as a potential candidate. The discussions concentrated on the relative scientific performance of the concepts. Because of lack of manpower there was little engineering input.

Though one can imagine a discussion on basic telescope concepts becoming rapidly emotional and inconclusive, J.-P. Swings managed to get the group to agree to a preferred solution: a limited array of four 8-m telescopes. This conclusion was reached already mid-1982. This was indeed the concept that L. Woltjer and R. Wilson had in mind when it was decided to conceive the NTT as a prototype for the active optics technology to be used later in the VLT.

From mid-1982 till May 1983, the study group concentrated its efforts on the scientific advantages one could draw from the limited array concept and particularly on interferometry. P. Léna, F. Roddier and O. Citterio advised the group on this matter.

At the end of 1983 there were mixed feelings. In the visible the prospects for interferometry appeared poor whereas in the I.R. the situation looked definitely more favourable. Everything was hanging on the possibility or not of correcting the atmospheric turbulence with adaptive optics which, at that time, did not appear as promising as it does now. Interferometry was therefore not considered as a driver, but as a potential advantage of the limited array concept. The hope that interferometry could be a definitive concept discriminator seemed to have vanished. It was then clear that the discussion could not be carried on further without some extensive engineering analysis which indeed required a financial commitment and an official decision. The first step was to take the community pulse. It was therefore decided to organize a workshop at Cargèse in May 1983.

Nearly 50 European scientists gathered together in this lovely Corsican village to discuss the opportunity for the European community to build a very large telescope.

As Prof. Woltjer pointed out in his concluding remarks:

"It was not the function of the Cargèse workshop to come to definitive conclusions about the VLT, rather it was a meeting where a number of scientists from the ESO countries could review the present situation and see what needed to be done next. The workshop showed full unanimity about the need for a VLT for the dual purpose of collecting more light and of providing better angular resolution, at least in the I.R. and in speckle modes."

The direct outcome of the workshop was twofold:

(a) There was a clear trend that some form of limited array was the right direction for the VLT.

(b) The Scientific and Technical Committee which met after the workshop recommended that a dedicated project group be set up.

At its meeting of June 1983 the ESO Council endorsed this recommendation and mandated the Director General to set up such a group. Soon after Prof. Woltjer asked the author of this account to lead this VLT project group.

Thus, at the end of 1983 a project group existed, though it barely consisted of even one single person for some time. The NTT and instrumentation projects were by no means overstaffed and it was not possible to divert any manpower from within ESO. In fact, a few new positions had been made available, but it was not before the summer of 1984 that the first engineers did effectively arrive.

It was also necessary to ensure that the community be able to express its wishes and that scientific advice be provided to the project group. An advisory structure was set up, consisting of an advisory committee and of specialized working groups (imaging and low resolution spectroscopy, high resolution spectroscopy, I.R., interferometry and site selection). The findings of the W.G. were to be automatically relayed to the VLT advisory committee, composed of the W.G. chairmen and of a few scientists from ESO. The advisory committee was chaired by J.-P. Swings. This structure in which participated more than 40 scientists from the ESO community functioned efficiently till the Venice workshop and should probably continue to play an important role during the execution of the project.

In October 1983 the main question was: "what to begin with"! It could have seemed logical to study in detail a number of concepts in parallel and then establish some trade-offs and ask the community to select the preferred solution. This would have taken many years, would have dispersed the efforts, led to endless and inconclusive discussions and split the community into self-destructive lobbies. Time was pressing and for Europe to have a chance to get a VLT before the end of the century, a great deal of pragmatism was necessary. The VLT concept had to be definitely selected in the months to come for the engineering studies to be fully effective.

After the Cargèse workshop, there were indeed feelings that a limited array would be the best solution. However, to the extent that no engineering studies had been made, it was necessary first to be fully convinced that this solution would be competitive with other alternatives.

An array of small telescopes would not fulfill the I.R. requirements and, used as independent telescopes, would not provide any gain over existing telescopes. This solution, which was also clearly not optimal from the cost point of view, could therefore be safely eliminated.

The segmented mirror approach had considerable attraction. Neither ESO nor European industry had done any work on this technology. Conversely, ESO had a substantial lead in the active correction of monolithic mirrors. Since the segmented mirror appeared somewhat risky, it was decided out of pragmatism to consider exclusively a solution based on large monolithic mirrors. There were two possibilities: the MMT and the limited array.

To discriminate between an MMT and an array was not easy. Both solutions are very similar to the extent that an MMT can be viewed as an array of telescopes on a common mount. The decisive argument was the versatility of the array which was seen as an advantage not only from the scientific point of view, but also for the practical realization of the project: adapting the project to the available flow of resources and offering the community the possibility to use a part of the collecting area at an early stage.

Indeed, the array concept presented a number of problems which had to be matched by adequate solutions. There were three of them: the feasibility of the primary mirror, an efficient way to recombine the beams and a building concept combining a low cost, a minimal degradation of seeing, the best use of the sites topography, and an optimal arrangement for interferometry. A few months of reflexion and discussions with optical firms were sufficient to realize that solutions would be found and also that a mirror diameter of 8 metres was a good compromise between the scientific requirements, especially for the I.R., and the risks during manufacture and handling of the primary mirrors.

A preliminary concept, called the linear array, was presented to the Advisory Committee. After a few meetings it was decided to adopt it as the ESO base line concept. The first public presentation was on the occasion of the IAU Colloquium on large telescopes in April 1984 (No. 79).

By mid-1984, the project group had 4 people, the scientific working groups were operational and the real work began.

Quite a number of contracts mainly on feasibility studies were given to industry and institutes. A number of studies were also conducted by ESO directly. To the maximum extent possible, competitive studies were done in parallel. The result was an incredible amount of information, and a substantial number of new ideas. Parallel studies were found to be highly productive and very helpful to reliably assess the validity and costs of various solutions. The elements of the puzzle were then critically analysed and a coherent and detailed proposal could be presented in October 1986 at the

## The Pre-VLT Milestones

| | |
|---|---|
| 1976 | Completion of the ESO 3.6-m telescope. |
| December 1977 | ESO Conference on the large telescopes of the future. |
| 1978/1979 | First ESO study group on a 16-m telescope (Geneva). |
| 1981/1982 | Second ESO study group on a 16-m telescope (Garching). |
| April 1983 | Cargèse workshop. |
| June 1983 | Decision to create a project group. |
| September 1983 | Permanently manned station set up at Paranal. |
| October 1983 | ESO workshop on site testing for future large telescopes. |
| April 1984 | IAU Colloquium No. 79. First presentation of the linear array concept. |
| 1984 | Setting-up of the project group and advisory structure. |
| October 1986 | Venice conference. |
| March 1987 | Proposal for the construction of the 16-m ESO Very Large Telescope. |
| December 1987 | Decision to fund the project. |

Venice workshop on the ESO Very Large Telescope.

During this conference, the technical and scientific aspects of the project were discussed. Nothing can better summarize the conference than Prof. Woltjer's conclusion:

"... I am particularly struck by the large consensus that has been achieved. Of course, there are aspects where different scientists have somewhat different perceptions. But much more important is the strong support which the concept of the array of four 8-m telescopes has found. ... Now is the time to realize the project."

The official ESO proposal, which also included plans for the financing and organization of the project, was finalized at the beginning of 1987 and distributed to the ESO governing bodies in March for a final decision to be taken in December.

Site testing activities had begun as early as 1983. Arne Ardeberg had explored a number of places in northern Chile and found that several of them would combine an outstanding percentage of clear nights with very low atmospheric water vapour content. One of them looked particularly attractive, because it offered, in addition, an easy access. This was Cerro Paranal. A workshop on site testing took place at La Silla in October 1983. Before that, a permanently manned station had been set up at Paranal, sophisticated equipment acquired and progressively installed. A large quantity of data has been processed since. This effort is still expanding.

A lot more events than reported here took place during the project genesis. Also, many more people than could be quoted in this paper have made major contributions. The purpose of this article was not to give a detailed account of those last 10 years which preceded the decision to build the VLT, but rather to indicate the major milestones which led to it. What is important is that a decisive page of ESO history is about to be turned, and that this fascinating project is to become a reality.

# Pre-Assembly of an Inflatable Dome Prototype for the VLT

Those who are familiar with the present technical proposal for the VLT, or have just seen pictures of the model published in the press, will have remarked the peculiar inflatable domes proposed. They can be opened entirely, leaving the telescopes in the open air during favourable weather conditions.

While the idea and the basic technology for such domes have been derived from existing inflated radomes for antennas found all over the world, a quite innovative design concept was demanded by the particular requirements of an astronomical observatory. In order to prove the validity of this design and to acquire the know-how necessary for a successful realization of all details, ESO has built with French and Dutch contractors a prototype with a diameter of 15 metres, about half the size required to house the unit telescopes of the VLT.

The dome consists of a double-wall fabric hemisphere, supported by rigid hoops that open and close in two symmetrical parts. Each side of the double-wall cover is made of seven lenticular ribs which are inflated once the dome is closed, thereby providing a rather stiff surface. Also the interior is pressurized, with an overpressure that will be increased by an automatic system in case of strong winds. The dome has been pre-assembled in the Netherlands and found satisfactory. It will be installed on a specially made base at La Silla, starting in February 1988. After being thoroughly tested, it will be used to house experimental set-ups in connection with the development of VLT optical systems.

*L. Zago*

Figure 1: *The 15-m dome almost open.*

Figure 2: *The closed and inflated dome.*

# New Variable Stars in the Globular Cluster M4

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## Introduction

It is well known that there are RR Lyrae type variable stars in globular clusters. They are located at the Horizontal Branch (HB) of the colour-magnitude (C-M) diagram and were originally divided into three subtypes – Bailey a, b and c, but later combined into two – RRab and RRc. All of them are pulsation variable stars; the RRab type stars pulsate in the fundamental mode, while RRc do so in the first overtone.

According to the average periods of RR Lyrae stars, globular clusters are divided into two groups – Oosterhoff I and II. Within each group, the average periods of the variable stars form a continuous distribution. The average period of RRab is about 0.55 and of RRc is 0.32 days for the Oosterhoff I class; the corresponding average periods are 0.65 and 0.37 days for Oosterhoff II. The globular cluster M 3 is a typical Oosterhoff I cluster and so is the globular cluster M 4. According to Sandage (*Ap. J.* **248,** 167, 1981), all the relations of period-colour (temperature), period-amplitude, etc. are the same in M3 and M4.

Early in the 1940's, Martin Schwarzschild found that the RR Lyrae stars in M3 are confined to a small compact region in the C-M diagram. He stated that for a star to vary, it is a necessary and sufficient condition that it has a colour index between CI = −0.005 and CI = +0.235 magnitude and an apparent, visual magnitude between 15.54 and 15.70, i.e. the physical conditions of a star must be rather specific for oscillations to occur.

It is very important to check how sharply the boundaries of this instability strip are defined; does pulsation stop entirely at a given point in the C-M diagram, or do variations of small amplitude persist on either side of the supposed limits of the strip? If this is the case, then an accurate determination of these boundaries would be very important for testing theoretical concepts as well as for practical purposes, e.g. for the estimate of interstellar reddening. As a matter of fact, Schwarzschild's results for M3 were subsequently confirmed and have also been supported by observations in other globular clusters.

This work was done already 32 years ago by Morton Roberts and Allan Sandage (*A. J.* **60,** 185, 1955). Using the Mount Wilson 100-inch reflector diaphragmed to 58″, they obtained 25 IIa-O + WG2 and 26 103a-D + GG11 plates (exposure time 15 minutes). 22 apparently nonvariable stars located at both sides of the instability strip and 47 variables within this strip were measured and the conclusion was that none of the stars outside the strip can be variable with amplitudes $A_{pg} \geq 0.07$. The colour boundaries of the instability region were found to be very sharp with colour indices corresponding to (B-V) = +0.20 and +0.45. All stars lying within the region are variable and no variable stars are found outside the region. Incidentally, the authors also found three small-amplitude variables with $A_{pg} \leq 0.15$; the periods have been determined for two of them. They are located on the red and blue boundaries of the instability strip, but not outside it.

M.F. Walker also made the same type of investigation (*A. J.* **60,** 197, 1955). He used the same telescope, but a photoelectric photometer with a photomultiplier plus a yellow filter. The two globular clusters M3 and M92 were observed; the latter belongs to the Oosterhoff II group. 12 stars were chosen in M3 and 17 stars in M92, and he concluded that "the boundaries of the gap are extremely sharp, and that beyond the edges of the gap, no light variations occur with ranges greater than 0.02 magnitude.

## The Borders of the Instability Strip

B.V. Kukarkin, in his review "RR Lyrae and W Virginis type stars" (IAU Symposium No. 67, 522, 1975), wrote that it is necessary to undertake a careful investigation of the stars near the boundaries of the instability strip. Since the discovery of the two small-amplitude variables in M3 by Roberts and Sandage, nobody has investigated these stars to confirm or to disprove their results. Kukarkin also mentioned that in recent years Voroshilov at the Southern Station of the Sternberg Astronomical Institute discovered small-amplitude variable stars near the instability strip. Unfortunately, I have not yet seen these results.

I have thought about the apparent sharpness of the instability gap, ever since we began to observe the globular cluster M4 in 1975. While using M4 as a calibration cluster to measure our newly discovered flare stars and variable stars in the ϱ Oph dark cloud region, a group of unusual, suspected variable stars was found. When they were provisionally plotted in the C-M diagram, their potential importance immediately became apparent. We should have observed M3 and M92 first, but the exposure times would have been 8 times longer than for M4 to get the same photometric accuracy. Therefore, we had to observe the nearest cluster M4 with our small telescopes, in spite of the fact that its declination is $-26^{\circ}.5$, and it could only be followed during 6 hours in a single night. Although we observed it frequently during the past ten years by photographic methods, we could not solve the problem completely until we used the new CCD Camera at the Yunnan Observatory and also had the opportunity to use ESO's advanced computer system and MIDAS.

Now, we ask the old question: Are there really no variable stars outside the instability strip determined by RRab and RRc type stars? We do not mean the microvariability; if you could obtain an accuracy better than 0.001 mag., most stars would probably appear to be variable. Here we ask the question from the

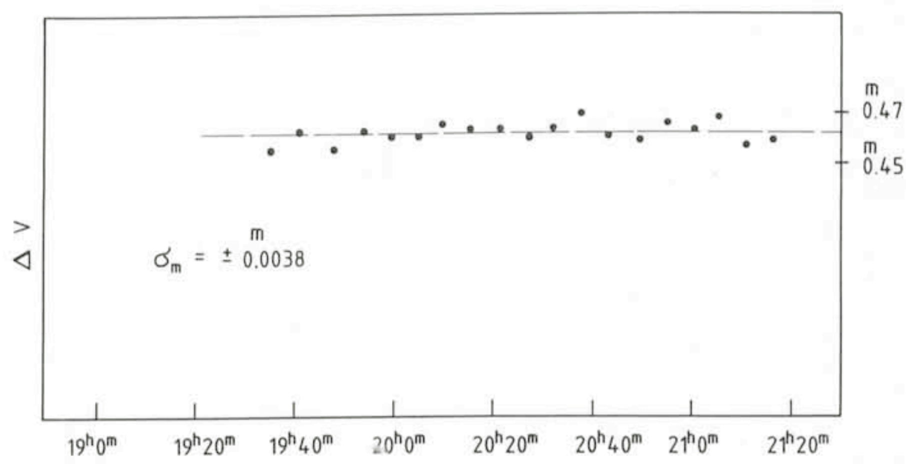


Figure 1: *Δ V between two constant stars on the night of 17 March 1986. Note the small r.m.s. value.*

## Notes on the Use of DAOPHOT

DAOPHOT is one of the best programmes in the world for stellar photometry in crowded fields. Many people use it, and it can also be run within MIDAS at ESO. A detailed DAOPHOT User's Manual by P.B. Stetson is stored on-line (and is also available from F. Murtagh). He recently added some supplements (P.A.S.P., **99,** 191, 1987). Our aim was to do low-amplitude variable star photometry with an accuracy of 0.01 mag or better. While we have been successful in running DAOPHOT at ESO, the following notes may be useful for other DAOPHOT users. These notes refer to the "old" version of DAOPHOT at ESO.

(1) The shape of the Point Spread Function (PSF) may not be unique within the whole frame. The CCD we used belongs to those which have variable PSF across the frame. For isolated bright stars, the systematic error caused by using the PSF from the lower part of the frame in the upper part is less than 0.02 mag (not including the extreme corners). But for differential photometry, the $\Delta m$ between the comparison and the variable star is less influenced by this kind of error.

(2) When the zenith distance was larger than 65°, even 60 seconds exposure was not long enough for $13^m$ stars to well establish the statistical properties of the seeing, and even stars located within a small area, say, 50 × 50 pixels, may have different shapes (PSF). This of course depends on the instrumentation used and also the seeing. Using different "CUTS" (one value to indicate the halo of the stars and the other to indicate the core) one can clearly see the difference of the shapes on the DeAnza screen.

(3) For poorly guided frames, the star images are irregular and the use of an inaccurate PSF may lead to disaster. We have encountered the case where after subtracting the bright stars from the original frame and then running the "FIND" routine again, the residuals of some bright stars were detected as *false* faint stars together with the *real* faint stars buried in the profiles of bright stars (sometimes the real faint stars were omitted). If these false faint stars were not deleted manually from the list when running the "NSTAR" routine, decidedly wrong results would be obtained. Checking the CHI value was no use at all in this case, because it was not worse than that of the nearby real faint stars. Somebody who is not familiar with his star field must be very careful.

(4) Even at the step of "GROUP", strong interactive operation is necessary. This automatic routine divides the star list for a given frame into optimal subgroups in order to reduce the CPU time and to describe the sky brightness with fewer parameters. For the version we used, the criterion to divide stars into subgroups is a critical separation, which is the sum of the brightest star image radius and the fitting radius. For the version used at DAO, the critical separation is a function of apparent magnitude. The stars within one subgroup are close enough so that the light of one will influence the profile-fitting of another and they should be reduced together. For the version of DAOPHOT now released, the maximum number of stars run by the "NSTAR" routine is 60.

The problems we have met in practice are:

(a) In our frames sometimes the stars in one subgroup form a long, thin and curved string over a large area. We do not think it is suitable to consider the stars of this long string as one unit which have the same PSF. It is also not good to break them into smaller subgroups by using a smaller critical separation value. We prefer to load the star list given by the "GROUP" routine onto the DeAnza screen and "EDIT" the stars manually, i.e. to find some star(s) on the string where it is relatively sparse, break the string over at this point and so group the stars in this way.

(b) Sometimes it happened that the stars which belong to one group are really located within a compact region and should be reduced as a unit, but the number is a little larger than 60. According to DAOPHOT, the "SELECT" routine must be used to select a slightly smaller critical separation value and break this group into several smaller subgroups. Unfortunately, it often happened that among these subgroups many stars were divided into one star per subgroup. For these "single" stars, the "NSTAR" routine became the "PEAK" routine, i.e. the multiple simultaneous profile-fitting advantage was lost. In this case, we simply edited the group file and took away some stars at the edge of the group on the screen, considering them as another small subgroup and sacrificing their accuracy. Now the original group contained less than 60 stars and could be run with "NSTAR".

(5) One must be very careful while running the "PSF" routine in a crowded field. In the DAOPHOT Users' Manual, Stetson vividly describes the process as an art, not a science. Obtaining a good PSF in a crowded field is a delicate business; do not expect to do it quickly, plan on spending a couple of hours for this endeavour.

The author of this article will be happy to directly inform interested persons about his experience with DAOPHOT in greater detail than is possible here.

classical viewpoint: are there any variables outside the strip with amplitudes larger than 0.02 mag.?

### Observations

An RCA thinned back-illuminated 320 × 512 pixel CCD (pixel size 30 × 30 μm) mounted at the 1-metre reflector (f/13.5) of the Yunnan Observatory in Kunming, P.R. China, was used to observe M4 during 8 nights in March and May of 1986. A series of successive frames was obtained during each night with a typical exposure time of 5 minutes through the V filter and each star was nearly fixed at the same position of the frame. As mentioned above, the zenith distance of M4 is always large for northern observers.

The data reduced at ESO were obtained on May 11, 1986 and consist of

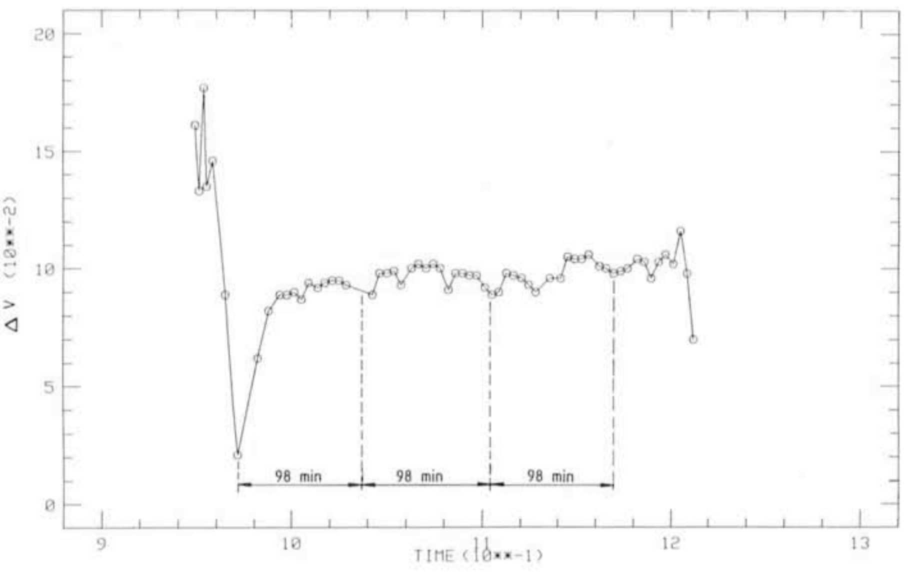


Figure 2: *Δ V (G266–G265) with some apparent minima, separated by 98 minutes. Magnitudes in this and the following figures are in units of 0.01 mag. Time is in units of 0.1 day.*

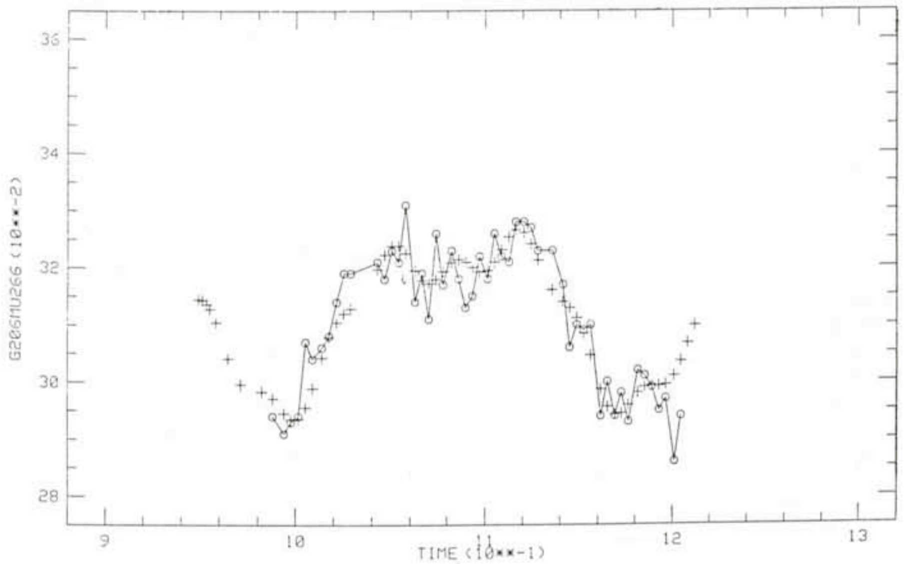


Figure 3: *Δ V (G206–G266). In Figures 3–5, crosses are observations and circles indicate a composite curve of sine functions, obtained by a straightforward fit to the observations and not necessarily with any physical meaning.*

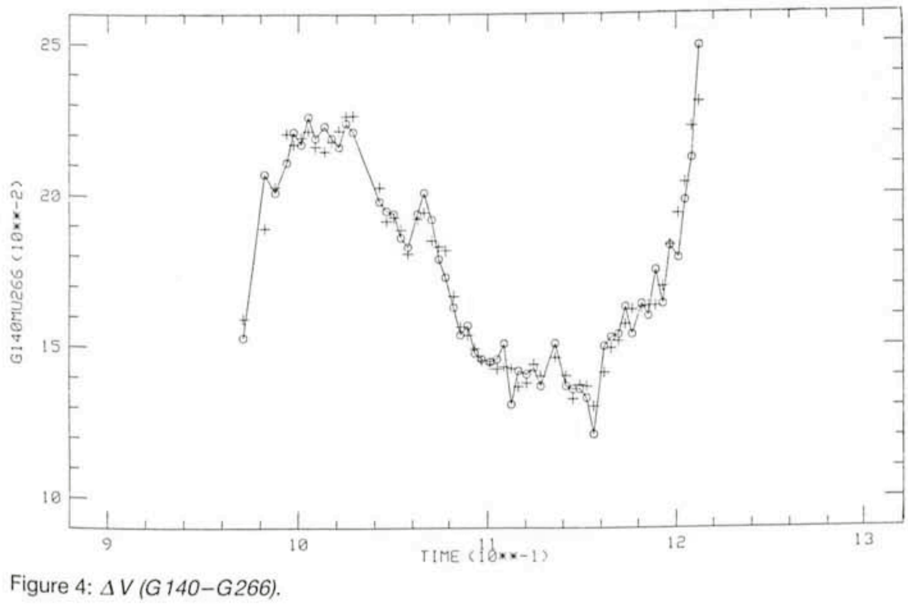


Figure 4: *Δ V (G 140–G266).*

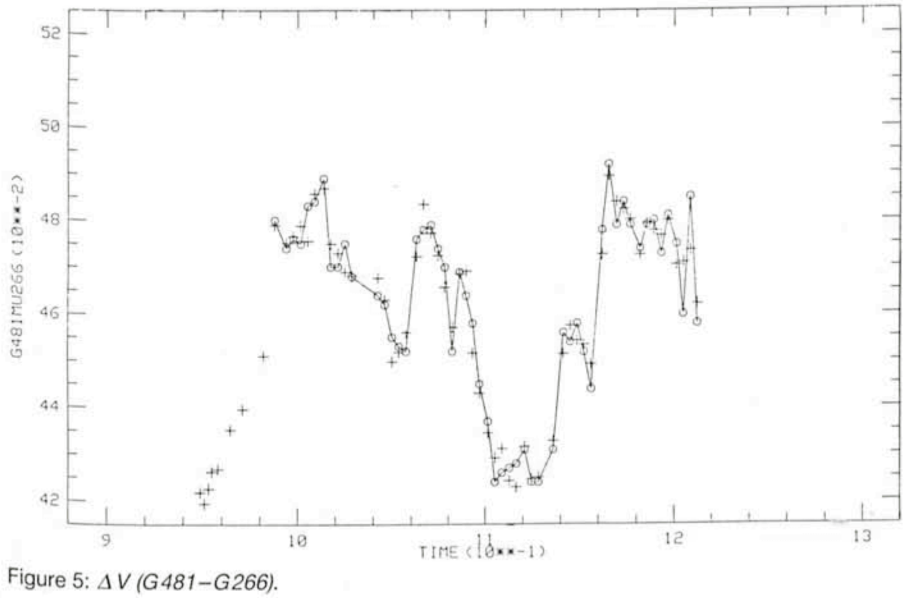


Figure 5: *Δ V (G481–G266).*

62 frames with zenith distances from 71° to 51°.5 (meridian) and then to 66°. But the signal-to-noise ratio is still good, and the typical intensity accumulated by the CCD is about $10^5$ ADU for a V = 13 star exposed for 5 minutes. Entering this ADU value and other parameters such as readout noise into the formula, the calculated standard error is about ± 0.002 mag., the accuracy of the magnitude difference between two V = 13 stars is about $\sqrt{2} \times 0.002 = \pm 0.003$ mag.

We almost reach this accuracy in practice. It is generally believed that the current accuracy of CCD photometry, even in a sparse star field, is 0.01 magnitude or worse, due to the limitations mentioned in Stetson's paper about DAOPHOT. However, differential photometry is always better. Since we exposed in such a way that every star occupied approximately the same pixels in all frames, and since we chose a comparison star with a colour similar to that of the variable star, we can obtain more accurate results. For example, Figure 1 represents the magnitude difference between two stars (V = 12.7 and V = 13.3), observed on March 17th and reduced by a running aperture photometry routine (APERASP in STARLINE) at the Beijing Observatory. Here $\sigma$ = 0.0038 mag.

We decided to use DAOPHOT (see also the box), because we wanted to identify any faint nearby stars embedded in the wings of the bright variables and to eliminate them in order to improve the accuracy.

## Unusual Variable Stars in M 4

The main purpose of the present study was to confirm the previous observations of variability which were made by photographic methods. With our small telescopes only the outer part of the cluster could be investigated so among the five variable stars discussed here, only three have faint stars embedded in their wings with influences ≤ 0.01 mag. The other stars have no detected blended stars, so for them the accuracy is more or less similar to that of aperture photometry. The V and (B-V) values from the literature are listed in the Table and their positions in the C-M diagram of M 4 are shown in Figure 7.

Well aware that it is not possible to determine accurate periods on the basis of observations from only one night reduced so far, we have used all the three methods of time series analysis available in MIDAS (PDM, SVM, DFT) to make a provisional search for periods; they give similar results. There is little doubt that the stars are variable, but as shown below, the light curves are com-

*Data for 5 Variable Stars in M4*

| Star | V | | (B-V) | |
|---|---|---|---|---|
| | Alcaíno | Lee | Alcaíno | Lee |
| G265 = A375 = L4508 | 12.9 | | 1.3 | |
| G206 = A491 = L4632 | 13.50 | 13.43 | 0.28 | 0.45 |
| G140 = A488 = L3602 | 13.33 | 13.22 | 0.36 | 0.49 |
| G481 = A371 = L4512 | 13.45 | 13.41 | 0.87 | 0.90 |
| G543 = A376 = L4507 | 13.46 | 13.46 | 1.29 | 1.27 |

Alcaíno (ref. 2). Lee (ref. 3).

plicated, similar to those of Population I δ Sct stars. It might therefore be useful to organize some international cooperation in the future, in order to analyse the periods in these light curves.

(a) *A variable star with periodicity in the middle part of the Red Giant Branch*

G 265 = Alcaíno 375 = Lee 4508 (refs. 1–3) is a red giant star, about 3.3 arcmin from the centre of the cluster (see the map in ref. 2). All the authors put it slightly below the middle part of the Red Giant Branch. Norris (ref. 4) determined its radial velocity (62 km/s) and showed that it is a cluster member.

Using G 266 as comparison star, the resulting light curve is shown in Figure 2. It may be compared with the curves in our previous paper (refs. 5, 6). Apart from the irregular variations superimposed on the curve, the period P = 98 min. is possibly real. In Figure 2 and in the earlier photographic curves (refs. 5, 6) there are several minima which are separated by this interval. In Figure 2, from U.T. $15^h50^m$ (corresponding to the ninth point from left) to $20^h50^m$, the amplitude is only 0.02 mag., but the accuracy is so good that a 0.01 mag. variation is significant.

If the 98-min. period is confirmed when more nights have been reduced, it may be assumed that it has a cause other than pulsation, e.g. rotation and/or binary. Huge star spots may also persist for some time on the surface.

(b) *RRe – another subgroup of RR Lyrae stars in globular clusters?*

Here some data are given about 3 variable stars; the light curves are shown in Figs. 3, 4 and 5. Their positions can be seen in the map in ref. 2, and they are identified in the C-M diagram of Lee (ref. 3) in Figure 7.

G206 = Alcaíno 491 = Lee 4632 is located on the blue side of the HB and has a nearby faint star separated by 3.3 pixels (1.6 arcsec). The influence is ~ 0.01 mag. if this 4.2 mag. fainter star is not subtracted. A possible period is P 1 = 0.205 days and the total amplitude is 0.04 mag in V.

G 140 = Alcaíno 488 = Lee 3602 is located on the blue side of the HB: it has 3 nearby faint stars. Their angular distances and the brightness differences from G 140 are: 10.9 pixels, 4.6 mag.; 6.5 pixels, 3.5 mag.; 5.9 pixels, 3.7 mag. The combined influence of these is ~ 0.01 mag. The main period appears to be P 1 = 0.216 days with amplitude 0.043 mag. The total amplitude is 0.1 mag. in V.

G 481 = Alcaíno 371 = Lee 4512 is located on the red side of the HB. No nearby faint stars have been found, so its results are more accurate than the others. However, in some frames, the star was exposed near the edge. A possible period is P1 = 0.167 days and the total amplitude is 0.07 mag. in V.

According to stellar statistics at galactic latitude 16°, there should be

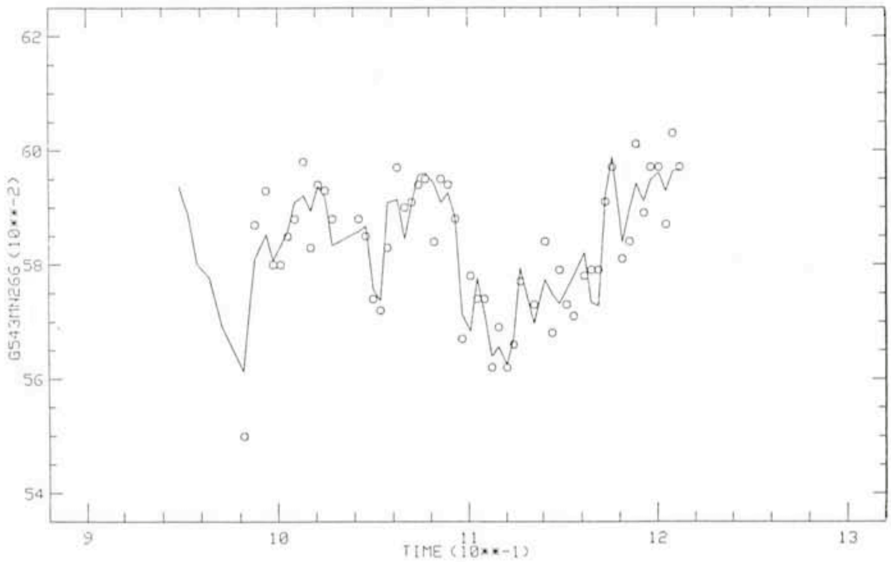


Figure 6: *Δ V (G543–G266). The observations are indicated with open circles.*

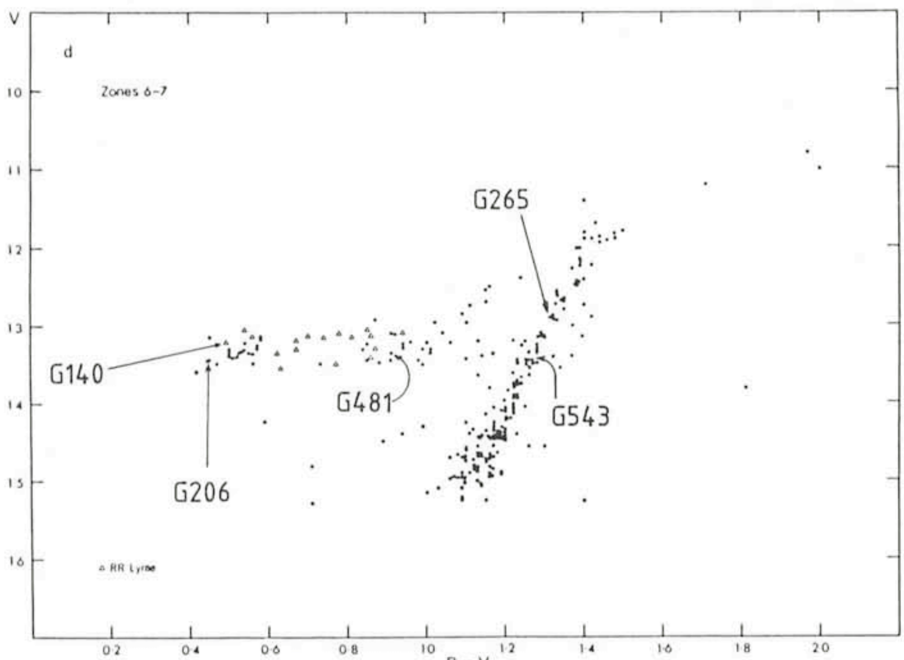


Figure 7: *Colour-Magnitude diagram of M4 from Lee (ref. 3), with the new variable stars indicated.*

3.5 field stars with $m_{pg} < 14.5$ mag. within an area with radius 3.6 arcmin., so it is unlikely that these variable stars all belong to the field. Furthermore, the star G 327 (V = 13.28, B-V = 0.35; ref. 5) is also located at the blue side of the HB, and at least 5 unpublished, similar stars are waiting for checking.

A provisional conclusion is that these stars may form a new group. For the time being we call them "RRe" and maybe they should be divided into two: one on the blue side and the other on the red side of the classical boundaries of the instability strip.

*(c) A Variable Star at the HB/RGB Intersection*

G 543 = Alcaíno 376 = Lee 4507 has a nearby faint star separated by 4.2 pixels (1.9 arcsec) with brightness difference about 3.6 mag. The influence of the faint star is ≤ 0.01 mag., but the influence varies with seeing and guiding. The light curve is complicated and the time interval is not long enough for it to be analysed. This would be the first known variable at the intersection of the HB and RGB.

I hope that these results, albeit provisional, will stimulate similar research in other places and that more astronomers will become interested in pointing their large telescopes at globular clusters in the future.

**Acknowledgements**

I am grateful to ESO for letting me use its advanced computer and MIDAS system and also for the financial support. I also thank Drs. Ortolani and Aurière for help in running DAOPHOT.

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# Neutron Density and Neutron Source Determination in Barium Stars

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## Introduction

The origin of the large s-process enhancements observed in the classical Barium (Ba II) stars (Lambert 1985) remains one of the most fundamental challenges in stellar nucleosynthesis theory. An understanding of this phenomenon would lead to an improvement in our knowledge of both s-process systematics, and mixing processes occurring during the late phases of stellar evolution. A determination of two crucial aspects of the s-process site, namely the neutron source and the neutron density, would be a significant advance towards this goal. Knowledge of these two parameters would allow strong constraints to be placed on any evolutionary hypothesis purporting to explain the Ba II star phenomenon. Hitherto, the neutron source has been analysed in only two Ba II stars, and the neutron density also in only two.

In order to extend such studies to other members of this important stellar class, spectroscopic observations of a large number of both northern and southern hemisphere Ba II stars were obtained. This work was carried out in collaboration with D.L. Lambert at the University of Texas, Austin. In this paper, which reports the first results of our survey, we discuss the determination of the neutron source and neutron density in the cool (K4) Ba II star HD 178717, and compare our results with the abundances predicted if mass transfer from an evolved asymptotic giant branch (AGB) star has occurred. This scenario for the origin of the s-process enhancements in Ba II stars has received a great deal of theoretical and observational attention in recent years (see Malaney 1987).

## Observations of Neutron Indicators

The two most likely neutron producing reactions in a stellar interior are the $^{13}C(\alpha, n)^{16}O$ and the $^{22}Ne(\alpha, n)^{25}Mg$ reactions. It is well known that the operation of the $^{22}Ne(\alpha, n)^{25}Mg$ neutron source should lead to an observable distortion in the relative abundances of the magnesium isotopes from their solar system distribution of $^{24}Mg : ^{25}Mg : ^{26}Mg = 79 : 10 : 11$. In order to obtain information on the source of neutrons, the magnesium isotopic mixture in HD 178717 was determined from observations of the molecular MgH (0,0) band lines at 5101 Å and 5107 Å. The MgH lines at 5101 Å have the advantage of a large isotopic splitting (~0.14 Å). Contamination by lines from the $C_2$(0,0) and $C_2$(1,1) bands, however, leads to significant blending in this spectral region. Although the MgH lines at 5107 Å have the disadvantage of a smaller separation (~0.1 Å), the $^{25}$MgH and $^{26}$MgH lines are unaffected by $C_2$ blends. In addition, since the observed rubidium abundance is known to be an indicator of the neutron density at the s-process site, the abundance of this element in HD 178717 was determined from observations of the Rb I line at 7800 Å. In order to minimize non-LTE effects, this rubidium abundance determination was carried out differentially with respect to the standard K3 giant μ Aql.

The observations discussed here were obtained in April 1987 at the ESO La Silla observatory using the Reticon-equipped echelle spectrometer of the 1.4-m Coudé Auxiliary Telescope. The length and the resolution of the spectra were 40 Å and 0.05 Å, respectively, for the 5100 Å centred spectrum, and 60 Å and 0.08 Å, respectively, for the 7800 Å centred spectra. The signal-to-noise ratio in the continuum exceeded 100 in all of the obtained spectra. The raw data were reduced at Caltech using the spectral reduction package FIGARO.

In order to determine the magnesium isotopic distribution and the rubidium abundance of our stars, the observed spectra were compared with synthetic spectra calculated using an LTE spectral synthesis programme (Sneden 1974; assistance in the use of this code was provided by A. McWilliam). The required input for the synthesis programme, namely the parameters of the observed lines and atmospheric parameters of the observed stars had previously been determined. To allow a proper comparison of the theoretical and observed spectra, a composite of the rotational, macroturbulent and instru-

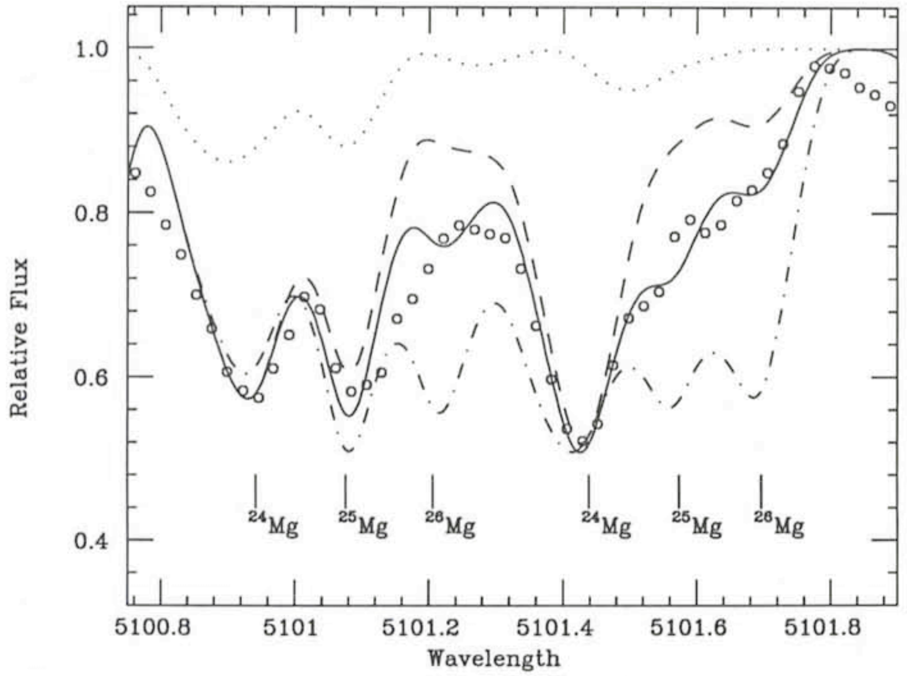


Figure 1: *Comparison of the observed MgH feature at 5101 Å with synthetic spectra. The synthetic spectra are calculated assuming a $C_2$ contribution alone (dotted curve); a solar distribution of magnesium isotopes (dashed curve); a best fit distribution of magnesium isotopes where $^{24}$Mg : $^{25}$Mg : $^{26}$Mg = 60 : 25 : 15 (solid curve); and an equal distribution of magnesium isotopes (dot-dashed curve). The circles represent the observed data points. The principal lines of the spectrum are indicated.*

mental broadening was applied to the synthetic spectra.

Figure 1 displays a comparison of the observed MgH spectra of HD 178717 in the 5101 Å region with synthetic spectra calculated for different distributions of the magnesium isotopes. The strength of $C_2$ was estimated by fitting the profile of the $C_2$ line at 5086 Å. The calculation with the magnesium isotopes in the ratio $^{24}$Mg : $^{25}$Mg : $^{26}$Mg = 60 : 25 : 15 clearly gives the best fit to the observed data. The fact that this fit is not exact could be the result of a number of error sources, such as poor fitting of the continuum, poorly determined gf values or stellar parameters, a poor determination of the $C_2$ strength, or the presence of unknown blends. The latter source of error is the most likely in view of the cool nature of the star under study. In light of these uncertainties it is important to check these results using another portion of the stellar spectrum. Figure 2 shows the observed and synthetic spectra in the region of the MgH lines at 5107 Å. It can be seen that a good fit is obtained for a magnesium isotopic mixture of $^{24}$Mg : $^{25}$Mg : $^{26}$Mg = 56 : 22 : 22, which is very similar to that used in the best fit of the 5101 Å region. We would tend to give somewhat less weight to this distribution due to the presence of an unidentified line (indicated by a ? in Figure 2) blended between the $^{25}$Mg and $^{26}$Mg lines. However, the good agreement of the results obtained from the different MgH features, gives us a high degree of confidence that HD 178717 does indeed possess an excess of $^{25}$Mg and $^{26}$Mg relative to the solar distribution of the magnesium isotopes.

Only two lines of atomic rubidium are accessible in the visible spectrum. These are the neutral Rb I lines at 7800 Å and 7948 Å. The 7800 Å line was chosen for analysis since the 7948 Å line is blended with an unidentified line. Figure 3 displays the observed Rb I line at 7800 Å in HD 178717, and in the comparison star μ Aql. Shown in each spectrum is the best fit synthetic spectrum computed for each star. A nearby Fe I line at 7802.5 Å was used in order to determine the Rb/Fe ratio in each star. Using the notation [Rb/Fe] = log (Rb/Fe)$_{\rm BaII}$ – log(Rb/Fe)$_{\mu \rm Aql}$, we find [Rb/Fe] equal to +0.2 in HD 178717. Knowing the dilution factor of the irradiated material, the Rb/Fe ratio of the irradiated material can then be estimated in a simple manner.

## AGB Stars

Calculations of AGB models for core masses in which the $^{22}$Ne(α, n)$^{25}$Mg neutron source is assumed to operate, show that the relative abundance of $^{25}$Mg and $^{26}$Mg should be at least equal to the $^{24}$Mg abundance. For example, calculations for an AGB model possessing a core mass of 1.16 $M_\odot$ predict an observed $^{26}$Mg/$^{24}$Mg ratio of ~3 (Malaney 1987). From Figures 1 and 2 where calculations of synthetic spectra assuming an equal distribution of the magnesium isotopes are shown, it is clear that such a distribution of isotopes results in a very poor representation of the observed data. Even taking into account uncertainties in both the calculations and the observations, this large discrepancy leads us to the conclusion that mass transfer from an evolved intermediate-mass AGB star is not responsible for the s-process enhancements observed in HD 178717.

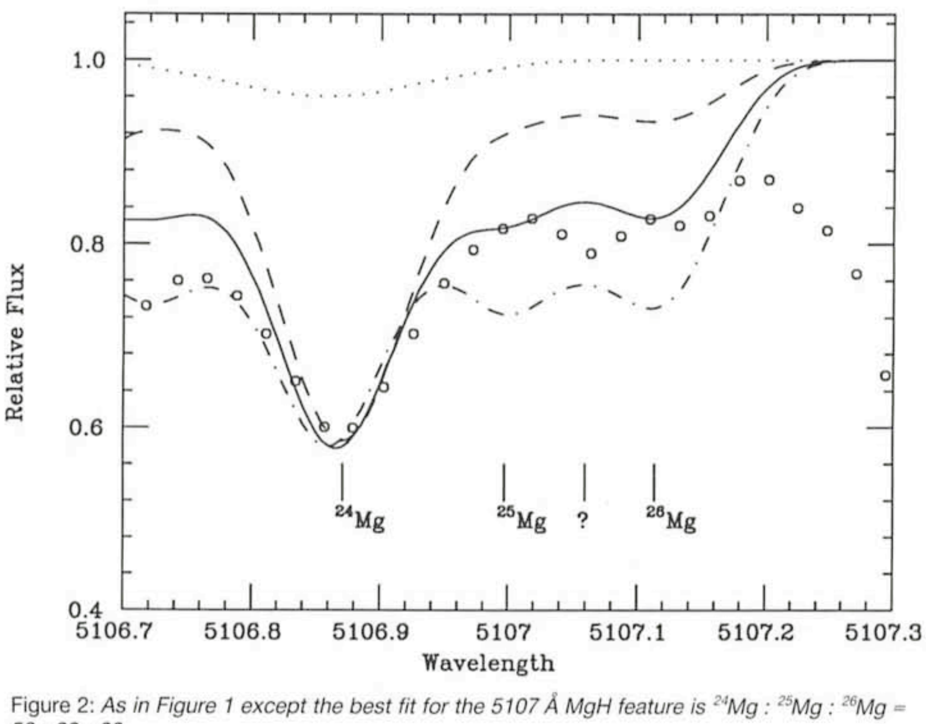


Figure 2: *As in Figure 1 except the best fit for the 5107 Å MgH feature is $^{24}$Mg : $^{25}$Mg : $^{26}$Mg = 56 : 22 : 22.*

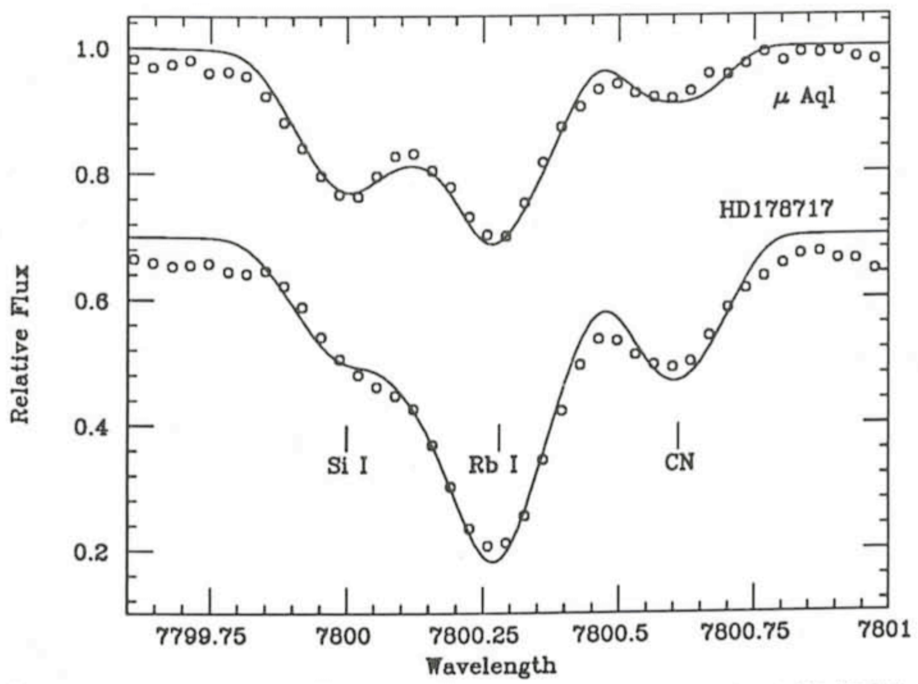


Figure 3: *The observed and best-fit synthesized spectra for μ Aql (top) and HD 178717 (bottom; a constant is subtracted from this spectrum) in the region of the Rb I 7800 Å line.*

Do these results imply that mass transfer from a low-mass AGB companion is the mechanism whereby the Ba II stars are formed? The $^{13}C(\alpha, n)^{16}O$ neutron source is believed to operate in such stars. It is normally assumed that the $^{13}C(\alpha, n)^{16}O$ neutron source does not lead to any significant alteration of the magnesium isotopes due to the small neutron absorption cross section of $^{16}O$. However, recent calculations (Arnould and Jorissen 1986) have shown that it may be possible, in a limited parameter space, to produce observable anomalies in the magnesium isotopic mixture if it is assumed that all the CNO isotopes in the intershell region of the AGB star have been transformed into $^{22}Ne$. In such circumstances, neutron absorption reactions on $^{22}Ne$ and up through the magnesium isotopes, could lead to a small observable excess of $^{25}Mg$ and $^{26}Mg$ similar to that observed in HD 178717. The question as to what fraction of the CNO isotopes are transformed into $^{22}Ne$ will be determined by the temperature history of the stellar interior, and the competition between the $^{22}Ne$ producing reaction sequence $^{14}N(\alpha, \gamma)^{18}F(\beta)^{18}O(\alpha, \gamma)^{22}Ne$, and destruction reactions such as $^{18}O(p, \alpha)^{15}N$. The fact that some Ba II stars show normal (i.e. solar) isotopic magnesium mixtures (Lambert 1985), whereas some do not, could simply be an indication of the different temperature histories of the different stars. Since the temperature structure of the star depends sensitively on the stellar mass, it is plausible that this is the stellar parameter determining any distortion of the magnesium isotopes.

Regardless of the stellar mass, the observed rubidium abundances of the Ba II stars either pose a serious problem for current AGB models, or else for the proposed mass transfer scenario. This can be seen from Figure 4 where a calculation (Malaney 1987) showing the Rb/Sr ratio as a function of neutron density is shown. The Rb/Sr ratio of HD 178717, which is also indicated, is deduced assuming a previously measured [Sr/Fe] ratio for the star. The horizontal dashed lines in Figure 4 correspond to the maximum and minimum value of the Rb/Sr ratio assuming a conservative error of $\pm$ 0.2 dex. Current models of the nucleosynthesis occurring in AGB stars, irrespective of the neutron source or core mass assumed, result in Rb/Sr ratios of at least 0.5. It can be seen from Figure 4 that the observed Rb/Sr ratio in HD 178717 indicates that the neutron density at the s-process site cannot be greater than $\sim 5 \times 10^7$ cm$^{-3}$. In contrast, the neutron densities of AGB stars are typically in the range of $10^9$ – $10^{12}$ cm$^{-3}$. If we assume an AGB mass transfer mechanism as the correct interpretation of the Ba II star phenomenon, then the observed Rb/Sr ratio of HD 178717 would appear to be incompatible with current AGB models.

## Conclusions

We find that a distribution of $^{26}Mg$ : $^{25}Mg$ : $^{26}Mg$ equal to 60 : 25 : 15 gives a good fit to MgH observations of the cool Ba II star HD 178717. This distribution would appear to rule out the operation of the $^{22}Ne(\alpha, n)^{25}Mg$ neutron source, and therefore any relationship of this Ba II star to intermediate-mass AGB stars. From our deduced rubidium abundance, we find for HD 178717 a neutron density of $\sim 2 \times 10^7$ cm$^{-3}$ at the s-process site. If an AGB mass transfer mechanism is responsible for the s-process enhancements of Ba II stars, then,

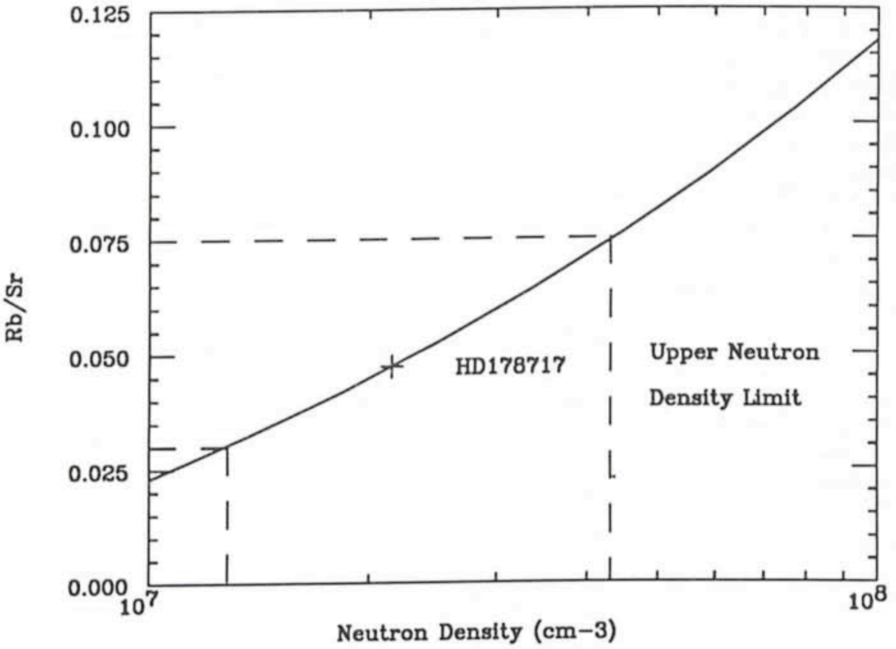


Figure 4: *The calculated Rb/Sr ratio as a function of the neutron density (solid curve). Also indicated (cross) is the measured value of Rb/Sr in HD 178717. The horizontal dashed lines correspond to our estimated error of this ratio. The vertical dashed lines are the resultant error limits on the neutron density.*

this low neutron density implies that significant revisions of present low-mass AGB models are required.

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# Of Whirls and Molten Gold

## An Introduction to Fontenelle's "Entretiens" (1686)

*R.M. WEST, ESO*

Whereas everybody agrees that there has been enormous progress in many areas of astronomy and astrophysics during recent years, nobody knows for sure which contemporary achievements of our science will be considered particularly important by scientists in a distant future. It is therefore sometimes interesting to place yourself in that privileged position by looking backwards in time and to judge the ideas of our forefathers in the light of our present knowledge.

Some time ago, when I glanced through A. Pannekoek's "History of Astronomy", I happened to come upon the name of Fontenelle. According to Pannekoek, whose text is one of the best introductions for non-specialists to the accomplishments of our predecessors, "Great popularity was won by Fontenelle's *Entretiens sur la pluralité des mondes* (Conversations on the Plurality of Worlds) 1686." I must admit that I had never heard of this author, but I became intrigued about the "plurality" and decided to find out what this was about. First I asked some of my colleagues about Fontenelle, but none of them seemed to know him. "At which observatory does he work?" was one of the kind, but not very helpful replies.

Calling the Bavarian State Library in Munich, I learned that no less than three editions of Fontenelle's book were available there, although it was slightly puzzling that the first was from 1687, the second from 1750 and the third from 1796! So I decided to have a closer look and soon entered a fascinating world, so different from our modern one, and yet in some regards so similar that it might also interest those readers of the *Messenger* who are not familiar with "Entretiens". Since I am not a specialist in the history of astronomy, the following account must of course only be taken as reflections of a modern astronomer when confronted with the thoughts of a popular writer in the late 17th century.

### Popularization and Fontenelle

Any scientist, who has written articles that are destined to be read by a wider circle, knows that they have to be quite different from those that appear in professional journals. With the increasing importance of popularization of the sciences, in particular within the "natural" ones, more and more scientists go through this experience. Many of them do so because they feel that it is useful to call attention to the research at the institute where they work – in some countries the regular reporting in the media may even have a decisive influence on the funding. Some of their colleagues feel that they have a moral obligation to inform the taxpayers on whose money they subsist and others simply think it is great fun to tell about the work in which they are currently engaged.

The information flow from scientists to the media and onwards to the public is not a new phenomenon, although it may have become more intense in our days. We have all read the books by the fathers of modern science fiction, like Jules Verne and H.G. Wells, who based their thrilling stories on the science and technology of their epoch. Further back in time, the public interest in the natural sciences was often satisfied by dramatic accounts of journeys to distant continents. In astronomy, the so-called Broadsheets played an important role in conveying news about celestial phenomena, although they were not always to be trusted; see for instance the article by P. Véron and G. Tammann in the *Messenger,* **16,** 4, 1979.

Fontenelle's book, which was first published in 1686, is in retrospect a significant milestone in the noble art of science popularization and it contains elements from which even modern members of this trade may learn. The author was born in Rouen, France, on February 11, 1657 and he died in Paris on January 9, 1757, after a long and busy life. His full name was Bernard le Bovier, sieur de Fontenelle; his mother was a sister of the famous Pierre Corneille. He was educated by the Jesuits in Rouen. Having unsuccessfully tried his luck as a lawyer (he lost his first court case and left in disgust!), he then turned towards the sciences and later became one of the most read philosophers of his time. Voltaire described him as the most universal mind produced by the era of the "Sun King" Louis XIV.

Still in his twenties, he wrote libretti to two tragic operas and in 1683 he became well known by some philosophical treatises, followed by the "Entretiens", three years later. In 1697, he became permanent secretary of the French Academy of Sciences, a position that

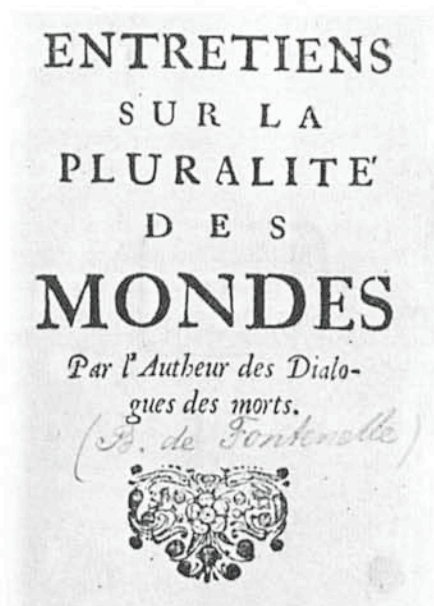
ENTRETIENS
SUR LA
PLURALITE'
DES
MONDES
Par l'Autheur des Dialogues des morts.
(B. de Fontenelle)
A AMSTERDAM,
Chez PIERRE MORTIER, Marchand Libraire fur le Vygendam, a la Ville de Paris.
M. DC. LXXXVII.

Figure 1: *Title page of the French edition in 1687.*

brought him into contact with many of the leading scientists in the age of Enlightenment, including Newton and Leibnitz, whose obituaries he later wrote. During his lifetime a major revolution took place in the attitude towards the natural sciences and their importance for progress in human society was recognized.

## The Publication of "Entretiens"

There is little doubt that Fontenelle's "Entretiens" was his most successful publication. From the bibliographic sources available in Munich, it can be seen that the demand in Fontenelle's home country continued, and new French editions were published in 1687, 1694, 1698, 1703, 1707, 1708, 1714, 1733, 1745, 1750, 1793, 1796, 1800, 1812, 1818, 1820, and finally in 1824! How many popular works can show such a series over so many years?! The book was immediately translated into English in 1687 and there were about thirty English editions until 1803. The German edition appears to have been somewhat slower in coming; the famous astronomer J.E. Bode wrote a voluminous commentary to the first one in 1780. There was a Greek edition in 1794 and a Russian one in 1802. In Denmark the readers had to wait until 1748, before they could read it in their own language. There may have been other translations, which I have not been able to trace.

The book is concerned with the "World System" of 1686 and it is one of the very first examples of serious science popularization, readily accessible to the literate public. With the exception of Galileo's "Dialogo sopra i due massimi systemi del mondo" from 1632, which was quickly banned by the Church and led to its author's forced abjudication of the heliocentric system, "Entretiens" is probably the first major attempt to bring Copernicus' thoughts to a wider public in their own language, almost 150 years after the death of the revolutionary in 1543. It took a long time before the heliocentric system of Copernicus was accepted by more than a few daring scientists – witness the resistance by the great observer Tycho Brahe at the end of the 16th century. When Fontenelle wrote his book, common people in Europe firmly believed that the Earth was at the centre of the Universe. The fact that it was written in France testifies to a more liberal attitude in that country.

## Tricks of the Trade

When you hold the edition from 1687 in your hand, you first of all remark its tiny size, only 9 × 13 cm. It is clearly a "pocket" book and was intended as such. The language is easy to read and there is no doubt that Fontenelle went into some trouble to ensure this. The words are simple and the arguments are well explained. It is divided into a Preface, an Introduction and five Chapters: "First Evening", "Second Evening", etc. A "Sixth Evening" was added in 1694, in order to explain a number of additional phenomena.

Let us have a closer look at the content in order to understand what was of concern to people in those days and also how Fontenelle presents the astronomical "results". Already in the Preface, he defends his decision to write in his mothertongue and not to use Latin, the international, scientific language of that time. Like Cicero, who wrote in Latin (and not in Greek, the language of science in his time), Fontenelle would like to tempt those who "are not philosophers" (i.e. those who do not know about the natural sciences) to read the book, because it is easy for them to read their own language. "The philosophers", who already know it all, might still find some interest in seeing it exposed in another language. Fontenelle explains that he has introduced a lady into the narrative – "who has never heard about these matters" – hoping to encourage "les Dames" to read his Book. He has tried to make it more interesting by the inclusion of "digressions", but he regrets that it may still be less interesting than Ovid's "The Art of Love"!

Fontenelle realizes of course that there will be resistance against his ideas from certain quarters, in particular from the religious authorities. He mentions a special problem in connection with the lunar inhabitants. According to the dogma, the forefather of all people is Adam, but since you cannot travel from the Earth to the Moon, the lunar people cannot be descendants of Adam! This is embarrassing for the theologians. However, "c'est vous qui mettez des Hommes dans la Lune, je n'y en mets point – J'y mets des Habitans qui ne sont point du tout des Hommes." Yes, Fontenelle is clever, his lunar beings need not be human after all!

The Introduction is directed to Monsieur de L***, and Fontenelle tells about some pleasant days spent in the country house of Madame La Marquise G***. Surely L***, who expects to hear about parties, hunting and card games, must be surprised to read about "planets, worlds and vortices; the talk was almost only about such things". And here commences the narrative about how Fontenelle (the "I" in the book) and Madame La Marquise G*** spent five evenings in

Figure 2: *Portrait of Fontenelle from the luxury edition in 1796.*

the park, discussing philosophical themes under the starry skies. The dialogue form is well known from the classics and Madame is rather intelligent, in any case she puts many clever questions to the author. Only once or twice does she become stubborn and Fontenelle has to use all his powers of persuasion to convince her that his ideas are correct. No doubt the readers had little difficulty in identifying themselves with Marquise G***.

## The Copernican System

During their first walk in the park, on the First Evening, Fontenelle explains how the light from the stars disappears in the bright sunshine during daytime, but that the stars are still there all the time. He continues to compare Nature with a theatre; everything is controlled by invisible ropes and counterweights. "So the whole thing is just mechanical?" asks the Marquise and Fontenelle, who is pleased to see that his didactical method works, replies that it is indeed so and also that the explanation of what we observe in Nature is always the simplest possible one. He tells about the five major planets and that they, contrary to the fixed stars, move in the sky. He mentions that the cradle of astronomy can be found with the Chaldeans, and that Geometry was born in Egypt. We must not think that everything in the sky is just there for our sake, as some philosophers believe. In the same way, it is not the Earth, but the Sun which is the centre of the Univers, as we have been told by Copernicus, "qui fait main-basse sur tous ces Cercles differens, & sur tous ces Cieux solides, qui avoient esté imaginez par l'Antiquité. Il detruit les uns, il met les autres en pieces" (who takes away all those different circles and all those solid skies which have been invented by Antiquity . . .).

Now the Earth is just the third planet in the system, among five others. Fontenelle feels obliged to excuse himself, but Madame answers: "Do you think that you have humiliated me by telling me that the Earth orbits the Sun? I swear that I feel no smaller!" Later Fontenelle argues that although the Earth is big and heavy and it would therefore appear difficult to let it turn around an axis in only 24 hours, it would certainly be even more incredible if the entire Universe, so much bigger and heavier, would turn around the Earth. Now the Earth floats freely in space and this might of course give rise to some feeling of dizziness; well, Madame believes that she will manage and she goes on "I do not want to say stupid things, but there is a difficulty. If the Earth turns, we change the air all the time and we always breathe that of a different country." Fontenelle explains how the atmosphere is like a silk-cocoon, a thin envelope and that it turns with the Earth. He then goes on to imagine that he and Madame are out in space, watching the rotating Earth below. They see Englishmen discussing politics, Indians who devour their prisoners alife, Japanese ladies who spend all their time cooking for their husbands, towers of porcelain in China, tartars, beautiful Circassian ladies and finally Turcs.

And when they come back to the house, Fontenelle mentions the Tychonian system (supposedly to avoid criticism from many of his friends), but Madame rejects it "vif & prompt", and they happily agree that Copernicus must indeed be right.

### Life Outside the Earth?

Next morning, the Marquise is happy to tell Fontenelle that she has slept very well, despite the Earth's rotation. And later, when they again meet in the garden at the beginning of the Second Evening, Fontenelle discusses the Moon and its possible inhabitants. He asks Madame to imagine that she is standing in the outskirts of Paris and looks towards the nearby town of Saint Denis (now a part of the city of Paris). Although she cannot see the people in Saint Denis, she can be reasonably sure that it must be inhabited, since it resembles Paris with its houses, church towers, etc. So, as the Moon resembles the Earth with its mountains and abysses, it must also be inhabited. The Sun shines by itself, but both the Moon and Earth shine by reflected sunlight. The lunar inhabitants can therefore observe the Earth, as we see the Moon, although the Earth shines brighter than the Moon. Fontenelle explains the Moon's phases and also the principle of solar and lunar eclipses. "I am very surprised that there is so little mystery to the Eclipses and that they are not understood by all people!" (Henceforth, the self-respecting reader will find it very difficult to show any ignorance.)

At this point, Fontenelle deviates from his rather scientific approach and tells the story about Astolfe, who with the help of St. Jean travelled to the Moon in order to recuperate the good humour of his friend Roland (here the reader will have time to relax). What do the lunar inhabitants look like? Fontenelle is honest enough to say that he knows little about this. He compares the space between the Earth and its satellite with the ocean that separates the known landmasses from the mythical Terra Australis and he recalls how little we knew about America before the voyage of Columbus, less than 200 years earlier. Imagine how the Indians felt when they first saw the white sails and heard the thunder of the guns! "Aprés cela, je ne veux plus jurer qu'il ne puisse y avoir commerce quelque jour entre la Lune et la Terre . . . L'art de voler ne fait encore que de naistre, il se perfectionnera, & quelque jour on ira jus'quà la Lune". (. . . some day we shall travel to the Moon). Like the Indians who knew the art of sailing before the arrival of Columbus, perhaps the lunar inhabitants have already visited Venus?

During the Third Evening, Fontenelle has to admit that the Moon nevertheless is different from the Earth: it has no clouds. There are no "exhalations" from the Moon which must therefore be "infinitely more hard and solid than our Earth". The lunar "mare", which were earlier taken to be seas of water, are possibly just cavities. "But must we then abandon our belief in lunar habitants?", worries Madame. Surely not, maybe the lunar air is different from ours and cannot be seen. And the moment we observe some motion on the lunar surface, the habitants must be there. But if the air around the Moon is different, it might not be so easy to travel to the Moon. It is difficult to breathe on the highest mountains on the Earth, so there appears to be a natural barrier.

Then Fontenelle continues to Venus and talks about the variety of life. He mentions the mini-fauna on a leaf and feels that the further away a planet is from the Earth, the more different must be the life-forms it harbours. "My imagination is overcome by the infinite multitude of inhabitants of all these planets!", exclaims Madame. "Perhaps the inhabitants of other worlds have a sixth sense beyond the five we have", says Fontenelle and he goes on to ask whether Madame is now satisfied? Indeed she is and she looks forward to happy dreams about extraordinary creatures on other worlds.

The Fourth Evening Fontenelle continues the fictive journey in the solar system. He makes a mistake in stating that Venus is 40 times smaller than the Earth, although astronomers at that time already knew that they are of about the same size. The talk centres on the inhabitants on Venus and Mercury (who must feel hot, so near the Sun). Sunspots are described and the solar surface is compared to molten gold. There are probably no inhabitants on the Sun; "anyhow the poor people would not be able to see the planets and the stars" adds the Marquise. Then onwards to Jupiter with a description of Galileos observations of the moons. Fontenelle imagines, how Jovian astronomers discover the Earth. One of them believes that it is inhabited and his colleagues laugh at him. The rings of Saturn must be a beautiful sight to those who live there.

### Cosmology

At this point, Fontenelle introduces the Cartesian theory of vortices, which was put forward by Descartes around 1640: "Ah! Madame, répliquayje! Si vous sçaviez ce que c'est que les Tourbillons de Descartes, ces Tourbillons dont le nom est si terrible, & l'idée si agreable". (According to this theory, the universe is filled with a thin fluid which rotates in whirls (tourbillons) around the sun and the stars; the rotation carries the planets along.)

Coming now to the stars on the Fifth Evening, which according to Fontenelle must be at least 50 million miles ("lieuës") from the Earth, the Marquise wishes to know whether they are also inhabited. But her teacher explains that they are suns like our own and that each has its own vortex. There are small and large vortices and sometimes a new star can be seen in the sky. The Milky Way consists of myriads of stars and our solar system is just a small part of the Universe. In some places, the stars must be quite near each other and there the poor people live in eternal daylight and cannot sleep! And others may live in big vortices, far from their central star, in "les tenebres tres-profondes" (deep shadows).

Madame wants to know if a star, itself a source of light, may die and again Fontenelle refers to Descartes, who thought that sunspots may grow and ultimately cover the entire surface of the unlucky Sun – "Adieu le Soleil!". Indeed the Sun seems to have been rather faint

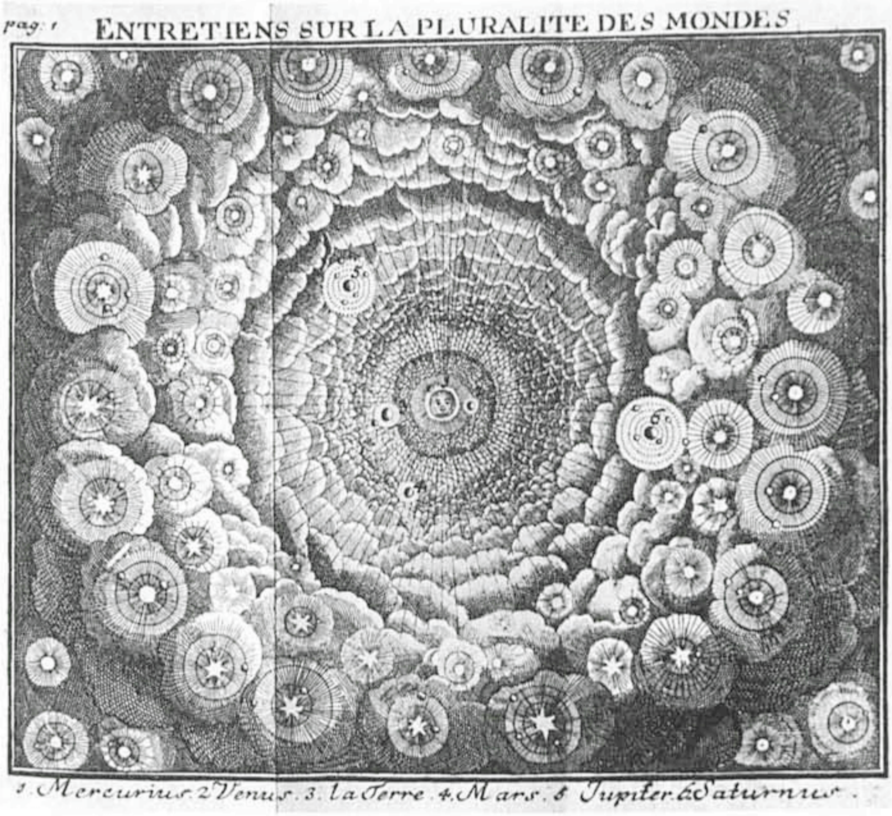


Figure 3: *The solar system, surrounded by fixed stars, each with its vortex. From the French edition in 1750.*

during some years, for instance after the death of Caesar. Naturally, Madame is rather upset, but Fontenelle reassures her that much time is needed to destroy a World. As a matter of fact, the stars and the Sun live very long; we still see the same as our ancestors. Very poetically, he compares us with roses in a garden – each generation of roses sees the same gardener.

And here the text ends with the following words: "Oh", she exclaimed, "I have now the entire Universe in my head! I am learned!" "Yes", I replied, "you are reasonably so . . . I only ask you to recompense my efforts by not looking at the Sun, the sky or the stars without thinking of me".

### Conclusion

I hope that the above has given a feeling of Fontenelle's book, its contents and form. We may of course smile at some of the ideas and we certainly think that there is too much talk about very hypothetical themes, like the lunar inhabitants. However, we must be impressed by the clever presentation techniques and also Fontenelle's ability to foresee his readers' objections and then convince them by easily understandable logics. He obviously fascinated contemporary readers with his most lively language and vivid examples.

The observational astronomy of Fontenelle's time was mainly descriptive and mostly concerned with the determination of positions of celestial objects. Astrophysics had not really started yet. And only one year after the first edition of "Entretiens", Newton's "Principia" in 1687 did away with all of Descartes' vortices. Still, Fontenelle was a pioneer in the popularization of our science, whom we ought to honour as such. Having made his acquaintance, his colleagues of later times may reasonably wonder, how their literary products will appear to well-informed readers after 300 years.

# The First School for Young Astronomers Organized by ESO and the Astronomical Council of the USSR Academy of Sciences

The first international school for young astronomers organized jointly by ESO and the Astronomical Council of the USSR Academy of Sciences took place from the 22nd to the 29th of September at the Byurakan Astrophysical Observatory of the Academy of Sciences of Armenia and was dedicated to "Observations with Large Telescopes". It was appropriately closed with a one-day visit to the Special Astrophysical Observatory at Zelenchukskaja, in northern Caucasus, home of the 6-m telescope, the largest in the world. The lecturers came from ESO and from the Soviet Union; the 45 participants were from ESO member states, from Bulgaria, Czechoslovakia, the German Democratic Republic, Poland, Spain and the USSR. After the welcome addresses by Academician V.A. Ambartsumian and by E.Ye Khachikian, Chairman of the Local Organizing Committee, the school was opened by M. Tarenghi of ESO who spoke on the characteristics of existing ESO telescopes and on the innovative features of the ESO 3.5-m New Technology Telescope, to be erected at La Silla next year. H.A. Abrahamian and J.A. Stepanian of the Byurakan Observatory presented the Byurakan 2.6-m telescope and the 1-m Schmidt respectively, illustrating the scientific programmes carried out in the recent past and presently at these two facilities.

V.L. Afanas'ev and L.I. Snezhko of the Special Astrophysical Observatory spoke on the history and the status of the 6-m telescope of the Academy of Sciences. The project was started in 1960 and had to cope with two difficult tasks: fabricating the largest mirror ever and building and controlling a large mounting of alt-azimuth design. From the present performance of the telescope (90 % of energy within 0.8 arcsec, accurate tracking and pointing) it can now be stated that the effort has been very successful. Possibly the one limitation of the telescope is the quality of the site, which even though quite good by European standards, does not compare in a favourable way with locations in Hawaii, northern Chile or the Canary Islands in terms of numbers of clear nights. Three talks were dedicated to instrumentation at Large Telescopes: S. D'Odorico and A. Moorwood of ESO spoke of instrumentation for imaging and spectroscopy at optical and infrared wavelengths respectively; S.N. Dodonov of the techniques for multiple-object spectroscopy at the 6-m telescope. Data processing was the subject of the talks by T.Yu. Magakian, who presented the system implemented at Byurakan (ADA) and by T. Kipper who spoke about computer analysis of high-

resolution spectra at the Tartu Observatory. The subject of Very Large Telescopes of the future (aperture larger than 8 m) was treated by Prof. Woltjer, who illustrated the options open in this field and discussed in detail the properties and the status of the ESO 16-m equivalent diameter VLT project, now submitted for approval to the ESO member states. N.V. Steshenko from the Observatory of Crimea presented the preliminary plans to build in the USSR a 25-m diameter telescope with an adaptive primary mirror made up of 1-m circular segments. Our kind host in Byurakan, Academician Ambartsumian, closed the school with an inspiring talk. Drawing on examples among the amazing number of astrophysical problems that he has effectively dealt with in his 50 year career, he stressed the importance of developing modern facilities and of collecting and analysing observational data to improve our understanding of the universe, not only to reach very distant but also intrinsically faint objects. There were also a number of short but interesting reports presented by the participants and a final general discussion. The subsequent visit to the Special Astrophysical Observatory, though brief, provided the unique opportunity to see the largest optical telescope of the world and the impressive RATAN 600 radio telescope.

This first school organized jointly by ESO and the Astronomical Council of the USSR met its goal to offer to the participants a wide view of the prospects of modern observational astronomy. For the lecturers, it was an opportunity to think over and discuss some of the most recent developments in astrophysics and instrumentation and to find out about work in progress in other observatories. This was especially useful since channels of information between scientific institutions in Eastern and Western Europe are relatively rare. It is hoped that the school will be repeated in 1989 in one of the ESO countries, and that it will serve as a regular meeting point between the two communities.

Acknowledgements are due to the Director General of ESO, L. Woltjer, and to the President of the Astronomical Council of the Academy of Sciences, A.A. Boyarchuk, for promoting and supporting this initiative. A special thank-you from all of the participants goes to Professor E.Ye. Khachikian, Chairman of the Local Organizing Committee and untiring driving spirit through all of the scientific and social events of the school. Possibly, the only action in which he did not actually take part was the football match between an ESO and the Byurakan Observatory team (Byurakan won after a hard fight 5 to 2). He, and the whole of the Local Committee, are to be praised for the perfect organization.

The week of the school was blessed by magnificent weather, which made the stay in Byurakan and the weekend excursions organized to various locations of historical and architectural interest a very enjoyable experience. The topics treated during the lectures will need to be updated with time, but the beautiful landscapes of Armenia and of the Caucasus have certainly found a permanent place in the hearts of all the participants.

*S. D'Odorico*

*Professors V.A. Ambartsumian and L. Woltjer.*

**Students to the 1987 School for young astronomers in Byurakan**

G. Aliakbarov, N. Andreassian, N. Asatrian, I. Bikmaev, E. Cappellaro, M. Della Valle, A. Dobrzycki, V. Elkin, E. Giraud, G. Goumelari, V. Ambarian, U. Hopp, M. Ibrahimov, L. Iliev, Yu. Isotov, G. Javachishvili, V. Karduamian, A.M. Khalinov, A. Krivtsov, J. Kubat, T. Kvernadze, S. Larsson, L. Leedjaerv, B. Leibundgut, H. Lehmann, U.P. Linde, A. Melkonian, K.J. Mighell, S. Milyutikova, R. Morganti, E. Nikogosian, I. Nosov, G. Petrov, M.M. Pierre, G. Pogosian, K. Postno Priebe, A. Prieto, A. Richichi, O. Silchenko, S. Sudakov, G. Tovmasian, M. Tsvetkov, M. Turatto, V. Vasjuk.

# First Fully Automatic Telescope on La Silla

*R. FLORENTIN NIELSEN, P. NØRREGAARD and E. H. OLSEN,*
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The Danish 50-cm telescope on La Silla can now do the observing all by itself for many hours, while the observer visits the kitchen or library; or maybe uses another telescope. This is accomplished by having a single computer set the telescope, centre on a star, manipulate the instrumentation and take care of the data acquisition. The observing rate for stars brighter than ninth magnitude is often around 30 per hour. The telescope is dedicated to Strömgren uvby-$\beta$ photometry, and the instrumentation consists of one unit, which contains a 4-channel spectrometer and a conventional 2-channel $H_\beta$ photometer. This instrumentation is only taken off the telescope, when the mirror has to be aluminized.

Autocentring is accomplished by scanning two slits, arranged in a wedge shape, across a small area of the sky. This is done by moving the telescope, while sampling the output from the uvby channels every 50 milliseconds. From the double-peaked profile detected, the position of the star is calculated and the star is centred. Of course, this requires positions of highest accuracy. It is recommended to use SAO Star Catalog positions *and proper motions* or data of similar quality (AGK 3), if possible.

Data acquisition can be done in two ways. An integration can be stopped, either after a specified number of seconds have elapsed, or after a specified number of photo-electrons have been counted in a chosen channel. Before a set of integrations is initiated, either the 4-channel spectrometer or the 2-channel $H_\beta$ photometer must be selected. The data are then recorded simultaneously from four or two channels, respectively.

To operate automatically the system needs at least three files stored on a hard disk:

(1) A star catalogue containing positions, equinoctium (= epoch), proper motions and identifications. The units of the two components of the proper motion are the SAO units (disregarding the decimal points).

(2) An output file to store results, error messages, and comments supplied by the observer.

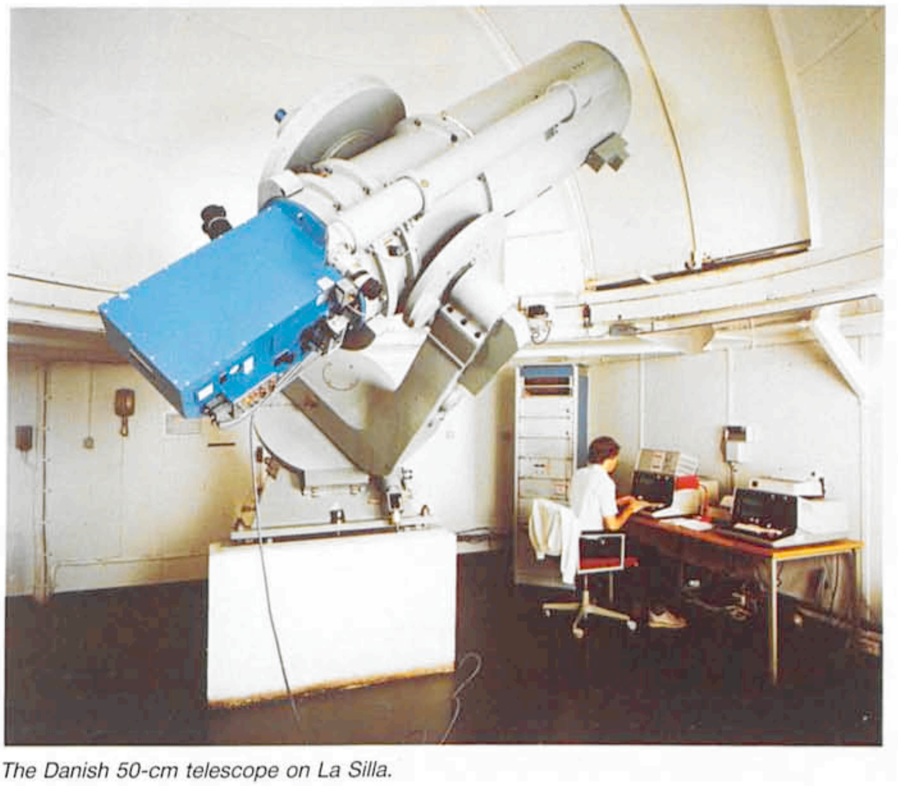
(3) A so-called command file, containing a set of instructions, which guides the telescope throughout the long, cold and windy night, while the bewildered photometrist sits in the comfortable office (or kitchen), still with too many layers of warm clothes on and a bit unsure about what to do with all his newfound spare time.

There is a variety of instructions with which to build up the command file. The philosophy is that each instruction should initiate a series of actions, which is a logical operational sequence. Therefore, most instructions are followed (on the same line) by a number of parameters. The most important instruction is OBS, which will slew and/or set the telescope to a selected spot on the sky, initiate an autocentring (if that is wanted), select one of the two instrument sections, select diaphragm size and initiate an integration sequence, the details of which can be specified as mentioned above. In an ordinary observing programme the only difference between successive OBS instructions will be the record number (referring to the star catalogue), which defines the telescope position. This record number may be replaced with N, which selects the next star in the star catalogue. A jump instruction (JMP) makes it possible to define an endless loop, which will observe all stars in the catalogue successively. After the last star has been observed, the next star selected is the first star in the catalogue. Thus, if the catalogue contains only three stars (e.g., a variable and two comparison stars) many hours of a light curve will be recorded without any intervention from the observer. Of course, there is also an instruction for off-setting to facilitate measurement of the sky background (OFS). The instruction SIT will read the sidereal time and make a jump decision according to the result.

It is obvious that a command file must be prepared with the same care as a computer programme. Further information and details can be found in the manual by P. Nørregaard. It will be sent to you, if you write to E. H. Olsen (Brorfeldevej 23, DK-4340 Tølløse, Denmark).

It is still possible to operate as usual in the human – and, therefore, slow – mode: type in coordinates and equinoctium, set telescope, centre star by eye, select integration stop conditions, type identification, start integrations, etc., all manually. But even for faint stars with less accurate coordinates it is a distinct advantage to use a command file. The instructions can be executed one at a time, and the OBS instruction can be truncated to exclude the integration instructions, so that only a setting and an attempt at autocentring will be made. The observer can then go to the telescope and locate his star.

Finally, a few words about the advan-



*The Danish 50-cm telescope on La Silla.*

tages of simultaneous multi-channel photometry compared to conventional single-channel photometry. If the seeing is variable on short-time scales, this will affect differently every single filter measurement made with a single-channel photometer, thereby ruining both colour indices and magnitudes. In simultaneous photometry only the magnitudes are affected, but colour indices are unaffected, i.e., it is still possible to obtain the astrophysical information about temperature, absolute magnitude and metallicity with the highest accuracy. Any variable absorption, *which is grey,* has the same effect on the measurements. This means that field star programmes aiming at, e.g., galactic structure studies, are unhampered by cirrus clouds. Variable star research with our equipment, however, still requires photometric conditions.

We hope that even more observers will exploit the Danish equipment in the future.

Welcome to the Strömgren Automatic Telescope.

# A New CCD Camera for the Echelec Spectrograph

*A. GILLIOTTE and P. MAGAIN, ESO*

The Echelec spectrograph, installed at La Silla in 1973, was designed to be used with an electronographic camera. However, by adding a flatfield corrector, it can be operated with other detectors, such as CCD's. As part of the upgrading programme of the 1.52-m telescope, and in order to improve the spectroscopic capabilities of that instrument, the Echelec spectrograph has been modified and is now working with the same CCD detector as used on the Boller and Chivens spectrograph.

The main modifications of the Echelec consist in the installation of a support for the CCD cryostat, a new Echelle grating, a TV slit viewer and a new calibration lamps unit, with flat-field and thorium lamps (and some others possibly available). The motorization of the cross-dispersion device, for automatic selection of the central wavelength, is in progress. An autoguider system should also be installed in the future.

In the present configuration, the Echelec is equipped with a 31.6 gr/mm Echelle grating and a 632 gr/mm Carpenter prism as cross-disperser. The linear dispersion varies from 3.1 Å/mm at 4000 Å to 4.5 Å/mm at 6000 Å. The cross dispersion amounts to 35 Å/mm. With an RCA chip as the detector, one frame covers approximately 275 Å, in 5 to 10 orders (see Fig. 1). A reasonable order overlap is insured up to 6500 Å, but the presently used flat-field corrector limits the spectral range to wavelengths lower than about 5500 Å. A 15 μm pixel corresponds to 0.65 arcsec on the sky, so that an optimal sampling is obtained with a 1.3 arcsec slit.

A few nights were allocated for the astronomical tests of this new combination in September and October 1987. The use of a 1.4 arcsec slit led to a resolving power of 32,000 (FWHM) as measured on the Th lines. As such, the Echelec resolution falls in between those of the CES with short camera ($R \approx 50{,}000$) and CASPEC ($R \approx 20{,}000$). The efficiency of the instrument was estimated by observing the spectrophotometric standard star HR 9087. With the same 1.4 arcsec slit, the measured count rate at 5000 Å corresponds to 0.6 electrons per second per wavelength bin (0.06 Å) for a star of visual magnitude 10. Taking into account the readout noise (57 $e^-$ per pixel) and the dark current (60 $e^-$ per pixel per hour) of the CCD chip used (ESO number 13), a S/N of 10 would be reached in 1 hour for a star of $m_V = 10.1$ ($m_V = 7.3$ for S/N = 100) in unbinned mode. A limitation of the present configuration is the rather high readout noise of the CCD chip number 13. Fortunately, the wide separation of the orders allows some binning in the direction perpendicular to the dispersion. This improves the S/N without any loss of resolution. With a binning of 4 pixels, the limiting magnitudes would be $m_V = 10.6$ and 7.7, for a S/N of 10 and 100, respectively, in 1 hour.

To give the potential observer a better feeling of the quality of the Echelec spectra, we reproduce in Figure 2 one order of the spectrum of the solar-type star HR 810, after flat-fielding and calibration in wavelength. The exposure time was 30 minutes, in rather poor meteorological conditions.

In its present state, the Echelec spectrograph is able to produce useful results in the blue-green spectral range (up to 5500 Å). It is expected to help lowering the pressure on the CASPEC and CES spectrographs. Further improvements should allow to extend the

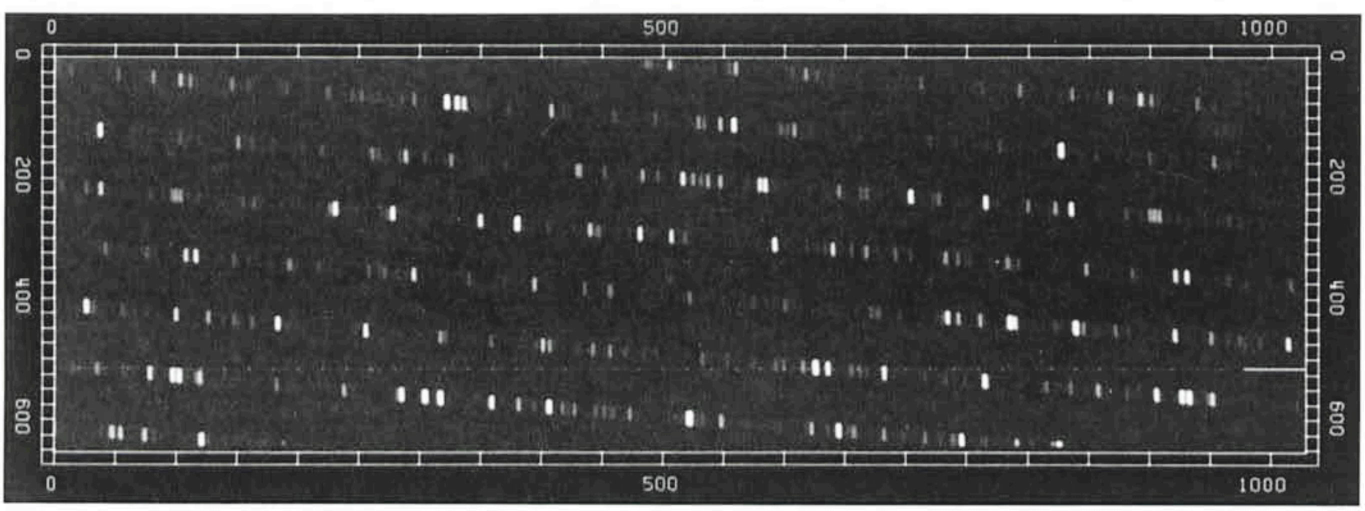



Figure 1: *CCD frame of the Thorium hollow cathode lamp in the region 5300–5600 Å.*

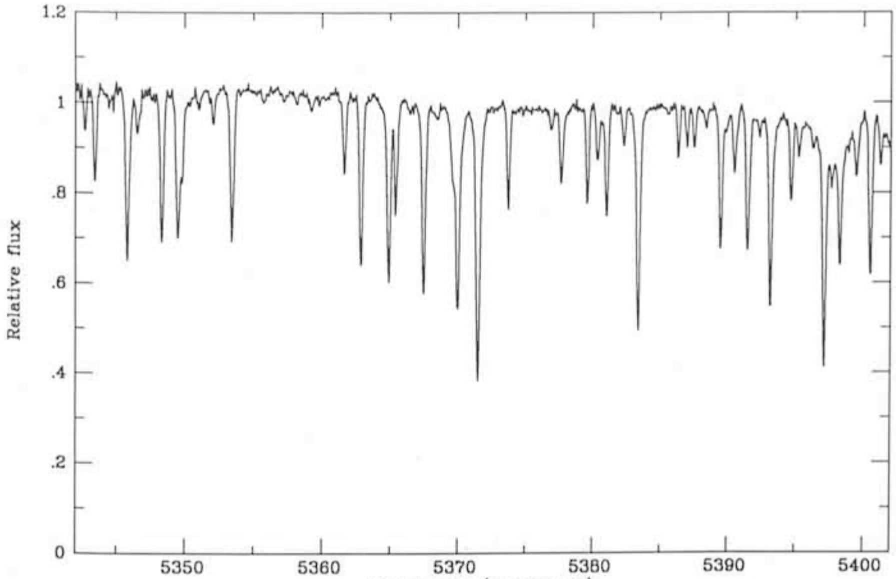



Figure 2: *Portion of the spectrum of the solar-type star HR 810 in the spectrum order 107 (5340–5400 Å) recorded on October 6, 1987 with the Echelec.*

spectral range available in one exposure.


## Acknowledgements

We thank Mr. W. Eckert for his help on the mechanical design. The design of the Echelec spectrograph was by A. Baranne. The implementation of the CCD at the Echelec was proposed in a feasibility study by J. Breysacher, B. Delabre, S. D'Odorico, A. Gilliotte and P. Giordano on the improvement of the spectroscopic capability of the 1.5-m ESO telescope.


# First Results from Remote Control Observations with CAT/CES


*P. FRANÇOIS and E. BROCATO, ESO*


As announced in the *Messenger* No. 49 (September 1987) by G. Raffi, the CES spectrograph with CCD (using the CAT telescope) is now available by means of remote control from Garching.

In testing remote control operations, in October 1987, we had time to obtain some spectra which are interesting from an astrophysical point of view.

Of course, even if a night assistant was available at La Silla, most of the standard observation procedures were done from Garching: the pointing of the telescope, identification of the stars, all the operations available on the instrumental console (setting of the instrument, definition and start of exposures, etc.). For files containing CCD spectra, a typical transfer time from La Silla to Garching was about 1–1.5 min. This means that quick-look analysis was possible on-line and that all spectra could be transferred to Garching, making full data reduction possible only few "hours" after the observing night.

## Observations

Three stars have been observed: HD 211998, HD 219617 and HD 4307; the detector was a high-resolution CCD (1,024 × 512 pixels) and the CES was used with the long camera configuration. The resolving power was about 60,000 and the signal-to-noise ratio was not less than 100. The reduction procedure has been described in detail in a previous paper (François 1986). As an example, a part of the spectrum of HD 211998 is shown in Figure 1.

The observed stars have been previously studied by Laird (1985) and the main characteristics of their atmospheres are known. With these parameters, we have interpolated the models in the grid of Gustafsson's model for dwarf stars (Gustafsson 1981) computed under the same assumptions as in Gustafsson et al. (1975). The oscillator strengths of the lines have been determined by fitting the profiles of lines to the solar atlas of Delbouille et al. (1973). The oscillator strength of the Barium line has been taken from Wiese et al. (1980) and the value has also been checked on the solar spectrum. In the computations, the solar abundances of Holweger (1979) have been adopted and we have followed the results of François (1986) concerning the main assumptions and procedures used for computing the lines.

The errors have been estimated by assuming possible uncertainties in the atmospheric parameters ($\Delta T$ = 100°K, $\Delta V$ = 0.5 km/s, $\Delta \log g$ = 0.3). This leads to an error estimation of ± 0.15 dex.

## Results

In Figure 2, we have plotted the [Ba/Fe] as a function of [Fe/H] for our three stars and very recent data coming from Magain (1987) and Gilroy et al. (1987). Our measures are in good agreement with the observations of dwarf stars done by Magain. Gilroy and col-

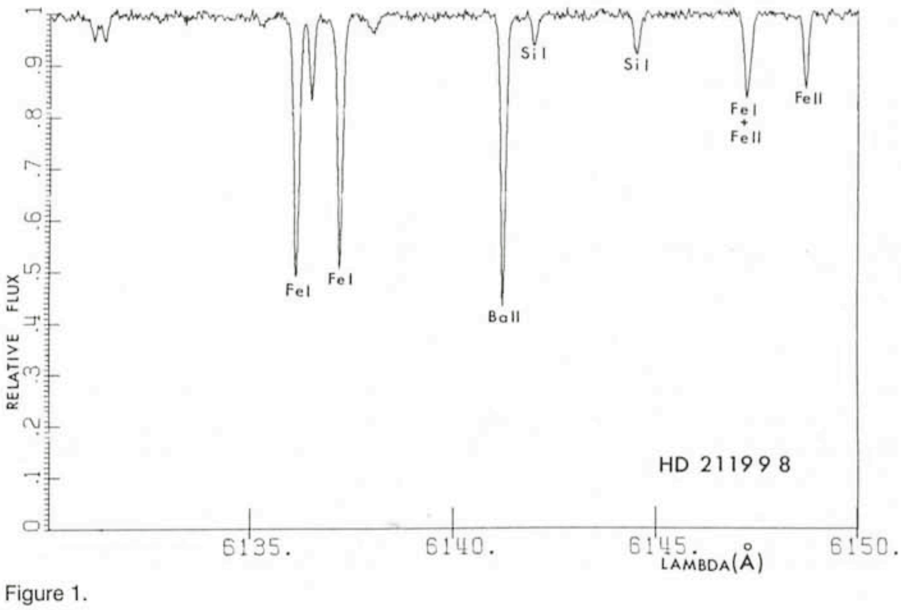



Figure 1.

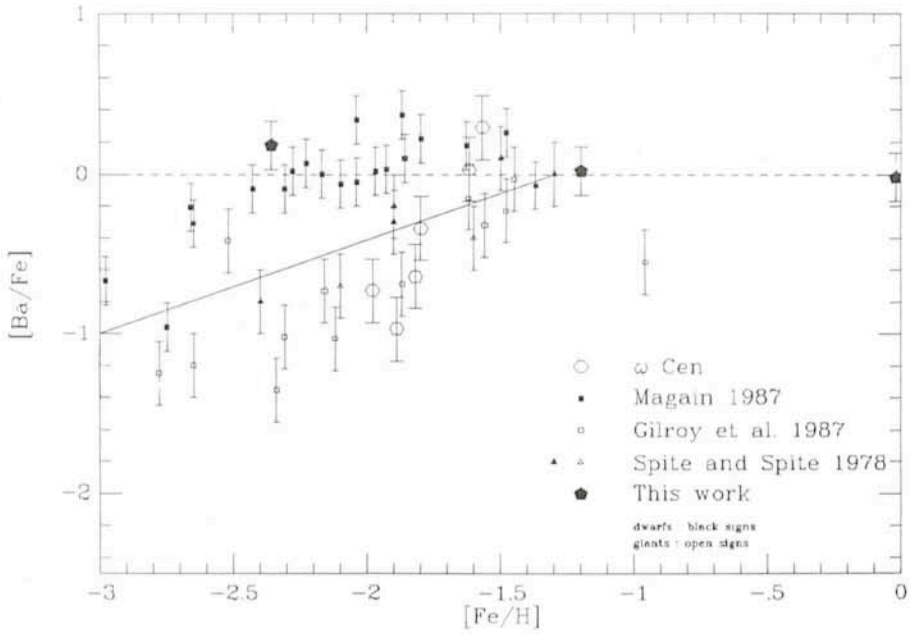


Figure 2.

laborators have observed only giants. Figure 2 shows that, for a given metallicity, the [Ba/Fe] ratio is lower when measured in giants than in dwarfs. In the same figure we have also drawn the line representative of the [Ba/Fe] versus [Fe/H] relation deduced by Spite and Spite (1978) from observations of a sample of dwarfs and giants. It is noticeable that this line separates data obtained from giants and data obtained from dwarfs. This is not surprising because this line has been deduced from a mixed sample of stars. We are quite confident that these results show that there is a systematic difference in the [Ba/Fe] determination between dwarfs and giants when we consider stars with a metallicity lower than [Fe/H] = −1.5. The difference in abundance determination can be as high as 1 dex, and this cannot be explained by stellar evolution theory.

These results are very important if one wants to compare abundances in metal poor globular cluster giants and metal poor field dwarfs. To stress this last consideration we have also plotted (in Fig. 2) the abundance determination of Ba in six ω Cen giants (François et al. 1987). These data are distributed in the "giant part" of the diagram and are a good demonstration of the importance of understanding the origin of this systematic effect. In fact, we should remember that all the detailed abundance determinations in globular clusters come from spectroscopic analysis of giant stars. For this reason we plan to go deeper into this problem, with more extensive and systematic observations of giants and dwarf stars (other elements could follow this [Ba/Fe] behaviour), and we also intend to investigate the theoretical explanations of this kind of behaviour (non-LTE effects?).


### Acknowledgement

We wish to thank G. Raffi, G. Kraus and M. Ziebell for having made remote control possible and for introducing us to this new mode of working for astronomers. We are also grateful to F. Matteucci for reading the manuscript.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# CCD Observations of Comet Wilson at the ESO 1-m Telescope with a Focal Reducer


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*E.H. GEYER, Observatorium Hoher List, Daun, F.R. Germany*


Comet Wilson 1986f was discovered in early August 1986 on plates taken with the 1.2-m Schmidt telescope at Palomar in the course of the new Palomar Sky Survey. Preliminary orbital elements published by the Central Bureau for Astronomical Telegrams as early as August 11 indicated that the comet had a nearly parabolic orbit and would reach perihelion only in April 1987, more than 9 months after discovery. Therefore this comet belonged to the as yet very small group of non-periodic comets, for which it was possible to propose observations in time for the proposal deadlines. This gave us the unexpected opportunity to study, besides Comet Halley (1), yet another comet with different characteristics.

We observed Comet Wilson at the ESO 1-m telescope from April 24 until April 30, 1987. At this time the comet had just passed perihelion and was located at a declination between −70° and −77°. Being circumpolar, the comet was visible all night but it was in conjunction with the sun, i.e. went through lower culmination around midnight. Therefore the comet was always at elevations between 10° and at most

Figure 1: *The 1-m telescope with focal reducer in its unusual position to observe Comet Wilson. Two small wide-field photographic cameras are mounted on the front ring.*

40° above the southern horizon, by far not an ideal observing position. Given the fact that the comet was observable all night it seemed possible to tolerate the large zenith angle.

For the observations the focal reducer of Hoher List Observatory and the Max-Planck Institute for Aeronomy was used. This system is similar to EFOSC and consists of a lens collimator of 760 mm focal length corrected between 360 and 660 nm and, depending on the wavelength range, a blue (360–500 nm) or red (420–660 nm) camera lens system of 140 mm focal length. Instead of the previously used image intensifier we employed a CCD camera built by C. McKay, Astromed, Cambridge, UK, and a GEC 8603/B chip which had been coated for UV sensitivity with a fluorescent coating at ESO Garching (2).

The scale of the reduced image on the CCD is about equal to the scale of the ESO Schmidt telescope but, instead of the Schmidt plate of 300 × 300 mm size we are limited to the size of the CCD chip of approximately 8 × 12 mm (the optics provide a corrected field of 25 mm diameter). The effective f-ratio is f/2.8. One pixel of the GEC chip of 22 μm width corresponds to 1.6 arcsec on the sky. Two grisms of 300 and 600 grooves/mm can be placed into the parallel beam for spectral work in the visible and UV spectral ranges. Because of the small size of the CCD-chip we could not use a slit mask as with Comet Halley but had to restrict ourselves to a single long slit of 10 arcmin length across the chip. The grisms can be replaced by interference filters to provide direct images. In the blue spectral range, where most of the interesting cometary emissions are located, the interference filters serve as an order selector for a narrow-gap tunable etalon which provides images with a spectral bandwidth of 15 Å. The CCD is controlled by an HP 300 computer with a small colour terminal and 3 MByte memory. Figure 1 shows the 1-m telescope in its unusual position to observe Comet Wilson. In the telescope fork the CCD controller is visible. The optics of the focal reducer and the CCD dewar are on the "wrong" side of the telescope fork and therefore hidden from view. On the wheeled table the etalon controller can be seen. As in our Comet Halley run, two small cameras were mounted on the telescope front ring to provide overview images of the comet and slitless wide-field spectra on IIa-O plates. As we were told this was the first time that a CCD was used at the 1-m telescope.

As compared to comet Halley, Comet Wilson was a rather weak object. This is demonstrated in Figure 2 where wide-field images of Comet Halley and Comet Wilson are compared which were taken with identical equipment and exposure times. In the figure the heliocentric distances of both comets are about 1.2 A.U., but Comet Halley was at a geocentric distance of 0.45 A.U. as compared to 0.64 A.U. for Comet Wilson. During our observations Comet Wilson always displayed a thread-like ion tail and a short dust tail strongly curved towards west. Because of weather conditions only three of the six nights awarded to the project turned out to be useful. The first night was devoted to getting UV-spectra to derive ion compositions in Comet Wilson's coma. The spectra are very weak. At the end of the night we obtained a well-exposed interference filter image of the comet tail in the light of $CO_2^+$ at 367.4 nm. Therefore it was decided to use the etalon in the second night to study the $CO_2^+$ tail and the nearby continuum with increased spectral resolution as had been done

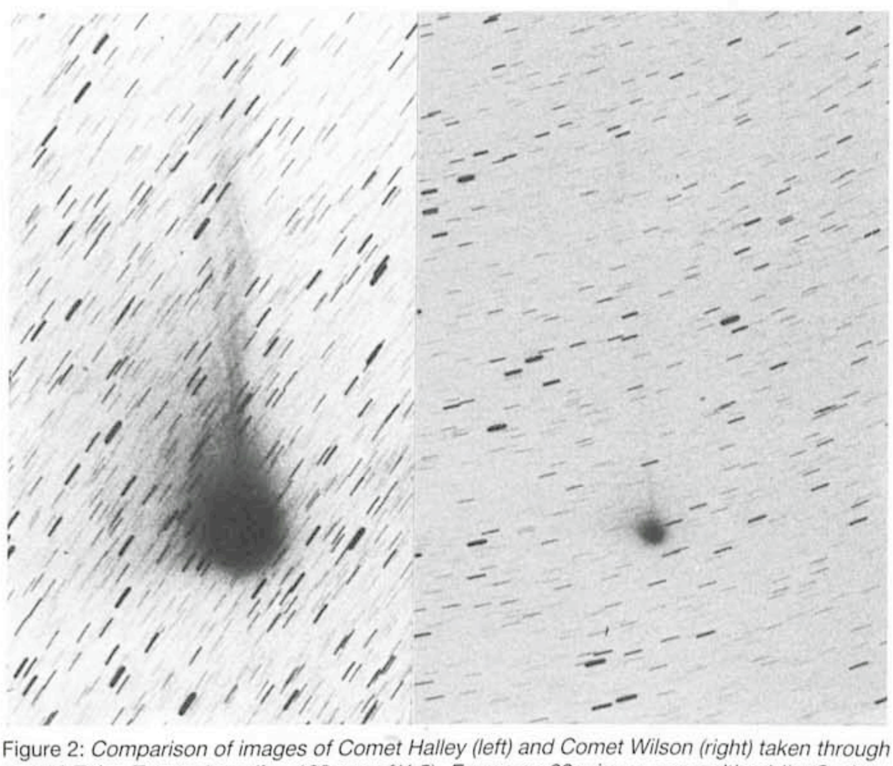

Figure 2: *Comparison of images of Comet Halley (left) and Comet Wilson (right) taken through an old Zeiss Tessar lens (f = 180 mm, f/4.5). Exposure 60 min on unsensitized IIa-O plate. Comet Halley: April 11, 1986. Comet Wilson: April 28, 1987.*

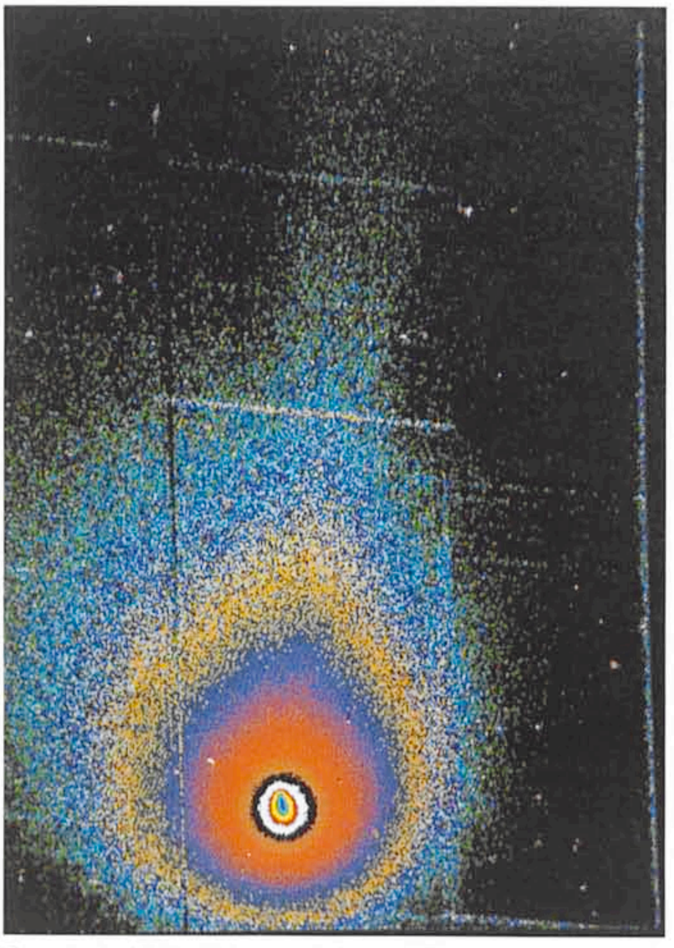

Figure 3: *A CCD raw image of Comet Wilson taken through an interference filter of 10 nm bandwidth centred at 426 nm ($CO^+$, $N_2^+$, $CH^+$). Exposure 30 min, April 29, 1987.*

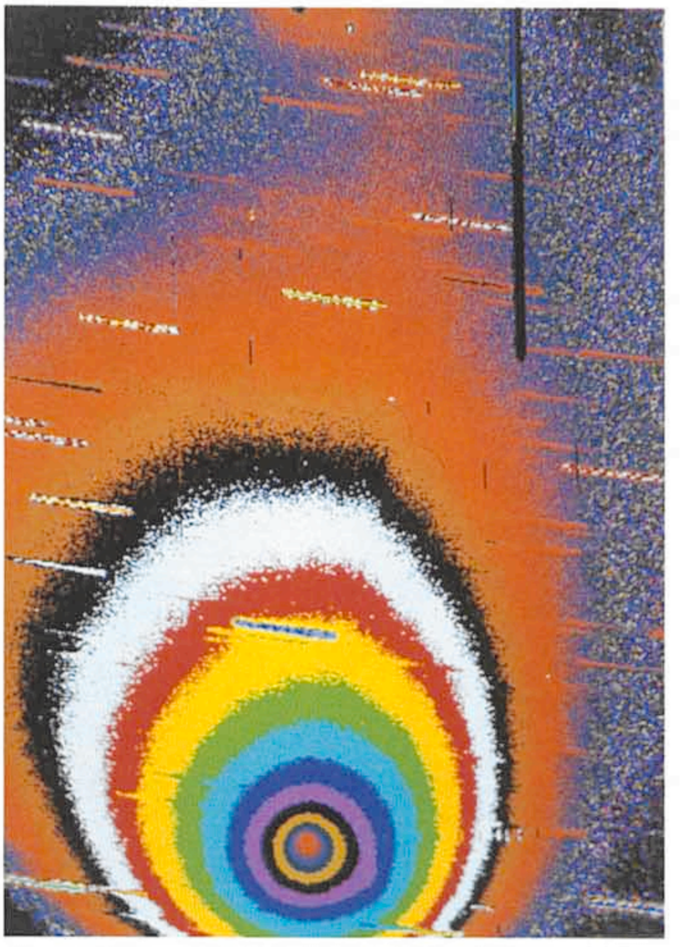

Figure 4: *A CCD raw image of Comet Wilson taken through an interference filter of 20 nm bandwidth centred at 660 nm ($H_2O^+$, $NH_2$, $C_2$). Exposure 5 min, April 29, 1987.*

very successfully with Comet Halley (3). Despite good transparency of the atmosphere in this night, we were unable to obtain any useful $CO_2^+$ images but, to our surprise, we found an $N_2^+$ ion tail at 391.4 nm. In the third night we used the "red" camera to record images and spectra in the range 420–650 nm. Figure 3 shows a false-colour image in the light of the $CO^+$ ion at 426 nm. Some $N_2^+$ or even $CH^+$ emission may contribute to the image. In this raw image each new colour represents a factor of 1.4 in the signal. The plasma tail is well visible. The dust continuum is noticeable from the elongation of the isocontours towards west (left side of figure). In Figure 4 we present an image of the comet taken through an interference filter centred at 660 nm with a bandwidth of 20 nm. Again each new colour represents a factor of 1.4. This image shows the $H_2O^+$ tail (O-7-O band) and a strong dust continuum. In addition, a neutral coma of $NH_2$ and of the $\Delta v = 3$ band of the $C_2$ Swan sequence fall into the filter bandpass (notice the strong intensity gradient around the nucleus). In the top of the frame a ghost image of the inner coma (scattered back from the CCD and reflected at the interference filter) appears. The spectra, which were taken with the slit intersecting the tail at right angles 5 arcmin from the nucleus, show the $C_2$ Swan band and some $H_2O^+$ lines against the background of an extensive night sky spectrum.

We would like to thank S. Deiries and S. D'Odorico for the coating of our CCD to make it UV sensitive and D. Hofstadt and his crew for their effort to find a possibility to point to the comet with our focal reducer. We appreciate help from P. Sinclaire concerning our CCD camera.

### *References*


(1) Jockers, K., Geyer, E.H., Hänel, A.: 1986, *The Messenger* No. **44,** 12.
(2) Cullum, M., Deiries, S., D'Odorico, S., Reiß, R.: 1985, *A & A* **153,** L 1.
(3) Jockers, K., Geyer, E.H., Rosenbauer, H., Hänel, A., 1987, *A & A,* in press.


# MIDAS Memo

*ESO Image Processing Group*

### 1. Application Developments

The routines for calculating centres of stellar images have been improved by M. Ghigo to take into account the finite pixel size. This gives a significantly better accuracy for undersampled images such as direct EFOSC frames taken with a good seeing. For well exposed images a positional error of less than 0.02 pixels can be reached.

The first MIDAS version of the ROMAFOT photometry package (ref. R. Buonanno) is foreseen for the 88 JAN 15 release. Although the user input to the package differs in some respect from the original version, the MIDAS implementation will provide all basic features of the original. The first release will still be based on the internal ROMAFOT data format; subsequent future releases will work on MIDAS images directly and will use the table file system for the storage of the extracted parameters.

In the new release the plot package will be upgraded by adding the possibility of specifying the formats of the axis tick labels. In addition, a command PLOT/GRAY is now implemented which allows the production of gray scale plots on all graphic devices supported. The 88JAN15 release of MIDAS will use the AGL version 2.1.4.

A new context has been included in collaboration with M. Pierre. The context, in this preliminary version, contains three commands to model interstellar lines.

Work on the reduction and analysis of IRSPEC data is in progress.

### 2. Manual

As the MIDAS manual has now outgrown its present folder, it has been decided to split it into two volumes. The first volume will contain a description of the MIDAS system including system commands, syntax, data structures and general applications. It will also give the full help text of all available commands. The second volume will deal with data reduction using MIDAS. There will be chapters describing the general reduction of different types of astronomical data and several appendices each devoted to a specific ESO instrument.

### 3. Measuring Machines

The upgrade of the OPTRONICS measuring machine with a high speed scanning is in progress. The problems associated with the reticon array were solved and it is now possible to digitize and calibrate its 256 elements in approximately 20 msec. The main limitation on the speed is the MC68010 processor which does the dark current and flat field corrections. Due to significant delays in the delivery of disk drives and network equipment it is unfortunately not yet possible to offer the scan mode to users. We expect to switch to the new microprocessor control system in the spring of 1988 and offer the scanning mode to visitors in the summer.

After reviewing the usage of the GRANT machine it has been decided to discontinue its operation as of August 1988. After this date, measurement of coudé spectra must be done on the OPTRONICS machine. Those who want to use the GRANT machine are strongly encouraged to arrange for time as soon as possible.

### 4. MIDAS Hot-Line Service

The following MIDAS Support services can be used in case of problems to obtain fast help:

- EARN: MIDAS@DGAESO51
- SPAN: ESOMC1::MIDAS
- Tlx.: 528 282 22 eso d, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

Also, users are invited to send us any suggestions or comments. Although a telephone service is provided, we prefer that requests are submitted in written form through either electronic networks or telex. This makes it easier for us to process the requests properly.

# NTT Status

*M. TARENGHI, ESO*

Work on the NTT telescope is progressing at full speed both in Europe and on its location at La Silla. During September and October this year there was extensive preparation of the ground and roads on La Silla. Civil engineering work began on the small hill next to the 3.6-m telescope at the place which was used during the past years for the Geneva Observatory Telescope. About 3000 $m^3$ of earth was removed by means of a sequence of minor and finely controlled dynamite explosions. Figure 1 shows the Chilean workers in the process of checking the locations of 28 explosions. The picture also shows their precautions to avoid excessive damage to the surrounding area. Large lorry tyres are placed on the ground and a strong metallic net is used as a protective cover. Figure 2 shows the explosion some minutes later. The smoke on the top of the hill indicates the future location of the NTT.

Following the excavation work the task of ensuring a flat surface began and a bulldozer opened the way for the 3 access roads foreseen in the project. Figure 3, taken on 28 October 1987, shows the subsequent preparation of the concrete slab upon which the NTT will stand.

The civil engineering work is expected to be completed in February 1988. In the meantime construction of the rotating building has been completed in Europe and it will be shipped to Chile during the course of the next weeks. The unconventional shape of the building optimally combines the highest thermo-fluid dynamic demands resulting in greater protection of the telescope without introducing a dome seeing component.

The rotating building was conceived by F. Franza and W. Bauersachs at ESO

Figure 1.

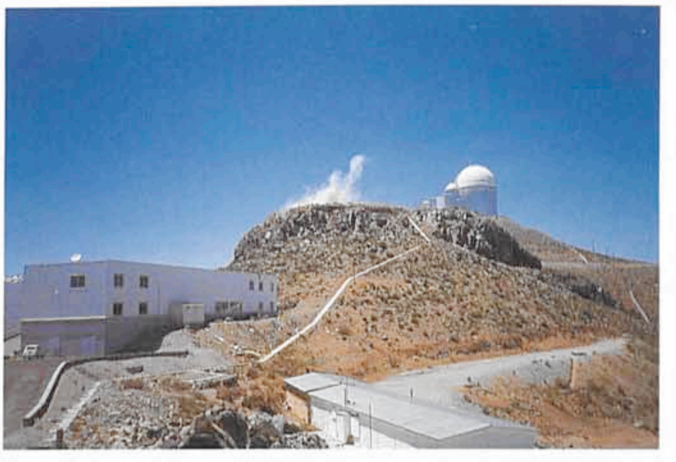

Figure 2.

Figure 3.

Figure 4.

and the design and manufacture was the result of a consortium of Italian companies (MECNAFER, Marghera; ZOLLET, Belluno; ANSALDO Componenti, Genova) in close cooperation with a number of European industries, one of which is RKS France who manufactured a roller bearing of 7 m diameter which will be the key unit of the rotation system. Some of the more sensitive elements of the construction have been premounted and tested in Europe to avoid unpleasant "surprises" on La Silla. Figure 4 shows a picture of the large square base measuring 8 m × 8 m which will be directly coupled with the RKS bearing which will support the entire load of the rotating building.

Figure 5 shows the preassembled 12 m high windscreen undergoing a series of functional tests at MECNAFER, Marghera (Italy). This permeable windscreen was specially designed for the NTT telescope. The red frame supported by scaffolding which is used only for the tests in Europe, guides horizontal bars with interconnecting strong, permeable material (of the type used for yacht sails). It operates by slowing down the speed of the wind and thus protects the telescope. It will be integrated in the complete structure and will operate automatically when the wind speed increases. Erection on La Silla of the rotating building will take almost 6 months to complete, starting in February 1988.

At INNSE, Brescia (Italy) the mechanical structure and electronic hardware has been completed and the software integration phase has started. The telescope can already perform elementary functions such as pre-setting, slewing, and tracking. Particular attention has been given to the measurement of the resonance frequency of the telescope resulting in the lowest resonance frequency of around 9.5 Hertz in perfect accordance with the calculation values.

The telescope's expected shipment to Chile in March 1988 has been confirmed by the present progress of work.

The telescope will be equipped with a Schott Zerodur primary mirror (M1) of the meniscus type with aspect ratio D/h = 15, F-number F/2.2 and a weight of 6 tons. The mirror blank was delivered to the optical workshop of Carl Zeiss in June 1986. After 78 axial invar pads had been glued to the back of the mirror unit and adjustment of the delicate support system, the aspherical deformation of about 200 μ took place under IR-interferometric control.

Just above the polishing machine is a laser-interferometer set-up with 3D stabilization which monitors accurately the figuring process and responds with full computational evaluation via a direct wire to a μVax computer.

With "high tech" equipment of this kind, Carl Zeiss is on the way to reach the intrinsic optical quality requested by ESO, so that 80% of the light energy is concentrated in 0.15 arcsec at the Nasmyth focus. At the end of October 1987, progress with the M1 mirror was extremely encouraging and the average radial profile was smoothed to a rms of 32 nanometers. The small flat tertiary mirror has been completed with an intrinsic quality of 8 nanometers rms. The polishing process is well within the time schedule and completion is expected around the middle of 1988.

Considering the present situation with the project we feel confident that we shall have the first light at the end of 1988.

Figure 5.

# An Interferometric Mode for the VLT

*P. LENA, Université Paris VII and Observatoire de Paris, France*

## 1. The Emergence of Optical Interferometry

The heart of the VLT concept is the choice of an 8-m thin mirror. As early as 1983 (at the Cargèse Workshop), it was thought that an array of several telescopes, with its great flexibility, might be preferable to a giant Multi-Mirror Telescope. An array concept was presented at IAU Colloquium 79 in April 1984. It immediately appeared obvious then that one had to investigate whether a coherent combination of the array telescopes would be possible. On the one hand, formidable difficulties were expected, on the other it presented an exceptional possibility to greatly increase the scientific potential of the VLT and to give it a unique and long lasting capability among planned instruments. This evaluation became the task of the Interferometry Working Group.[1]

The main questions to be answered were: Which gain can the use of large telescopes in optical interferometry bring? Do acceptable compromises exist between the interferometry requirements and the more conventional use of the VLT, as required by a large fraction of today's European astronomical community? Is interferometry technically feasible with large telescopes, given the limited experience in this field available today? Can the associated costs be identified and accepted?

Fortunately, during the investigation by the Working Group (1984–1986), the interest for diffraction-limited imaging at optical wavelengths rapidly grew within the community. The maturation of speckle techniques led to several discoveries: separation of Pluto and its moon Charon, resolution of the hypothetical supermassive star R 136a, of T Tauri, of the nucleus of NGC 1068. Shells (IRC +10216, OH-IR stars) and disks (MWC 349, IRc2) were identified in the infrared. Moreover, a spectacular image of the $\alpha$ Orionis dusty environment produced by C. and F. Roddier at the 3.6-m CFHT showed that interferometric techniques can also produce images. Two-telescope interferometry also emerged from the prototype to the operational stage (M. Shao, Center for Astrophysics interferometer at Mount Wilson), measuring stellar diameters with an accuracy not achieved since Michelson (R. Foy and P. di Benedetto at Cerga).

The considerable corpus of imaging techniques accumulated by radio-astronomers during the last 40 years became progressively available to optical interferometry: phase closure, a classical radio technique to overcome atmospheric and instrumental phase errors, was demonstrated in the optical in 1986 by J. Baldwin at Cambridge; image reconstruction procedures, in daily use at the Very Large Array or in VLBI, were found to be identical to specific techniques developed by G. Weigelt for optical interferometry, such as speckle masking.[2]

This short report will outline how it has become apparent that a coherent combination mode of the VLT is no longer an unreal dream. Indeed, in the mean time, other projects of large telescopes are exploring similar ideas: among the most advanced, the COLUMBUS (or "twin-shooter") project combines two 8-metre telescopes on a 15-m centre-to-centre baseline. Other large telescopes may be interferometrically combined in the future, but the originality of the VLT is to integrate the coherent mode *ab initio* into its design.

## 2. What is a Good Interferometer?

The quality of an interferometer may be judged by its angular resolution, its sensitivity and its instrumental profile. Each factor is wavelength-dependent over the broad spectral range (0.32 to 22 μm) observable from the ground.

Next generation telescopes (D = 10 to 15 m) may produce diffraction-limited images at resolutions of 4 to 300 milliarcsec at these wavelengths when operated in speckle mode (visible) or with adaptive optics (infrared). A ten-fold increase is obtained with 100–150 m interferometric baselines. This gain, needed to resolve a whole class of infrared sources just unresolved today, remains small enough to ensure continuity in the spatial frequency coverage.

The sensitivity of an interferometer is controlled by three factors: the average number N of speckles present in the image given by individual telescopes – or, in an equivalent manner, the average number of instantaneous atmospheric coherence areas on the telescope pupil; the integration time; the noise of the detector. Each of these is strongly wavelength-dependent, and no single conclusion applies to the whole range under consideration. Broadly speaking, three domains of increasing difficulty appear: beyond 10 μm, where N = 1 in good seeing; between 3 and 10 μm, where adaptive optics appear suitable to actively phase each telescope and obtain N = 1; shorter wavelengths, where N becomes large (>1,000) and difficult to reduce with existing techniques. A detailed analysis shows that the full sensitivity gain brought by a large mirror is only obtained when N = 1. When $N \gg 1$, the large mirrors do not improve the sensitivity limit, but reduce as $D^2$ the integration time necessary to reach a given signal-to-noise ratio. Only with D = 8 m will active nuclei of galaxies and quasars become observable at infrared wavelengths.

The issue of instrumental profile (Point Spread Function) is a critical one: modern radio-interferometers combine a large number n of movable antennas which sample densely the spatial frequency domain and give a PSF with limited sidelobes. Residual lobes are "cleaned" with a posteriori numerical treatment. Conversely, VLBI images are, *par la force des choses,* produced with a poor, very diluted frequency coverage, but nevertheless recovered at a high degree of quality by suitable algorithms. The recovery from atmospheric phase errors on each telescope requires to increase n at least to 4 and to use phase restoration methods such as phase-closure, not yet tested with multi-telescopes optical interferometry, or an analogous method developed for single telescope optical interferometry (speckle masking). It is on this particular issue of PSF that interferometry with the VLT is most compromising with the rules an ideal interferometer should obey: the large telescopes are fixed, only four will exist, and for aerodynamic reasons their baseline will almost certainly be linear. Depending on the site, the telescope spacing may be uniform (redundant) or cover different frequencies (non redundant): both configurations have advantages and drawbacks with respect to the final image quality. Since a coverage in the direction perpendicular to the baseline is essential, even with reduced sensitivity, the ESO VLT Proposal included two additional interferometric telescopes (ca. 2 m in diameter) movable on tracks perpendicular to the main baseline. Simulations have shown that a good image quality will result.

To summarize, if it appears practical to operate the VLT as an interferometer, this mode will offer an order of magnitude gain in resolution, several orders

[1] The VLT Interferometry Working Group was composed of R. Citterio (later replaced by P. di Benedetto), D. Downes, A. Labeyrie, P. Léna, J. Noordam, F. Roddier, G. Weigelt, J. Wijnbergen, with the ESO participation of D. Enard, F. Merkle, M. Sarrazin, R. Wilson and numerous outside contributors as the late L. Weliachew, and S. Guilloteau, R. Foy, A. Maeder, J.-P. Swings, etc. The group issued an Interim Report (No. 44), a Final Report (No. 49) and contributed to the ESO VLT Proposal (Chapter 12).

[2] The growing interest is shown by several successive meetings: ESO Conference on High Angular Resolution (Garching 1981); joint ESO-NOAO Workshop (Oracle 1987); ESA Workshops (Cargèse 1984, Granada 1987) and their copious Proceedings, as well as the increasing literature on the subject. A recent review (F. Roddier, *Physics Reports*, 1987, in press) gives over 1,000 references on "Interferometric Imaging in Optical Astronomy".

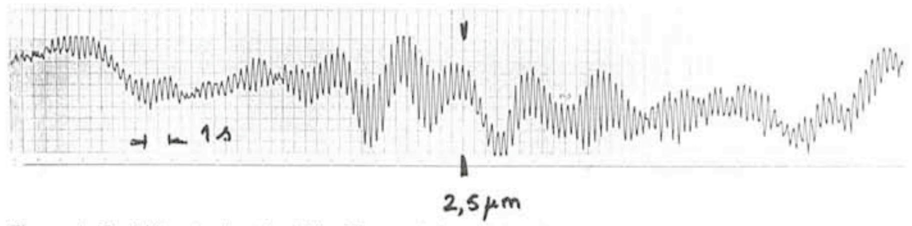


Figure 1: *Stability study at La Silla: The variation of the distance between the tops of the 3.6-m pier and the CAT pier at the base of each telescope, versus time, as measured with a laser interferometer, with a strong wind blowing outside. Horizontal axis: time; vertical axis: distance. A vibration appears at 5 Hz, but the stability of the distance is remarquable.*

of magnitude gain in sensitivity and/or integration time over smaller interferometers, and limited but appreciable imaging capabilities comparable to the ones of VLBI.

## 3. A Scientific Programme for Interferometry

On the basis of the above conservative performances, and when a factor of 20 in angular resolution is obtained over almost two decades of wavelength, a wide field of new observations and programmes will open. It is probably within the fields of star formation and galactic nuclei that the new contributions will become most important, at least during the first phase of infrared observations and programmes.

Only VLA centimetric observations give today access to the innermost part of the core of an object like L 1551, considered a prototype of a very young object. The high dust opacity of the disk and its temperature make infrared interferometry one of the most powerful tools to investigate the environment of proto- and young stars. Recent indications on the existence of accretion disks around T Tauri stars lead to the same conclusion. Presently, the sample of very young objects embedded in dense molecular clouds is limited to a few dozens, rapidly increasing as IRAS survey data are analysed and followed up by ground-based studies. Although none of these can yet be proven to be a protostar *stricto sensu,* spectroscopy indicates that the regions of accretion or ejection of matter will only be accessible to interferometry. About five disks have been identified with reasonable certainty and more than ten are suspected in nearby associations, all are a few hundred A. U. in size. The relations between disks and large scale mass outflows, local magnetic fields, locally collimated flow and rotation axis all need to be investigated on the 10–100 milliarcsecond scale.

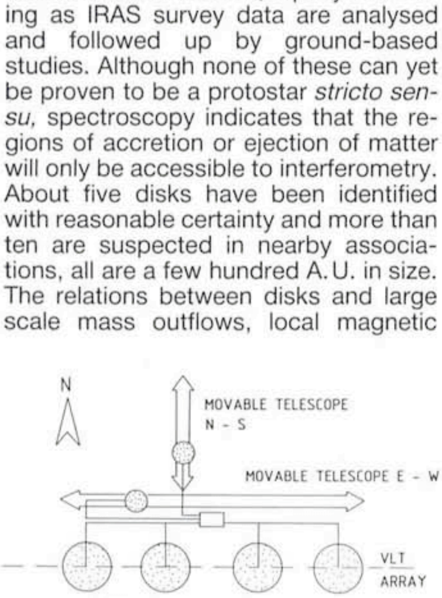


Figure 2: *Schematic configuration of the VLT as a long baseline interferometer, in the redundant (100 m East-West) arrangement.*

Galactic nuclei at infrared and visible wavelengths offer another field of investigation. The structure of the Broad Line Region appears to be close to the available resolution. The small (<1 milliarcsec) and bright, visible nucleus of a Seyfert galaxy is suitable as point-reference source for infrared interferometry which allows phase control, similar to self-calibration in radio astronomy, and long time integration.

When interferometry progresses toward visible wavelengths, the mapping of the star surfaces will open a new field in stellar physics: convection cells, surface magnetic fields, shock waves in red evolved variables, mass exchanges between close binaries are problems which all fall in the range of resolution and sensitivity discussed above.

## 4. Technical Feasibility

Since the currently existing optical interferometers are modest in size and recent in completion, the practical experience in interferometry, although growing continuously, is not very extensive. There is nevertheless agreement about the critical issues: they are mainly the vibrational stability and the beam combination.

The vibrational stability set very strict tolerances, never before encountered in telescope design except what concerns the stability of the primary and the secondary mirrors themselves: the longitudinal (i.e. along the optical axis) displacement velocities must remain below 5 to 10 μm/s rms, or certainly smaller than what current mechanical design may achieve. This necessitates the use of active control to cophase internally the array, in the same way as each VLT primary mirror is cophased by active optics. Recent measurements carried out at La Silla (Fig. 1) show that existing large telescopes, although not especially designed for this purpose, have a stability which is not far from interferometric requirements: surprisingly, this stability appears fully adequate to allow coherent coupling between the 3.6-m and the CAT 1.4-m at a wavelength of 10 μm!

The strategy for beam combination, path compensations, and signal detection is an issue that has a number of solutions, depending on wavelength, relative size of the source and field-of-view. The extraction of coherent beams from each telescope has to be considered first. The VLT Proposal relies on classical mirror trains, common to the incoherent and the coherent modes, but the emergence of single mode optical fibers may make this approach obsolete and provide a convenient and economical coupling between each Nasmyth focus and the interferometric tunnel. For the beam combination itself, some common facilities have already been studied (Figs. 2, 3, 4). The progressive construction and operation of small interferometers will bring considerable experience in the next decade. New ideas are emerging, such as the Double Fourier Technique (Fig. 5), applicable at infrared wavelengths and potentially efficient in the use of observing time.

Since the main phase disturbing factors, atmospheric phase distorsions, random time fluctuations and mechanical vibrations, all appear less detrimental and easier to correct when the wavelength increases, it has been proposed to begin the exploitation of the interferometric mode of the VLT at infrared wavelengths ($\lambda > 3\mu m$) and to progressively extend it towards the visible. This step-by-step approach should minimize the technical risks.

## 5. Operating the VLT as an Interferometer

The availability of VLT observing time in the interferometric mode can only be considered for programmes of the highest scientific value, where the sensitivity and/or time gains provided by the large diameter are justified, when compared with the performances of smaller instruments. This situation is rather similar to the one of speckle programmes on existing large telescopes. Together with the need of frequency coverage discussed above, this led the Working Group to propose the inclusion in the VLT design of two additional, smaller and movable telescopes which are permanently available for interferometry and which can be coupled to the large ones, whenever requested. The design of these telescopes could be derived from the current interferometric programmes underway in France, Germany, the United Kingdom and the United States. For instance, a well engineered Phase A study is now under way at the Institut de Radioastronomie Millimétrique (IRAM, Grenoble), under contract by the French CNRS/INSU for the concept of movable, interferometric telescopes of the 2-m class.

It has already been acknowledged that the VLT operation, even in incoherent mode, shall require more sophistication, more decision aids and more artificial intelligence than is usual in optical astronomy. Interferometry, which gradually adds some complexity to the operations, will also make use of the overall basic flexibility of the VLT design.

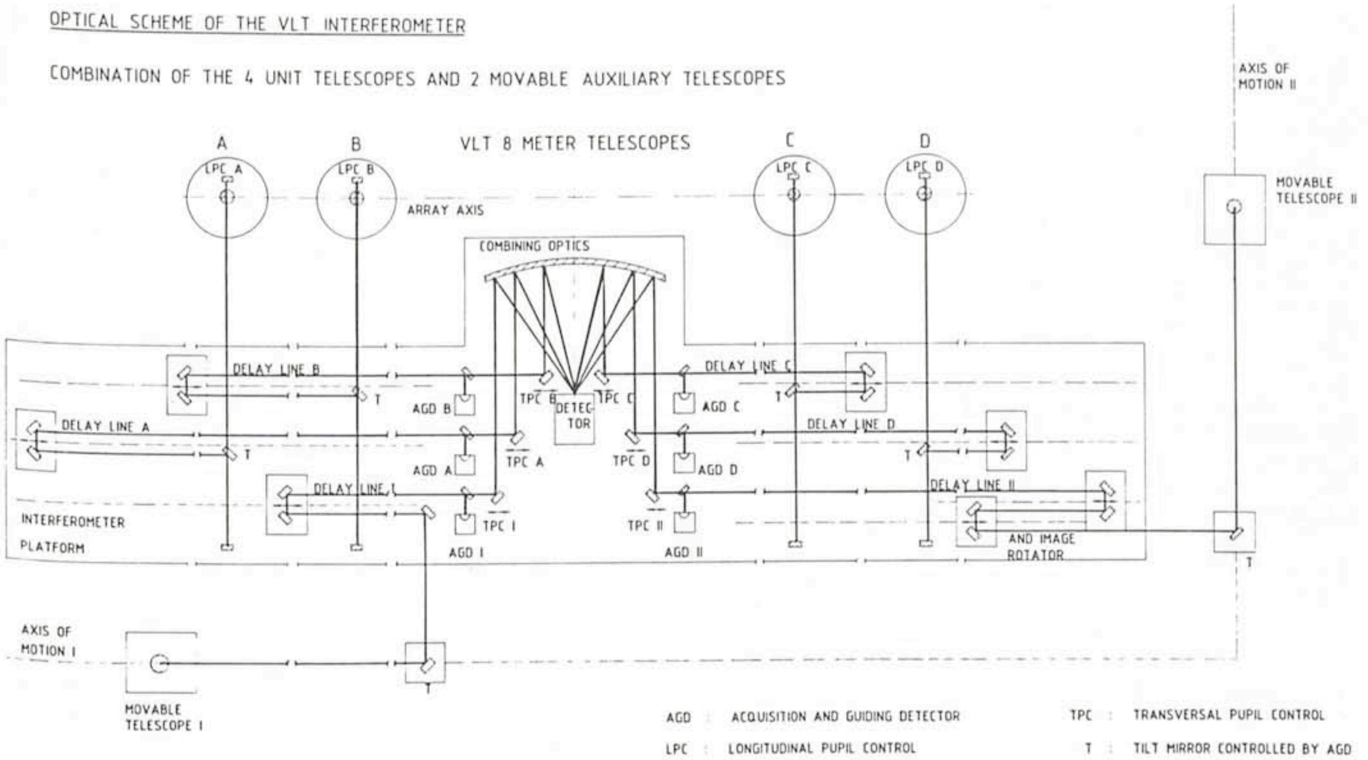


Figure 3: *Detailed optical design of the interferometric beam combination path, schematically showing the beams produced by the 4 large telescopes and the 2 additional ones, their delay lines, the pupil correctors (LGD, AGD and TPC), and a schematic combining optics.*

## 6. Impact of the Site

The most critical factors for interferometric quality are the seeing and the infrared transparency; these two factors are indeed essential for all VLT purposes. The baseline choice comes next. A compact site like the main Paranal summit would force us to accept a redundant configuration, with a maximum East-West baseline of ~125 m. There would be some difficulties in the North-South baseline implementation but it would nevertheless be acceptable. Some second-order parameters, specific to interferometry, like the microseismicity and the outer scale of atmospheric turbulence, will have to be investigated in the future.

## 7. Conclusions

In this short review we have summarized the main lines of thought which led to the inclusion of interferometry into the VLT Proposal. Subsequent cost estimates will have to be refined as the project progresses and several items deserve construction of laboratory models as well as research and development.

If the technical difficulties are solved, and it indeed appears that they are less formidable than initially thought, then the implementation of the interferometric mode will add a great and unique scientific capability to the VLT. It will represent long-term investment and put European optical astronomy in a leading position.

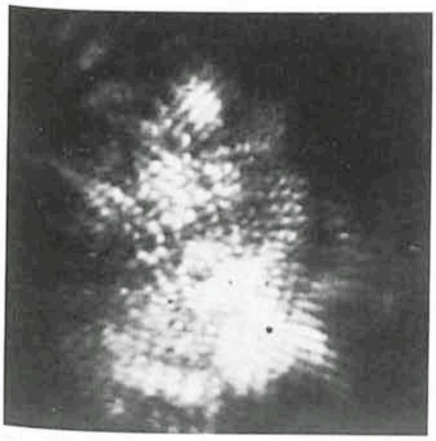

Figure 4: *An example of an interferometric combined image: the six mirrors of the Arizona Multiple Mirror Telescope (MMT) have been cophased at visible wavelengths to produce this instantaneous exposure. Many speckles are obvious (N is large for 2.4 m single pupils), and interference fringes appear for each baseline (Courtesy of J. Beckers and K. Hege).*

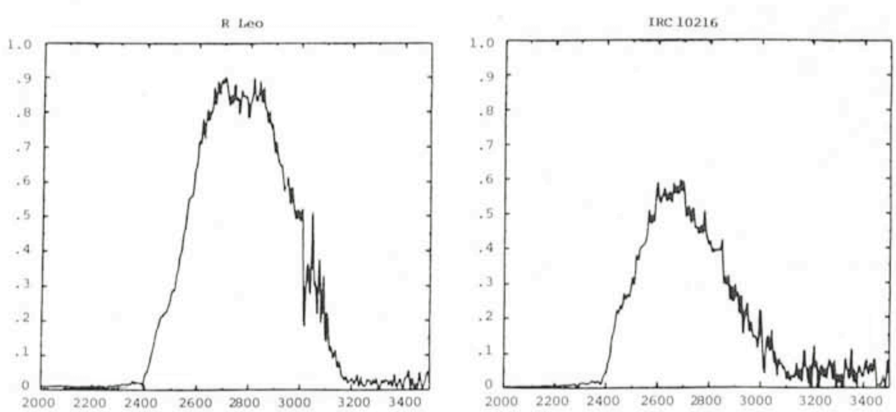


Figure 5: *The Double Fourier technique applied to the bright circumstellar envelope of the star IRC 10216 at 3.5 μm. (a) The spectrum of an unresolved star (R Leo) between 2,000 and 3,400 cm-1, chosen as a reference. (b) The spectrum of IRC 10216, obtained with a conventional Fourier Transform Spectrometer. The two interfering beams are issued from two subpupils of the 4-m KPNO telescope mirror, D = 1 meter apart, instead of being conventionally separated by a beam splitter. The ratio of the two spectra immediately gives the visibility V (σ) of the resolved source versus the wave number at a spatial frequency D σ , keeping the multiplex advantage of the FTS. The spectral resolution only depends on the FTS excursion and the source intensity (J.M. Mariotti and S. Ridgway;* Astron. Astrophys; *in press).*

# Europa decide construir el telescopio óptico más grande del mundo

El día 8 de diciembre de 1987 el Consejo de la ESO dio luz verde para el gran telescopio (Very Large Telescope – VLT) de ESO de 16 metros, que representa el sueño de cada astrónomo y significa un desafío impresionante para la ingeniería. El VLT será el telescopio más grande del mundo y para Europa "el ojo" hacia el universo.

# Algunos conceptos involucrados en el trabajo que se realiza en Paranal

La atmósfera afecta de varios modos las observaciones ASTRONOMICAS hechas desde la superficie de la tierra, cambiando su dirección y su intensidad. Se considera que ambos efectos consisten en un término constante y otro variable. El término constante del cambio de dirección del rayo de luz al pasar a través de la atmósfera se llama REFRACCION y las fluctuaciones al azar de la dirección producen un efecto llamado SEEING. El término constante de la pérdida de luz cuando el rayo de luz atravieza la atmósfera se llama EXTINCION, y las fluctuaciones no sistemáticas de la intensidad de la luz recibida en la superficie de la tierra constituyen el CENTELLEO o TITILACIÓN. EL SEEING se debe a inhomogeneidades en el índice de refracción de la atmósfera, a ras de suelo, en tanto que la TITILACION se debe a razones similares, pero a cierta distancia del suelo. (El índice de refracción depende de la temperatura, de ahí que muchos de los detectores diseñados para determinar el seeing lo hagan a través de mediciones de microturbulencia térmica.) Ambos fenómenos se traducen en un aumento del tamaño de la imagen, cuyo diámetro es mayor que el calculado teóricamente, de esta forma el PODER RESOLUTIVO y la LUMINOSIDAD del TELESCOPIO resultan menores que el calculado teóricamente (esto bajo la suposición que el TELESCOPIO es ópticamente perfecto). *R. Castillo*

# Contents



ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where thirteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. A 3.5-m New Technology Telescope (NTT) is being constructed and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is being planned for the 1990's. Six hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.


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