No. 51 – March 1988

Key Programmes on La Silla: a Preliminary Enquiry

H. VAN DER LAAN, Director General, ESO

Allocating Telescope Time

ESO's *raison d'être* is the provision of telescope time, a shorthand expression for a comprehensive package of services of which hundreds of European astronomers avail themselves every year. The core of that package is the number of nights during which the visiting astronomer has control of one of La Silla's dozen optical telescopes. We all know the procedure for obtaining those nights, the composition and submission of the proposal, the evaluation and grading by the OPC, the allocation by the DG. ESO has, in its eight member states, nearly two thousand potential users whose access to La Silla facilities depends on the (relative) scientific merit and the technical feasibility of their observing proposals. Obviously the very large ratio between number of competing observers and number of telescopes means that telescope time is a very scarce commodity. If many of the interesting proposals are granted time, then a likely result is the fragmentation of telescope time to such an extent that most proposers receive some time most of the time.

In an accompanying note, Jacques Breysacher, head of ESO's Visiting Astronomers Section, illustrates this fragmentation. He also provides information which shows that a large fraction of those requests for telescope time that are successful, are nevertheless curtailed. The time asked for per proposal is of course based on perceived needs as well as on experience: if you request fifteen nights on the 3.6-m telescope you get nothing and lose credibility in the bargain. For many users the present practice works well, their workstyle and programme scope are adapted to these facts of life, there is no reason to change a good thing.

On the other hand, the following scenario is also a painful reality for many an ESO user. You request five nights in a judiciously balanced trade-off between minimal astronomical needs and your estimate of the OPC's range. Then you get three nights, of which one is partly cloudy; your astrophysical goal shifts another year and the substance of your Ph. D. student's thesis erodes precariously. The focus of your own scientific attention is blurred, you have to work in several areas at once and a rival/friend on another continent takes a decisive lead.

The NTT, an Opportunity in More Ways Than One

Readers of the *Messenger* are well familiar with ESO's New Technology Telescope, now nearing completion. Late this year the NTT will be commissioned on La Silla; in Period 43, starting in April 1989, it will be available for visiting astronomers. With the NTT, ESO's effective "four-metre class time" more than doubles: both the 3.6-m and the NTT will be operationally more stable and efficient than the 3.6-m is now, given the inevitable, large number of instrument changes and their associated overhead at present.

It is clear that the established manner of distributing ESO telescope time adequately serves a good fraction of current research needs. It seems equally evident that the fragmentation of the time on intermediate-size and large telescopes precludes ESO users from initiating certain classes of programmes such as are, for example, successfully pursued on Mount Palomar's Hale telescope and some other American universities' and Foundations' telescopes on good sites. Our current procedures for allocating telescope time discourage the start of efforts of the required magnitude. The goal for an innovation in these procedures is to remove this handicap for astronomy in ESO member states. The NTT must signal a growth in quality as well as quantity.

It is my intention to use the addition of the NTT to our telescope park for an experiment in the allocation of telescope time. This experiment will affect all our major telescopes (and our shares in the MPG's 2.2-m and the Danish 1.5-m). Let me first sketch the factual essence of this intention, then provide a brief motivation and also request a structured response from you, our readers/users.

Regard the net amount of new telescope time gained as a result of having the commissioned NTT on La Silla, distributed among the following six tele-

Management Changes on La Silla

For the information of visiting astronomers I announce some changes in the La Silla management. Effective March 1, 1988, the management responsibilities at La Silla are shared by five department heads/group leaders. These are:

H. E. Schuster, VLT Site Services and Schmidt Telescope
Torben Höög, Maintenance and Construction
Daniel Hofstadt, Technical Research Support
Jorge Melnick, Astronomy Department
Bernard Duguet, Administration

Together they form the Management Team/La Silla. Daniel Hofstadt is the chairman of the MT/LaS and he reports to me on behalf of the Observatory's Management Team.

H. VAN DER LAAN, Director General

scopes: NTT, 3.6-m, CAT, ESO 1.5-m and ESO shares of MPG's 2.2-m and the Danish 1.5-m. Some or all of this new capacity will be allocated in a revised manner, such that a number of programmes can receive very substantial portions of telescope time, to be made available over a one to four year period. The net new time available in four years, applying weighting factors for the intermediate-size telescopes *vis-à-vis* the NTT, amounts to about 2,000 nights, half of which on the 3.6-m and the NTT. Some or all of these are to be allocated to, say, between one and two dozen *key programmes;* allocations to vary from minimally twelve to maximally fifty nights per year per programme.

Evidently, the introduction of such a scheme would be difficult to nearly impossible under circumstances of constant total telescope time. It is the major positive increment afforded by the completion of the NTT which provides this new opportunity for European astronomy without negative effects for ongoing activities. Whether some or, ultimately, all of the new capacity is allocated in the new manner must clearly depend on the proposal pressure. The histograms for the 3.6-m and 2.2-m allocations, shown in Dr. Breysacher's article, can in future also be broadened by the use of some of the additional time.

The Growth of ESO Astronomy

In the previous issue of the *Messenger* Professor Woltjer gave an overview of developments within ESO during the past dozen years. From a position of relative instrumental backwardness, European astronomical facilities have achieved world-class status. With the decision to proceed with the construction of the VLT, we must now also pay close attention to the further enhancement of the quality of our community's programmes and the development of long-term European goals in astronomy. In the next decade it is essential to prepare the next generation for an all out exploitation of the VLT's unique potential.

Schedules and Procedures

If we are to make a good start with the key programmes in period 43 (April through September 1989), then the schedule is as follows:

- Initial response to this preliminary enquiry: before 30 April 1988.
- Discussion of principles and procedures and of response to preliminary enquiry in ESO's STC and OPC: May 1988.
- Information and call for proposals in the *Messenger,* No. 52, June 1988.
- Proposal deadline for programmes starting in period 43, 15 October 1988.
- Outside refereeing in November 1988; time allocation upon recommendation by the OPC in December 1988.

Given the large investments in telescope time foreseen, the proposals require deep and careful argumentation. They must have much added value compared to normal proposals, opening research domains not hitherto accessible with ESO facilities. Normally the proposers who constitute the observing team will represent several institutes; hopefully the teams will usually be multinational. Since economic scheduling will require a good fraction of the observing to be done in "service mode", it is highly desirable to involve ESO astronomers employed on La Silla in the observing teams. (This has the additional advantage of involving these young astronomers in community programmes, which will make working on La Silla even more interesting, and will ease their way back into community employment.) Alternatively, observers must be prepared to spend substantial periods on La Silla.

One can foresee thematic proposals which set out a programme of work covering up to four or five years. The initial proposal is to contain the scientific justification as well as the observing and the interpretive strategies. It is to include an overview of the observing nights required as a function of time in the total programme period as well as specify the telescope(s) and instrument(s) to be used. The instruments may be existing ESO common user instruments, instruments to be provided by the observing team or instruments proposed to be constructed in collaboration for the purpose. (In the latter circumstances the planning must take place on a case by case basis.) In addition, an overview of the team members, their respective specializations and relevant experience, and the resources available for data reduction and analysis. Time allocation will be for the whole programme in principle, with an initial annual instalment; subsequent instalments dependent upon the contents of progress reports.

Readers/users are herewith invited to submit, before 30 April 1988, a statement of their intention to make use of this new part of ESO's programme. Forms, specifying the format of your response along the lines of the two preceding paragraphs, are available upon request from the Visiting Astronomers Section at the ESO Headquarters.

Final Remarks

Key programmes are not meant to simply be long-term acquisitions of large databases, which are thought to be good for several purposes, some of which are initially specified and others which have not yet been thought of. Such programmes are of course going on, perfectly justifiably, on the Schmidt and on several of the smaller telescopes. A successful key programme proposal will address a major astronomical theme, provide (a) very specific goal(s) and outline a structured research strategy.

Key programmes can involve postgraduate students from start to finish of their Ph. D. thesis programme, providing them with a coherent research context and using their full time efforts as well as all of their youthful enthusiasm. Analogous reasoning makes the participation of postdoctoral fellows very attractive.

Key programmes, as the term suggests, must open new research domains. They will require careful peer review and will be subject to public scrutiny by the ESO user community.

Successful applicants are likely to be required to make their results, calibrated and documented, available for general use after a prescribed period.

In a shifting pattern of one to four year key programmes it will be prudent to start with relatively few of the four year variety, in order to commit the time available gradually, to the most ambitious programmes of the best prepared teams. In addition to your formal response through the Visiting Astronomers Section, general comments concerning this intention, addressed to me, are welcome.

Some Statistics about Observing Time Distribution on ESO Telescopes

J. BREYSACHER, ESO

The aim of this note, which is to be regarded as an appendix to the article written by Professor van der Laan, is to give some statistical information about the observing time scheduled at ESO over the past four years. Only the five largest telescopes installed at La Silla will be considered here, namely the 3.6-m, 2.2-m, 1.5-m, 1.5-m Danish and 1.4-m CAT.

Needless to say, at ESO as in any other major ground-based observatory, given the heavy oversubscription of telescope time, the selection of the observing proposals is rather strict. Figure 1, which is taken from the 1987 ESO Annual Report, allows a comparison between the total numbers of applications received and finally accepted each year, for almost a decade.

Let us now turn to the successful proposals. The histograms presented in Figure 2 indicate how the 1,350 programmes accepted during the past four years for the use of the five telescopes mentioned above, were distributed with regard to the number of nights allocated to them.

If one considers only the 705 programmes scheduled at the 3.6-m and 2.2-m telescopes, there were 243 (34 %) observing runs of two nights and 269 (38 %) runs of three nights. The percentage of programmes which were allotted four nights was exactly the same on these two telescopes: 14 %. It must be noted that amongst the remaining programmes, most of those getting five or more nights were not sensitive to moonlight and consequently could be scheduled during bright time.

On the two 1.5-m telescopes, 42 % of the programmes were allotted four or five nights. At the 1.4-m CAT, a similar percentage (40 %) is obtained for the observing runs lasting six to seven nights. On these three telescopes the very short runs almost always correspond to programmes for which observations on two or more telescopes were combined.

With regard to the amount of programmes which, after the evaluation by the ESO Observing Programmes Committee and/or during the final scheduling phase, had to suffer from a reduction of the number of requested nights, the mean percentages obtained for the past four years are as follows. At the 3.6-m,

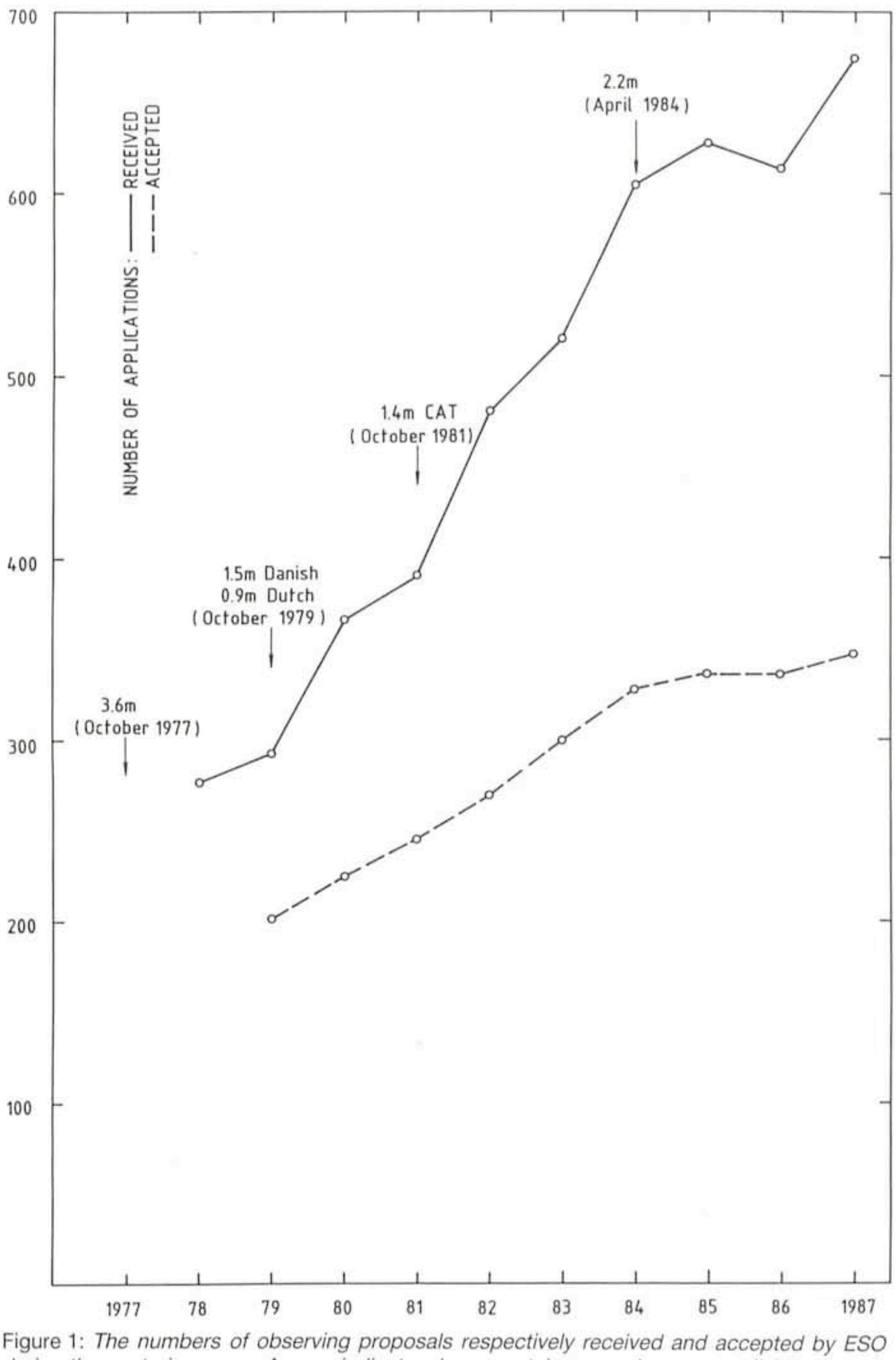


Figure 1: *The numbers of observing proposals respectively received and accepted by ESO during the past nine years. Arrows indicate when new telescopes became available.*

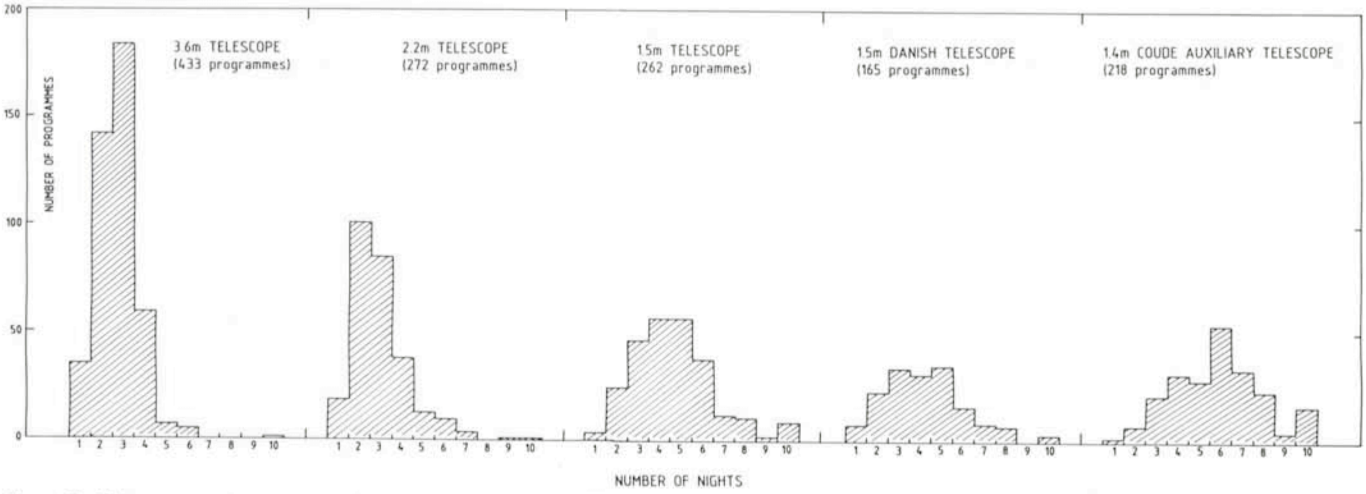


Figure 2: *Histograms showing the distribution of the numbers of observing runs as a function of the number of allocated nights. For each telescope the total number of programmes is given within brackets. It is recalled that the ESO shares of observing time at the 2.2-m telescope of the Max Planck Institute and at the 1.5-m Danish telescope are respectively 75 % and 50 %.*

2.2-m, 1.5-m Danish and 1.4-m CAT telescopes, about 60 % of the programmes receiving time were affected. At the 1.5-m telescope, the fraction of programmes concerned was somewhat smaller with a mean value of 45 % only.

Finally, and again during these past four years, the fraction of continuing programmes which were regularly resubmitted by the same applicant(s) and awarded observing time, has been of the order of 15 %.

Wide-field Photography at the 3.6-m Telescope?

This note serves to gauge the interest of the astronomical community in wide-field photography with the triplet facility at the 3.6-m telescope.

As photographic users will remember, the 3.6-m prime focus is equipped with two Gascoigne correctors (blue and red, field diameter ~ 16 arcminutes, 6 × 6 cm plates). Two grisms can be used with these correctors. There are also two triplet correctors of Wynne type with a field diameter of 1 degree; behind these an automatic plate changer loads up to eight 24 × 24 cm photographic plates. This instrument is rather complicated and after a period of declining use, it was decided no longer to offer it to visitors. Consequently, the 1-m Schmidt is now the only deep, wide-field instrument in regular use at La Silla.

In the past, good triplet plates had a limiting magnitude beyond 24^m. With the advent of the new T-grain emulsions and grid processing, and together with modern reduction techniques, even fainter limits may be reached in the future.

Astronomers in the ESO community who would like to use the 3.6-m triplet, are herewith invited to write to the undersigned. If you feel that the triplet facility should be reactivated, please provide a brief and succinct summary of the type of research you would like to do, the number and type of plates needed and also the total amount of observing time. Kindly note that this invitation does not imply any commitment by ESO.

R.M. West, ESO

Opportunities at the ESO Schmidt Telescope

About 90 % of the red plates for the ESO/SRC Survey of the Southern Sky have now been taken. Although the Schmidt telescope is presently engaged in the continuation of the earlier Quick Blue Survey in the declination zone −20° to 0°, it shall be possible to perform more observations for "visitors", starting with period 42 (from October 1988).

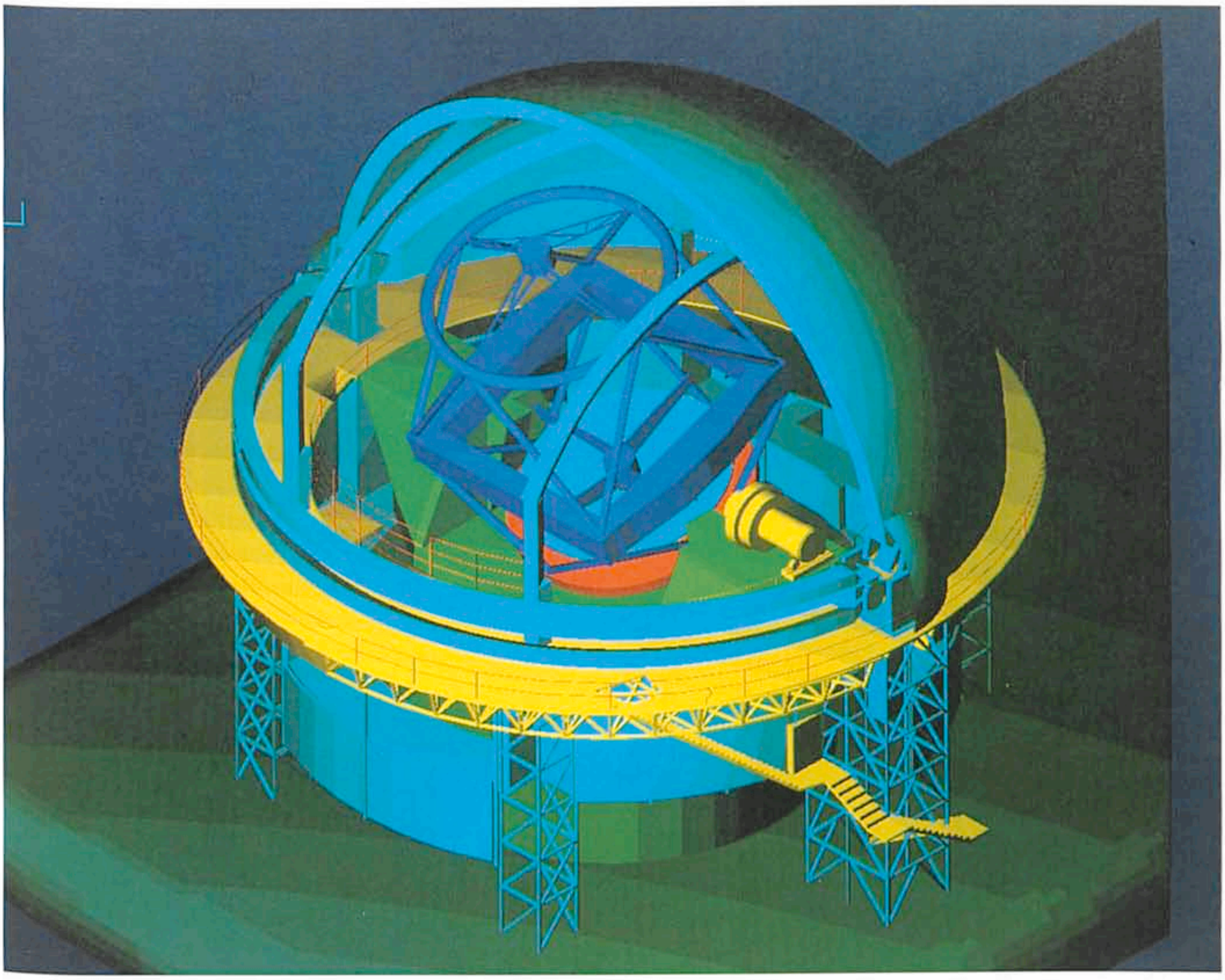
As before, the red and blue atlas plates will have priority. It should also be noted that the prism can only be mounted during a modest part of the available time.

Please remember that applications for period 42 must be received by ESO not later than April 15, 1988.

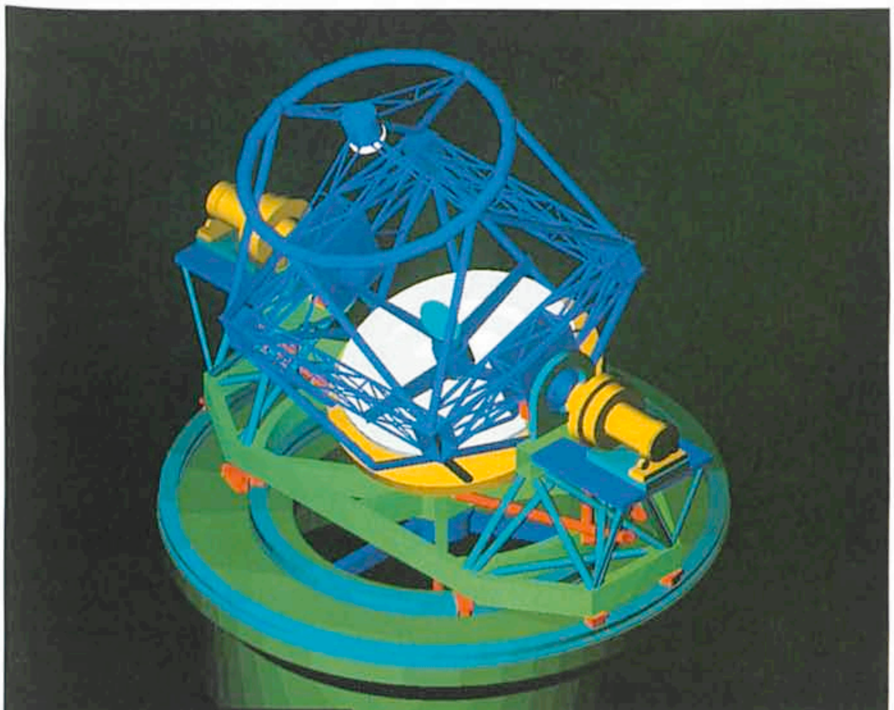
VLT NEWS

After the approval of the project on December 8, the project management structure is progressively being set up.

The final project schedule will be established soon after a decision on the mirror blank procurement is taken. For the time being two technologies, Zerodur from Schott and fused silica from Corning, are in competition. The decision will be taken when the final proposals from the two firms have been received. The mirror thickness has been fixed to 175 mm for both cases. This seems to be an acceptable compromise between cost and stiffness. As an alter-



These CAD drawings were made in February 1988 with the newly installed Euclid-IS software, running on a VAX 8600 at the ESO Headquarters. The upper one shows one possible solution to the integration of the telescope into the protecting dome structure; further work may lead to refinements. The lower picture shows the mechanical structure in more detail. It is based on geometrical and mass distribution analyses. The studies were made by the ESO VLT Mechanical Group and the CAD figures were prepared by E. Brunetto.



native, aluminium technology is being developed and a 1.8-m test mirror is going to be manufactured. An 8-m aluminium blank could be built in less than 2 years in case (unexpected) difficulties would be encountered with the glass mirrors.

A contract on the feasibility of direct drives has recently been issued to ETEL/CONTRAVES (Switzerland). The preferred solution would be 2 closed motors of about 2.4 m diameter for the elevation axis and 4 quasi-linear motors, 8 m long, for the azimuth axis. Power dissipated would be about 4 kW peak for each axis. The average power under typical wind speed conditions would not exceed 1 kW, but will nevertheless require cooling. The advantage of the direct drive is that it is a quasi-linear system with an improved frequency response. The extra cost for the motors is expected to be compensated by the elimination of expensive gear wheels.

Some more refined predesign of the building is under way (see CAD drawing). The present conceptual scheme is based on the inflatable shelter (a half scale model is being erected in Chile). The centre of the dome will be on the telescope base so that the primary mirror is always protected from the direct wind stream. Openings at the base of the building will allow a controlled flushing of the mirror surface. Wind tunnel tests of this concept are being done at the Lausanne Polytechnic.

More in the years to come.

D. Enard, ESO

CNRS–Observatoire de Haute-Provence and European Southern Observatory

Summer School in Astrophysical Observations

Observatoire de Haute-Provence, France, 4–13 July 1988

The school is dedicated to the practice of astrophysical observations and it is organized jointly by OHP and ESO. The aim of the school is to balance the education of young European students in astronomy, offering them an early opportunity to become acquainted with modern astrophysical equipment. Courses and observations will take place at the Observatoire de Haute-Provence where the instrumentation and the facilities for the reduction of digital data are in many respects similar to those available at the world largest optical observatories.

During the school, the students will be asked to carry out a short programme of observations at the 1.93-m telescope with a CCD detector, under the guidance of experienced observers, learn to reduce the data on HP and VAX computers and propose an interpretation of the results.

The courses will mainly be dedicated to the different observational techniques. The preliminary list of speakers and subjects is as follows:

M. Tarenghi (ESO): Modern und future telescopes
S. D'Odorico (ESO): Spectroscopic and imaging instrumentation
M. Dennefeld (IAP): Detectors
F. Rufener (Genève): Optical photometry
P. Bouchet (ESO): Infrared photometry
S. Cristiani (Padova): Low resolution spectroscopy
D. Gillet (OHP): High resolution spectroscopy
H. Schwarz (ESO): Polarimetry
J.M. Mariotti (Lyon): Interferometric observations

Applications: Students from ESO member countries intending to begin a Ph.D in astronomy or in the first years of their thesis are invited to apply using the form available on request from the organizers before May 1st. A letter of introduction by a senior scientist is also required. Fifteen applicants will be selected. Their travelling and living expenses will be fully paid by ESO or OHP.

The Organizers:

A.A. Chalabaev
Observatoire de Haute-Provence
F-04870 Saint-Michel-l'Observatoire
France
Telex: 410690 France

S. D'Odorico
European Southern Observatory
Karl-Schwarzschild-Str. 2
D-8046 Garching F.R.G.
Telex: 5282820 eo (F.R.G.)
Bitnet address:
SANDRO@DGAESO51

List of ESO Preprints

(December 1987–February 1988)

550. F. Matteucci: Iron Abundance Evolution in Spiral and Elliptical Galaxies. Invited talk presented at the New Orleans Meeting of the American Chemical Society on "The Origin and Distribution of the Elements", Sept. 1987. *World Scientific,* in press. December 1987.
551. D. Baade et al.: Time-Resolved High-Resolution Spectroscopy of an Hα Outburst of μCen (B2 IV–Ve). *Astronomy and Astrophysics.* December 1987.
552. A. Robinson: Photoionization of Extended Emission Line Regions. Proceedings of the NATO Advanced Research Workshop on "Cooling Flows in Clusters and Galaxies", held at the Institute of Astronomy, Cambridge, UK, 22–26 June 1987. December 1987.
553. M. Aurière and S. Ortolani: CCD Stellar Photometry in the Central Region of 47 Tuc. *Astronomy and Astrophysics.* December 1987.
554. I.J. Danziger et al.: SN 1987A: Observational Results Obtained at ESO. Paper presented at the Fourth George Mason Fall Workshop in Astrophysics, "Supernova 1987A in the Large Magellanic Cloud", October 12–14, 1987, George Mason University, Fairfax, Virginia, USA. December 1987.
555. A. Moneti et al.: High Spatial Resolution Infrared Imaging of L 1551 – IRS 5: Direct Observations of its Circumstellar Envelope. *The Astrophysical Journal.* December 1987.
556. R. Arsenault and J.-R. Roy: Correlations Between Integrated Parameters and Hα Velocity Width in Giant Extragalactic H II Regions: A New Appraisal. *Astronomy and Astrophysics.* December 1987.
557. L.B. Lucy: Modelling the Atmosphere of SN 1987A. Paper presented at the fourth George Mason University Workshop in Astrophysics "SN 1987A in the LMC". December 1987.
558. B. Reipurth and J.A. Graham: New Herbig-Haro Objects in Star Forming Regions. *Astronomy and Astrophysics.* December 1987.
559. H. Dekker: An Immersion Grating for an Astronomical Spectrograph. "Instrumentation for Ground-Based Optical Astronomy: Present and Future", ed. Lloyd B. Robinson (Proceedings of the 1987 Summer Workshop in Astronomy and Astrophysics at Lick Observatory). December 1987.
560. L. Noethe et al.: Active Optics II: Results of an Experiment with a Thin 1 m Test Mirror. *Journal of Modern Optics.* December 1987.
561. J. May, David C. Murphy and P. Thaddeus: A Wide Latitude CO Survey of the Third Galactic Quadrant. *Astronomy and Astrophysics.* December 1987.
562. G. Contopoulos and P. Grosbøl: Stellar Dynamics of Spiral Galaxies: Self-Consistent Models. *Astronomy and Astrophysics.* December 1987.
563. F. Barone et al.: On the Optimization of the Wilson-Devinney Method: An Application to CW Cas. *Astronomy and Astrophysics.* December 1987.
564. T.J.-L. Courvoisier: Multi Wavelength Observations of Active Galactic Nuclei. Invited paper given at the Strasbourg Colloquium "Coordination of Observational Projects", November 1987.
565. A. Renzini and Fusi Pecci: Tests of Evolutionary Sequences Using Color-Magnitude Diagrams of Globular Clusters. *Annual Review of Astronomy and Astrophysics.* January 1988.
566. L. Deharveng et al.: H II Regions in NGC 300. *Astronomy and Astrophysics.* January 1988.
567. R.H. Méndez et al.: Spectra of 3 Planetary Nebulae and a Search for Nebular Emission Around 12 sdO Stars. *Astronomy and Astrophysics.* January 1988.

568. E. Brocato and V. Castellani: Evolutionary Constraints for Young Stellar Clusters. II. The Case of NGC 1866. *Astronomy and Astrophysics.* January 1988.
569. R. Arsenault et al.: A Circumnuclear Ring of Enhanced Star Formation in the Spiral Galaxy NGC 4321. *Astronomy and Astrophysics.* February 1988.
570. G. Contopoulos and A. Giorgilli: Bifurcations and Complex Instability in a 4-Dimensional Symplectic Mapping. February 1988.
571. J. Surdej et al.: Search for Gravitational Lensing from a Survey of Highly Luminous Quasars. *P.A.S.P.* February 1988.
572. R. Buonanno et al.: CCD Photometry in the Metal Poor Globular Cluster NGC 7099 (M30). *Astronomy and Astrophysics.* February 1988.

From the Editors

In accordance with the new management of ESO, it has been decided that the ESO *Messenger* shall above all be a vehicle of communication between ESO and the user community. It is therefore the intention to bring the fullest possible information about new developments at ESO, technical and scientific, as well as those of a more administrative nature. In a similar spirit, we herewith invite contributions from users, in the form of articles and also as shorter Letters to the Editor.

Tentative Time-table of Council Sessions and Committee Meetings for First Half of 1988

May 2	Users Committee
May 3	Scientific Technical Committee
May 4–5	Finance Committee Oberkochen
May 31–June 1	Observing Programme Committee, Liège
June 6	Committee of Council
June 7	Council

All meetings will take place at ESO in Garching unless stated otherwise.

SN 1987A: Spectroscopy of a Once-in-a-Lifetime Event

R. W. HANUSCHIK, G. THIMM and J. DACHS, Astronomisches Institut, Ruhr-Universität Bochum, F.R. Germany

When Supernova 1987A in the Large Magellanic Cloud was discovered by Ian Shelton at Las Campanas Observatory in Chile on February 24, 1987, it immediately became apparent that this would turn out to be one of the most important astronomical events in this century. The timing of the supernova could not have been better – although the light from the site of the stellar collapse had to travel a distance of as much as 170,000 light-years before reaching our planet Earth, it arrived precisely when state-of-the-art photoelectrical detectors had become available at modern telescopes situated at the best observing sites all over the world, together with highly sophisticated spaceborn instruments working in the X-ray and ultraviolet regions of the electromagnetic spectrum. Even elementary particle physicists were well-prepared (except for some problems with their clocks) to catch two dozens of the neutrinos emitted by the dying star thereby providing for the first time the precise date of the collapse. (Only gravitational wave astronomy has still to wait to be born: all potential detectors had been switched off or did not work properly.)

To render the combination of privileges for earthbound observers even more impressive, SN 1987 A is just at the optimum distance for convenient measurements in the optical window: a galactic supernova would be too bright for professional astronomical instruments such as photometers and spectrometers which are especially designed to achieve the highest possible sensitivity for extremely faint radiation sources, and which therefore are in great danger to be destroyed when exposed to a naked-eye object. This problem has been discussed in greater detail in two papers by Michael Rosa and O.-G. Richter (*Observatory* **104,** p. 90 [1984]) and by Theodor Schmidt-Kaler (same volume, p. 234). Furthermore, a nearby supernova could not tell us very precisely its distance due to the strongly varying amount of dust in the galactic plane.

If SN 1987A were a distant supernova such as they are detected almost once per month, nobody would have obtained enough observing time at large telescopes in order to study and monitor it in sufficient detail for a long time. And again, the distance to a supernova beyond our Local Group of galaxies would be quite uncertain as compared to the well-defined and well-known distance to the LMC.

So it is not surprising that starting on February 25 literally every telescope in the southern hemisphere was directed towards the newly-born supernova (unfortunately enough, no spectrum exists from the night before when Ian Shelton made his discovery). This was of course also the case at the European Southern Observatory in Chile at La Silla where

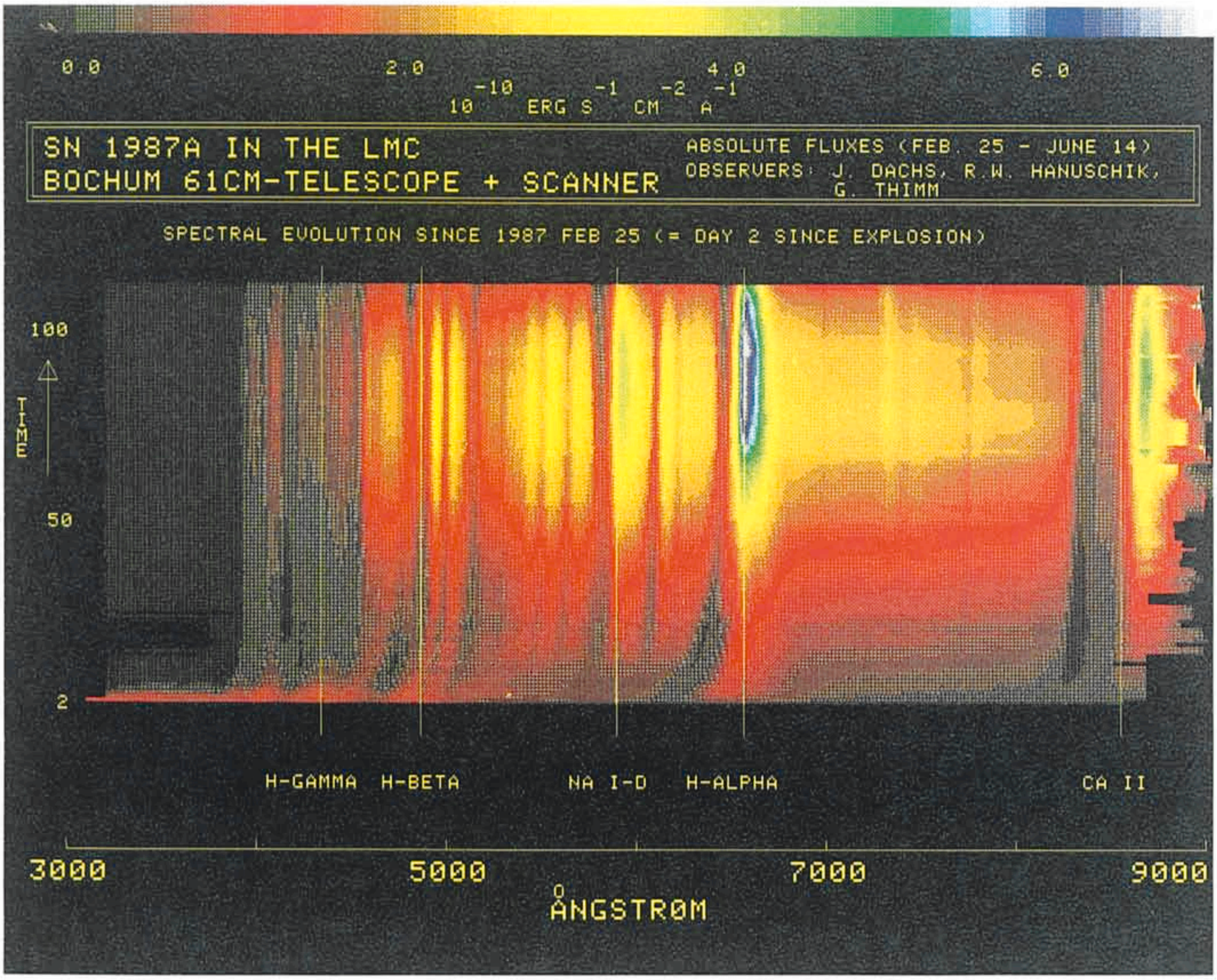
The Proceedings of the ST-ECF Workshop on

Astronomy from Large Databases – Scientific Objectives and Methodological Approaches

which was held in Garching from 12 to 14 October 1987, have now been published. The 511-page volume, edited by F. Murtagh and A. Heck, is available at a price of DM 50.– (prepayment required).
Payments have to be made to the ESO bank account 2102002 with Commerzbank München or by cheque, addressed to the attention of

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

Please do not forget to indicate your full address and the title of the volume.



This colour-coded plot of optical spectra depicts the dramatical spectral evolution of SN 1987A within the first 110 days (Feb. 25 to June 14). All spectra have been measured with the spectrum scanner attached to the 61-cm telescope of the University Bochum located at the European Southern Observatory at La Silla, by observers Joachim Dachs, Reinhard W. Hanuschik and Guido Thimm. The wavelength range covered is approximately 3200 to 9000 Å, the resolution is 10 Å. Absolute fluxes have been colour-coded according to the colour bar on top of the figure: colours run from black (zero flux) to blue-white (6.7 10^{-10} erg s^{-1} cm^{-2} $Å^{-1}$). Time series starts on February 25 (= day 2 since explosion); time scale is continued from bottom to top day by day. Last date is June 14 (= day 110).

one of us (J.D.) happened to work with the 61-cm telescope of the Ruhr-Universität of Bochum.

He was working on a long-term programme to monitor spectral and photometric variability in Be stars and original plans were to change instrumentation just in the afternoon of February 24, from the spectrum scanner equipped with a red-sensitive gallium-arsenid photomultiplier to the single-channel photometer. This plan, however, was rapidly given up, when the Acting Director, Hans-Emil Schuster, walked into the Hotel Dining Room during tea-time – the La Silla astronomers' breakfast – and announced the discovery of a supernova in the Large Magellanic Cloud. (In fact, the first IAU telegram did not mention that SN 1987A had been discovered at Las Campanas Observatory, only some 30 km from La Silla, and Hans-Emil Schuster first appeared to be rather sceptical about this event.) A few hours later, the first spectra of the supernova were obtained at La Silla, about 170,000 years plus 42 hours after the stellar collapse in the LMC.

Due to an agreement between ESO and the University of Bochum, the Bochum Astronomical Institute has access to this telescope during a total of eight months per year. In addition, ESO Director General Prof. Woltjer generously agreed to dispense with the four-month ESO period at the Bochum telescope as long the supernova could be observed.

So Joachim Dachs, and following him, Reinhard Hanuschik, Guido Thimm, Klaus Seidensticker, Josef Gochermann, Stefan Kimeswenger, Ralf Poetzel, Gerhard Schnur and Uwe Lemmer established a homogeneous series of flux-calibrated spectra obtained with a fixed instrumental configuration. The wavelength range of these spectra extends from 3200 Å to 9000 Å; the standard resolution is 10 Å. For limited spectral ranges, spectra at higher resolution, 3 to 5 Å, are being obtained in addition. Proper flux calibration of the spectra is always performed by means of bright southern spectrophotometric standard stars such as ζ Puppis or α Crucis.

This data set will certainly belong to the best available spectra of the supernova; maybe it is unique. Especially remarkable is the fact that these high-precision data were obtained with a small-sized telescope and relatively modest equipment compared to large observatory standards.

Between May and July when Supernova 1987A was below the celestial south pole all night, the 61-cm Bochum telescope turned out to be the only telescope at La Silla able to follow the supernova and to take spectra even at airmasses as large as 6 (corresponding to zenith distance 80°). For that purpose, observers had to work very close to the limit switches protecting the telescope against mechanical damage. The Bochum telescope certainly had never before been pointed at such extreme coordinates, at least not intentionally. In order to be able to look into the telescope's eyepiece without burdening the telescope axes with its body's weight, one author (R.W.H.) invented a rather unusual method for guiding the supernova: he installed a rubber rope at the dome wall and, hanging himself on the rope and balancing on top of a ladder two meters above the ground like a mountaineer, carefully moved his eye towards the eyepiece which was at some "impossible" position on top of the telescope tube.

By now, more than 300 days of Supernova 1987A have been covered observationally. The first 110 of them are depicted in a compressed manner in the accompanying figure. This plot shows the temporal evolution of the spectral fluxes of SN 1987A between 1987 February 25 and June 14.

The most obvious advantage of this compact representation is the visualization of the well-known photometric lightcurve: the flux distribution changes dramatically in the very first days due to the steep decrease of the effective temperature of the outflowing gas. After about day 10 since explosion, flux distribution remains approximately constant; the absolute flux level, however, increases steadily until, around May 20, the visual maximum is reached. Afterwards, flux decreases more rapidly.

The next obvious feature in this plot is the dramatic evolution of the Doppler shift, i.e. the decreasing velocities of spectral lines produced in the expanding envelope. The intensity minimum of the Hα absorption trough is at −17,400 km/s on February 25, falling off to −6,200 km/s by April 14 and −5,400 km/s by July 14. This general trend is already well known from other supernovae and is due to the fact that outflowing material is diluted by expansion and is assorted according to increasing velocity and decreasing density: in the expanding supernova shell, at any time velocity is proportional to distance from the centre of explosion. Therefore, expanding layers may be opaque at some time and later become optically thin, revealing lower, less rapidly expanding layers. Thus, in front of the supernova, optical lines characteristic for the most abundant elements in the supernova atmosphere (hydrogen, helium) or for particularly strong transitions (e.g., of calcium or sodium) are visible at the highest velocities towards the observer (corresponding to the lowest discernible densities in the outermost layers of the ejecta), while lines indicating less abundant constituents of the atmosphere are produced at lower velocites and higher densities. Then, as time goes on, it is possible to look deeper and deeper into the ejected atmosphere of the exploding star. So far, no indication has been detected for interaction of the ejecta with the surrounding pre-outburst material, and consequently supernova matter is still in free expansion. Decreasing velocities therefore result only from decreasing opacity of the expanding shell.

Maximum outflow velocities can be inferred from the blue edge of the absorption component of the Hα P Cygni-type profile: we measured −31,000 km/s on February 25; extrapolation back to February 23 even yields a velocity in the vicinity of −40,000 km/s as the velocity of the fastest ejecta, that is 13% of the speed of light. These enormously high velocities are now commonly believed to be responsible for the rather unusual lightcurve of the supernova, i.e. its extremely long rise until maximum was reached at a relatively low absolute level.

Our continuous time series of homogeneous spectral measurements offers a unique opportunity for safe identification of the bewildering amount of absorption and P Cygni-type lines in the supernova spectrum. Work on line identification and radial velocity determination is in good progress.

Meanwhile, forbidden lines such as [Ca II] λ 7291/7363 Å and [O I] λ 6300/6363 Å have become visible in the supernova spectrum marking the beginning of the nebular phase. As a whole, the dramatic evolution of the optical spectrum of SN 1987A has slowed down, but certainly will provide further surprising features in the visible. Our time series will be continued as long as possible and certainly provide invaluable information about an event which happens at most once in the lifetime of an astronomer.

Acknowledgements

We are greatly indebted to our Institute Director, Prof. Th. Schmidt-Kaler, who invested a lot of time in organizing financial and personal support for the continuous observing campaign, and to the former Director General of ESO, Prof. L. Woltjer, who generously gave several months of ESO time at the 61-cm telescope to our observers.

SN 1987A (continued)

It is now one year ago that SN 1987A in the LMC exploded. Since then, this unique event has continued to fascinate astronomers and physicists. The large number of scientific meetings, TV programmes, newspaper articles, etc. about SN 1987A at the time of its first anniversary prove its popularity.

During the past three months, since the last issue of the *Messenger*, several important observations have been made public. The first unambiguous detection of γ-rays was made with the Solar Maximum Mission satellite. Accumulating data from August 1 to October 31, 1987, two spectral lines were seen at 847 and 1238 keV, respectively; they originate during the decay of Cobalt-56. The intensities corresponded to about 0.0002 solar masses of exposed Cobalt-56 at a distance of 55 kpc. No obvious changes were observed during this period. Further γ-ray observations were made from balloon experiments flown in October and November and also from a balloon which was launched in Antarctica in early January. During the three-day flight at altitude 36 kilometres, it observed the supernova during 12 hours, permitting the registration of a detailed profile of the two Cobalt-56 lines.

After a long period of rather constant emission in the soft X-ray region, the Ginga satellite observed a sudden rise of the intensity in the 6–16 keV and 16–28 keV bands during the first days of 1988. The intensity in the first of these bands more than tripled over a two-week period.

Spectral observations in the ultraviolet, visual and infrared regions continue. Recent spectra from the IUE show UV emission lines from a variety of ions, e.g. C III, N III and possibly He II and N IV. The first detection of [O III] lines has been made with the ESO 3.6-m telescope and the Cassegrain Echelle Spectrograph (CASPEC). From the 4363 Å line, when compared to the doublet at 4959 and 5007 Å, and assuming low electron density, a plasma temperature of 40,000 K was computed. These lines are very narrow and their velocities are near 285 km/sec, indicating that they may originate in a circumstellar shell (ejected from the progenitor during an earlier mass-loss phase?)

A long-term programme is under way with the Bochum telescope on La Silla; see the article by Hanuschik et al., in this *Messenger* issue. In the far-infrared spectral region, several flights with the Kuiper Airborne Observatory (KAO) have showed emission lines from iron-group elements, synthesized during the supernova explosion. SN 1987A continues to be radio-quiet and the longest wavelength at which it has recently been detected is 95 μm.

Speckle interferometric observations with the 4-m telescope at the Cerro Tololo Inter-American Observatory in November have resolved the supernova shell at about 0.02 arcseconds, corresponding to a mean velocity of about 4,000 km/sec since the explosion. Similar observations with the 4-m Anglo-Australian Telescope, also in November, show that if there is a secondary object within about 0.8 arcsec of SN 1987 A, then it must be at least 4 magnitudes fainter.

The supernova faded to magnitude 6.4 in mid-January and to about 6.8 in mid-February. After a period of linear decline on the magnitude scale, corresponding to the radioactive decay rate of Cobalt-56, the decline became more rapid. Towards the end of January, observers at the South African Astronomical Observatory found that the bolometric (total) luminosity was 7% below a straight extrapolation from the linear decline between July and October 1987. The light in the U-band which had been constant over a long period, again started to fade in late December 1987.

The Editor (February 23, 1987)

Some Prospects of Galactic and Extragalactic Studies*

V.A. AMBARTSUMIAN, Byurakan Astrophysical Observatory, U.S.S.R.

The main purpose of the astronomical work is to obtain information about all kinds of bodies and systems existing in the Universe, about their past and future, and regularities of processes going on in them. Studies and the observational work with this purpose are developing in three main directions: the study of the Solar system and of its members (planets, comets, meteorites), the galactic research which studies our stellar system and its members (stars, nebulae, clusters of stars), and the extragalactic research.

Since the discoveries of Galileo, astronomers have applied and continue to apply optical telescopes in all three directions mentioned above. However, during this century new methods have been invented. It is sufficient to mention here the ground based radio telescopes, the X-ray receivers and telescopes, γ-ray receivers which are observing from the space around the Earth. But, of course, the recent technical progress has affected in the strongest degree the planetary astronomy. Some of the space vehicles give us the possibility to observe the planets, comets, satellites from the immediate vicinity. There is no doubt that the role of investigations with space vehicles in planetary studies will enormously increase in future and this means that the role of ground based telescopic observations in this field will diminish.

Of course, in the fields of galactic and extragalactic research the modern methods (radio astronomy, X-ray astronomy, far infrared, space missions and particularly space interferometry in different wavelengths) will play an increasing role, but they cannot replace, at least during the next several decades and probably during the next century the work of optical telescopes.

Therefore, let us concentrate our attention on galactic and extragalactic research, though we must not forget that the solar-system studies can have a great indirect influence on the studies of phenomena on the stellar and galactic scale.

What is the main purpose of astronomical research in the galactic and extragalactic fields?

I think it is (1) to understand the constitution of stars and nebulae as well as of systems, including the increasing volume of the Metagalaxy and (2) to study the origin, life, evolution and the future destiny of these bodies and systems.

This is the general formulation of goals of these fields of science. However, in the practice of scientific work these general goals dissolve into countless subjects, problems, questions and topics, each of which can prove its importance and can require a special programme of studies.

And you know well that very often the solution of each problem raises a large number of new problems, which in the past were under the scientific horizon.

The difficulty of formulating the multitude of special problems, of programming the ways of their solution is complicated by the fact that they very often intersect and penetrate each other.

Let us take one example. Everybody understands that we have two important and seemingly independent problems of stellar astronomy: the distribution of the stars in the Galaxy and the origin of stars. By studying the distribution of early-type stars in the Galaxy we arrived at the concept of OB associations, and the nearer study of OB associations has brought us nearer to the solution of the origin of early-type stars. In the same way the study of the distribution of dwarf variables of T Tauri and RW Aurigae stars has immediately demonstrated us the existence of T associations. From this the concept of the origin of stars in groups has followed.

Inversely, the understanding of the fact of desintegration of stellar associations has opened many questions on the kinematics of open clusters and individual stars which are the *remnants* of stellar associations.

Thus there are two problems: the origin of stars and their distribution in the Galaxy, and they are closely connected.

On the other side, the observations show that the formation of stars in the association is taking place in smaller subgroups in the, so to say, *recent star formation regions* which have linear sizes smaller than one parsec and comprise only a very small part of the volume of the associations.

The study of such regions where the complicated phenomena of the ejection of gaseous matter, of H_2O and other masers, as well as the formation and ejection of Herbig-Haro objects are characteristic is to be carried out with many different techniques, among which optical and infrared telescopes are playing an important part.

Last Wednesday Dr. Moorwood showed us some infrared pictures of such a region in Orion where the Becklin-Neugebauer object and other infrared sources are situated.

We are sure that the study of these phenomena will bring us much nearer to

* Talk given at First School for Young Astronomers Organized by ESO and the Astronomical Council of the U.S.S.R. Academy of Sciences (see the *Messenger* **50**, p. 43–44).

the understanding of the origin of stars of the disk population.

I am convinced that the study of such regions of "recent star formation" by direct, spectroscopic, infrared, radio methods promises to become one of the most rewarding fields of observations.

But if we know the direction in which we can strongly hope to find the solution of the problems of the origin of stars of Population I and of galactic nebulae, the situation in regard to Population II stars is not so hopeful.

Anybody who has some experience in the treatment of the problems of stellar origin will agree that the problem of the origin of Population II stars must be closely connected with the problem of the origin of globular clusters.

But apparently our Galaxy at its recent phase of evolution is deprived of the young Population II objects, at least we don't see them in our neighbourhood. It seems therefore that the progress towards the solution of this problem will be accelerated by combining the information obtained from observations of galactic and extragalactic objects.

Let me bring here two more problems which require the combination of galactic and extragalactic data.

We observe in our Galaxy a limited number of Wolf-Rayet stars. They are young objects. We observe them as a rule in OB associations. But there are many OB associations which don't contain any WR stars. The best example is the Orion association. It contains no WR star in spite of the fact that different parts of this association are apparently at different stages of evolution. Therefore, the evolutionary status of WR stars is not quite clear, but of course we are sure that they are comparatively young objects.

But the remarkable fact is that in 30 Doradus, which is a superassociation (or giant H II region), in its central part we observe at once a whole group of WR stars which form together with a number of O stars a compact nucleus of the superassociation. With great probability we can suppose that many superassociations in other galaxies also contain WR stars. We know also, that some Markarian galaxies contain not one, but several superassociations.

The future large telescopes will allow us to establish the abundance of WR stars in them.

The last problem which requires both the galactic and extragalactic information is connected with the giant molecular clouds. As is known, the considerable percentage of giant molecular clouds contains stellar associations. However, the emergence of the OB association in a molecular cloud must lead to its destruction and dissipation. We do not know the exact percentage of GMC which contain OB stars. Apparently, 30 % or 50 % is a good estimate of the order of the magnitude. But this will mean that the life-time of a GMC cannot be longer than the life-time of an OB association by more than *one order* of magnitude. On the other hand, the life-time of OB associations was estimated (until now) as 10^7 years. This means that the life-time of GMC must not be longer than 10^8 years. The urgent problem arises on the origin of molecular clouds. Of course, this is also a problem for theoreticians. However, it seems to me that the solution can be found on the basis of detailed observational studies of the whole problem of connection between the molecular clouds and young stars.

As I have insisted in some of my papers, the problem of the origin of nebulae and particularly of molecular clouds is now not less actual than that of the origin of stars.

Of course, there are countless problems which are to be solved in the frame of pure galactic observations.

As an example, we can consider the nature and cause of changes in T Tauri stars. A special problem is the variability of very faint red dwarfs (of visual absolute magnitude of about +17 or +18). We know that we can find the flare stars among very faint dwarfs. But are there also T Tauri variables among them? This requires the observation of very faint stars (of apparent magnitude of 21 or 23) both in open clusters and the general field.

In this connection I would like to remind you that by building larger telescopes we acquire the ability to study more distant objects as well as to observe intrinsically fainter objects. Comparing in this respect the requirements of galactic research we notice that for extragalactic research both abilities are equally important. However, in the galactic research the second is relatively more important. This is why I emphasize here specially the problems connected with extremely faint red dwarfs. But of course the study of white dwarfs is of no less importance.

Passing to extragalactic problems and taking into account our last remark we begin of course with the most distant objects – the quasars of very high redshifts. It is quite natural that astronomers are awaiting with deep emotions the discovery of new record redshifts. But it is necessary to tell that we need also the systematic study (both statistical and physical) of the whole range of quasars beginning with $z = 0.2$ to $z = 4.5$ and larger if they are there.

At the same time it is very important to consider deeper the connections between the world of Seyfert galaxies and quasars. For this the detailed study of the nearest quasars is important.

For us, theoreticians, quasars are galaxies which have a very bright nucleus. The stellar surroundings of them are sometimes of the scale of usual giant galaxies. But apparently there are cases where these surroundings are relatively faint. To understand the regularities of relationship between nuclei of galaxies and of stellar population around them is one of the major problems of extragalactic astronomy and in this respect the study of the nearest quasars must be of the greatest value.

On the opposite flank of extragalactic research is the study of dwarf galaxies. The most important regularity here is their irregular structure. Another property which apparently is connected with the question on their evolution is the relatively high mass of the neutral atomic hydrogen in them. It is a great priviledge for us and specially for ESO that our Galaxy has two of them so near. But to recognize the regularities within the irregularities apparently will require the study of a larger number of objects and therefore the detailed study of a number of objects on intermediate distances of the order of several millions of parsec is necessary. But there the stronger ties with radio astronomy, especially with 21-cm astronomy, are necessary. May I remind you that during the last years objects have been discovered which are giant H I clouds of galactic dimensions and at the same time have no discernible stellar population. It is of interest to find intermediate objects where gas and stars have masses of equal orders.

Between these two fields (very faint dwarfs and quasars) we see the vast field of investigations of normal galaxies and processes in them, the work on more detailed and apparently multidimensional classification of normal galaxies.

Of special importance are studies of active galaxies and specially of their nuclear regions, of wonderful changes of brightness and spectral properties of the nuclei of active galaxies and quasars.

The problem of large-scale distribution of galaxies and their clusters is a bridge between extragalactic astronomy and cosmology. And I am sure that the large telescopes of the near future will open fascinating prospects also here.

One of the important subjects of investigation remains the physical nature of interstellar matter. Now we are sure that the bulk of interstellar matter consists mainly of *molecular clouds.* The so-called Great Molecular Clouds (GMC) are individual objects of great interest and the problems of their origin are not less intriguing than those of stellar clusters. But at the moment our knowledge of them is very superficial. Great efforts are necessary.

But GMC clouds form only one of the components of interstellar matter.

The other components are connected with the general structure of the Galaxy as a whole as well as with external influences on the Galaxy. We are only beginning to understand their role in the Galaxy.

My talk, as I mentioned, reviewed only some aspects of the problems of galactic and intergalactic research and reflects mostly my personal views and interests, the interest of a theoretician. May I repeat here what I have said in my welcome to this school:

The real essence of our knowledge of the Universe is contained in the observational data. The role of the theory is to systematize the data and to connect them logically between themselves and with the data from other sciences.

Galactic Chronometry with the Coudé Echelle Scanner

H. BUTCHER, Kapteyn Observatory, Roden, the Netherlands

Introduction

I have recently proposed that observations of the radioactive nucleus 232 Th in stars may be used to derive a new kind of galactic chronometer (*Nature,* vol. 328, pp. 127–131, 1987). The extraordinary performance of the Coudé Echelle Spectrometer on La Silla has played a central role in making possible the difficult observations required. I congratulate the ESO staff on producing such an outstanding instrument.

The idea is simple – if G-dwarf stars sample a well-mixed interstellar medium in the Galaxy at the time of their birth, and if the compositions of their atmospheres have not changed since birth except for radioactive decay, then the abundances of radioactive species in these stars will represent an integration of element production and destruction (via radioactive decay, astration and possibly dilution) in the Galaxy, up to the moment of stellar birth, followed by free decay still observed today. If one can develop a sample of stars with accurately known ages, then one has a record of the history of nucleosynthesis, at least for thorium and the r-process elements, which may help resolve the model dependencies inherent in using solar system data alone. That is, solar system material provides an integration of element production and destruction activity up to 4,6 Gyr ago; observations of radioactive species in the oldest stars known will yield an integration over only a short period at the beginning of the Galaxy; and data on the youngest stars give an integration over the whole galactic history.

Thorium has several faint absorption lines in the solar spectrum, and the strongest of these, at 4019.129 Å, even has an accurately measured transition probability (Andersen and Petkov, *Astron. Astroph.* **45,** 237–238, 1975).

When combined with the measured line strength, this probability yields the same abundance for thorium as found in meteorites. The line, therefore, appears to be largely unblended and a good candidate for use in setting up a chronometer based on thorium. It should also be remarked that the element thorium has only one long-lived isotope, 232 Th, so that measurement of the elemental abundance is expected also to give the isotopic abundance of interest.

The Chronometer

Figure 1 shows the region around Th II 4019.129 Å in alpha Cen B, one of the stars in my final sample. The thorium line is seen to appear in the wing of a stronger line, which turns out to be a blend of a Fe I and a Ni I line. Also indicated is a nearby absorption line of neodymium, Nd II 4018.823 Å. This line has a lower level excitation only 0.05 eV above that of Th II 4019.129, and neodymium has a first ionization potential close to that of thorium. Both lines are, therefore, from the dominant ion throughout late-type stellar atmospheres, and will behave with temperature and pressure essentially identically. Furthermore, both lines are unsaturated in G-dwarf spectra, so that their strength ratio is proportional to the abundance ratio of these two elements, and is largely unaffected by unknown or poorly estimated stellar atmospheric properties. And finally, it is important that there exist two rather good continuum points, at 4018.66 and 4019.67 Å, in the near vicinity (see for example the high resolution but compacted plots of the solar spectrum displayed in Figure 5 of Rutten and van der Zalm, *Astron. Astrophys. Suppl. Ser.* **55,** 143–161, 1984). Because the lines are so close together in wavelength and are bracketed by good continuum points, the ratio of their strengths may be determined with considerable reliability.

The proposed chronometer is the ratio of the strengths of these two lines. This ratio has the property that it can be measured to high accuracy. Whether it will in the end provide a useful and reliable chronometer depends on the details of the measurement errors and on the reality of a crucial assumption.

A Crucial Assumption

To have a useful chronometer, it is necessary to be able to compare the abundance of the radioactive species at synthesis, which is normally a quantity predicted theoretically, with the observed abundance. For the U-Th data in meteorites, for example, one can estimate the relative production ratios of 232 Th, 235 U, and 238 U, rather accurately, because they are very close to each other in atomic mass and in a mass range expected to exhibit a relatively smooth variation of abundance with mass in the r-process. Nevertheless, a major source of uncertainty in applying U-Th data in the solar system for chronometry are the uncertainties in the production ratios.

The situation in the stellar case is, in principle, much, much worse. Thorium

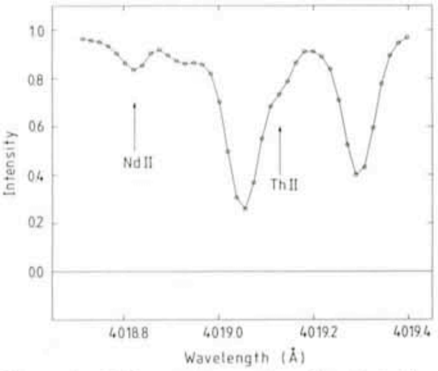


Figure 1: *CES spectrum of α Cen B in the region of Th II 4019.129 Å. The thorium and neodymium lines used to form the chronometric quantity Th/Nd are indicated.*

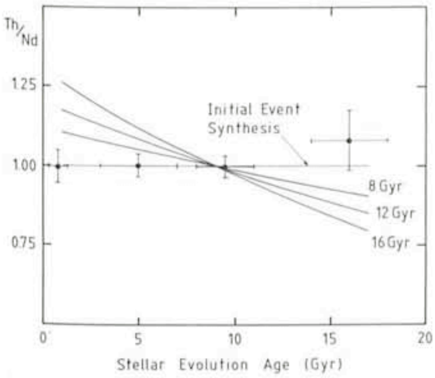


Figure 2: *Variation of normalized Th/Nd with stellar age. Individual data points have been combined here to show the statistical weight of the whole data set. Also shown are two models for the predicted variation of Th/Nd. The initial event model supposes that essentially all thorium and neodymium were synthesized before the sample stars formed; it predicts constant Th/Nd vs. age, and fits the data well. The second model supposes that net element production has proceeded continuously and at a constant rate over all time. The stellar ages are on Van den Berg's scale, but the latter model is shown assuming three different total timescales, as indicated, stretched to overlay the data points appropriately. Total durations of synthesis above about 10 Gyr in this model are seen to be excluded.*

is produced during fission cycling of the r-process. Neodymium also partakes in this cycling, but is probably also produced in the very short-lived process responsible for the lighter r-process nuclei. Its abundance, therefore, could very well evolve over time if the contributions to r-process synthesis vary. Furthermore, neodymium isotopes derive nearly 50 % of their abundance in the solar system not from the r-process, but from the s-process. The r-process is generally believed to have occurred in explosions, probably supernovae, whereas the s-process is seen to take place in red giant stars. There is every reason to suppose, therefore, that the ratio of r-process to s-process abundances will evolve over time and place in the Galaxy. If they do, the Th/Nd chronometer will be compromised, because it will be difficult to disentangle that evolution from the production and decay history of thorium. That is, for all but the oldest stars the observed Th/Nd ratio results from an integration of production and destruction activity over extended periods, and it therefore will not be easy to separate uniquely the effects of variations in the s-process contribution to neodymium in one model for the history of synthesis, from no variations in a different model.

Fortunately, the situation is not hopeless. It has been known for some time that the abundances of the s-process elements barium and strontium, and the r-process element europium, do not vary among dwarf stars in the solar neighbourhood, at least for stars having metallicities greater than about 3 % of solar. The best measurements to date limit any such variation to certainly no more than about 25 % (Butcher, *Ap. J.* **199,** 710–717, 1975; Lambert, *Astrophys. Astr.* **8,** 103–122, 1987). Hence in any star having strong enough lines for the thorium line to be measurable, the contribution to the neodymium abundance from the s- and r-processes has been sensibly constant over all time. And when it becomes possible to observe thorium in very metal deficient stars, it will be possible to apply a correction to account for any r/s evolution, because such stars are all very old and hence represent an integration of only a very brief period. They will not therefore produce uniqueness problems in the analysis.

The Data

A series of spectra were taken at the CAT and CES on La Silla, during 2–6 Sept. 1983 and 3–7 April 1985. Study of model and real data showed that spectral resolutions of at least 100,000 and preferably twice that would be required to be able to adequately measure the inflection that is the thorium line. For reasons of observing efficiency the CES was set to R = 100,000. The efficiency of the spectrometer is not optimal at 4000 Å, and with the 1,872 channel Reticon detector and integration times of up to 11 hours, the faintest star for which a S/N of several hundred could be obtained was about V = 6,5 mag. The instrument performed very well, except for some difficulty in obtaining a reliable instrumental profile using the blue laser (that is, the derived profile seemed to be a function of how saturated the line core became on the detector). Given the obvious importance of knowing with some accuracy and precision just what the instrumental profile is for a given measurement, I suggest that a careful study of known absorption line spectra, such as of an absorption cell, should be made. Perhaps then the saturation problems I encountered can be alleviated.

Results

It proved possible in the end to acquire data on 18 G-dwarf and several giant stars with narrow enough lines. These data have been analysed by fitting a model spectrum of the region to the individual spectra, of which there are typically two or three per star. The differences between the best-fit model spectra and the data are taken to give a measure of the noise in the line strength estimates, and I have argued that the resulting scatter in the data points about their mean is to be understood entirely as due to this noise. If that is so, then individual points may be appropriately summed to display the total statistical weight of the data set.

Such a display is given in Figure 2. Each of these data points is the average of 3 to 7 stars. The horizontal error bars give the range in age of the stars in each point (but also a rough estimate of the reliability of the age estimates), and those in the vertical direction the one sigma uncertainty in Th/Nd for the point.

The age estimates for the sample stars, except for the four youngest stars, are derived from trigonometric parallaxes (being all bright stars, the quality of the parallax data is quite reasonable), available broad band photometry, and the isochrones of Van den Berg (*Ap. J. Suppl. Ser.* **58,** 711, 1985). It is these isochrones which have given globular cluster ages above 15 Gyr, although there is now some suggestion that for large (factors of five) overabundances of oxygen in the most metal poor clusters, the maximum ages may be reduced to 14 Gyr (McClure et al., *Astron. J.,* **93,** 1144–1165, 1987).

In Figure 2 are also indicated the predictions of two extreme models for the history of synthesis, namely a single event at the beginning (initial spike model), and continuous synthesis at a constant net rate. It is evident that the initial spike model fits the data very well, whereas there is no support for any model with constant net production, even when it is assumed that the stars may be correctly ordered by age but with an incorrect total age scale. If the thorium line is contaminated by no more than 10 % (a value of 20 % seemingly ruled out by various tests reported in the *Nature* paper), then a two sigma upper limit on the total duration of synthesis in the latter model is less than 10 Gyr.

On the other hand, these data provide no independent age limit in the initial spike model. Any total age always yields a uniform composition at any given epoch in this case. But then the solar system U-Th data provide a sensitive limit, namely 11 Gyr maximum, with preferred values 2 or 3 Gyr less (see Fowler and Meisl, in *Cosmogonical Processes,* Arnett et al. eds., 83–100, VNU Utrecht, 1986; and Meyer and Schramm, in *Nucleosynthesis and its Implications on Nuclear and Particle Physics,* Audouze and Mathieu eds., 355–362, Reidel 1986, for discussion of results from models with synthesis peaked at early epochs). So combining stellar and solar system data constrains the total age scale, with the stellar thorium observa-

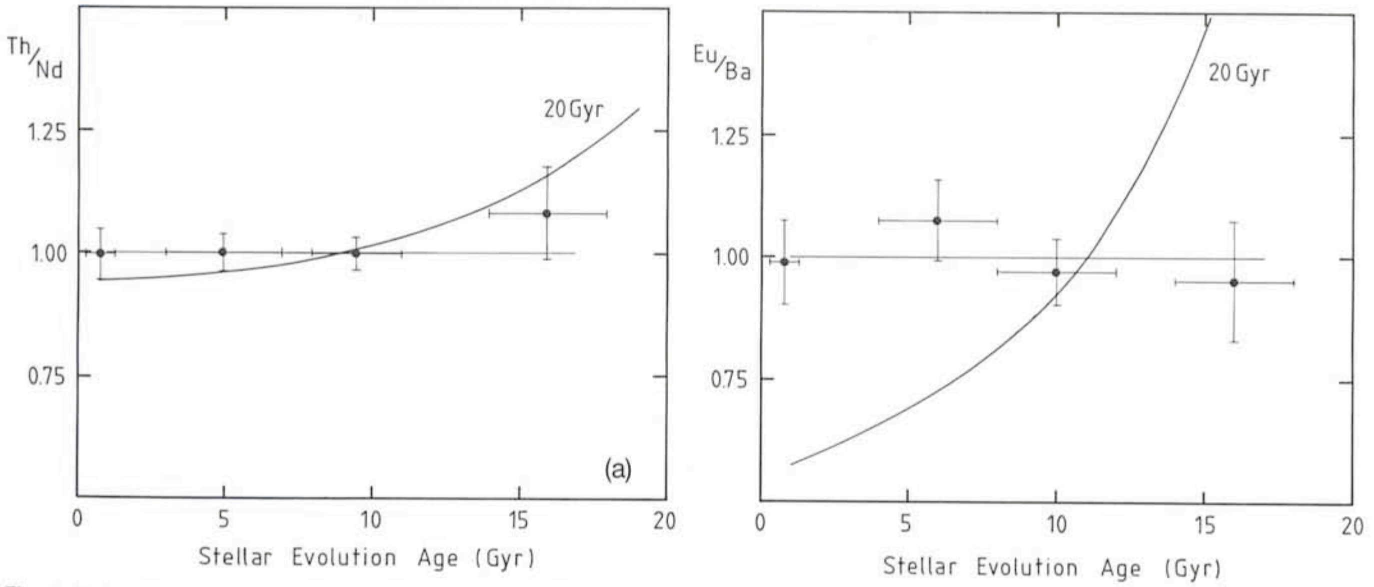


Figure 3: *Comparison of Clayton's galactic evolution model with stellar abundance results. This model assumes the r-process is a primary process, whereas the s-process is secondary. The resulting evolution of the neodymium abundance (52 % s-process and 48 % r-process in the solar system) compensates for the decay of thorium for ages above 15 Gyr, as seen in (a). The model predicts the europium (91 % r-process in the solar system) to barium (84 % s-process) ratio results displayed in (b), however, which is clearly inconsistent with existing measurements of these elements in the sample stars.*

tions limiting the constant rate model and the meteoritic data the initial spike model.

For models mid-way between the extremes, some sensitivity is lost in either case, and maximum ages of 11–12 Gyr are acceptable within both stellar and meteoritic constraints. But it remains the case that the best-fit model has synthesis concentrated in a single period at the beginning of the Galaxy (or before).

Potential Problems

The reliable use of Th/Nd for galactic chronometry rests on two assumptions that are still not fully verified. The first is that the thorium line at 4019.129 Å is not contaminated by more than, say, 10%; any much greater contamination would make the chronometer too sensitive to the exact amount of contamination. I suggested that none of the tests I made would have distinguished blending due to a line from a low lying level of an ion of an r-process element, and proposed that Tb II 4019.14 might be a candidate contaminator at the 10% level. Unfortunately, the spectrum of Tb II has never been fully analyzed, and I understand now that the line in question may in fact not really exist. But Holweger (*Observatory,* **100,** 155–160, 1980) has pointed out that Co I 4019.126 Å probably should be considered a candidate contaminator at this level. It is clear that a definitive discussion of the contamination question awaits further investigation.

The second area of uncertainty is the constancy of the thorium to neodymium ratio during synthesis. Of course, the data suggest that the initial event model is to be preferred, so that if negligible amounts of on-going s-process synthesis have occurred, then the data are fully consistent. It is only on the major synthesis at all epochs model, such as would be relevant if synthesis were directly tied to star formation, that the uncertainty becomes a matter for concern.

Several workers have proposed that the conclusion of a young age for the Galaxy is easily refuted, by simply taking account of a plausibly separate evolution of s-process and r-process abundances over time. Shown in Figure 3, for example, is a model due to Clayton (*Nature,* **329,** 397–398, 1987) which postulates a gradually increasing contribution from the s-process. The fit to the Th/Nd data is quite good, even for a galactic age of 20 Gyr. But I have been able to assemble Eu/Ba ratios for most of my sample stars, and display these data together with the prediction of Clayton's model. Here even though the Eu/Ba data are not as good as for Th/Nd, it is evident that the model fails. Mathews and Schramm (submitted to *Ap. J.* Letters) have also constructed a complicated galactic evolution model based on a varying s-process production. They claim that their model fits the Th/Nd data for ages up to 15 Gyr. This model is displayed in Figure 4, and their claim for Th/Nd is again seen to be correct. However, the model also cannot produce constant Th/Nd and simultaneously constant Eu/Ba, as is evident in the second part of the figure.

Simple schemes for compromizing the Th/Nd chronometer, therefore, run afoul of even existing data. It will be of considerable interest, of course, to determine observationally just how constant the ratios of r- to s-process abundances really are, and for the halo stars to find the corrections needed to the neodymium abundance for those stars ultimately to be usable for this sort of chronometry.

Speculation

Finally, I would like to communicate the following, deliberately provocative, speculation.

The so-called G-dwarf problem – that the distribution of metallicities among dwarf stars cannot be reproduced with simple galactic evolution models having synthesis closely tied to star formation – has traditionally been explained by supposing that infall of primordial material must have been important (although other schemes, such as metal-enhanced star formation, have occasionally also been proposed). The Th/Nd data suggest that synthesis peaked at early epochs is the right model, in which case the G-dwarf problem, as well as the metallicity gradients seen in the Galaxy, may be due to some other phenomenon than ordinary stellar nucleosynthesis.

I wonder, therefore, whether the generally accepted picture of continuous star-formation-linked synthesis, fixed up via mechanisms which are plausible but for which there is no real positive evidence to fit the metallicity distribution results, has any claim to preference over the initial spike model. For the latter, some mechanism will have to be found to account for the metallicity gradients, but this deficiency must be weighed

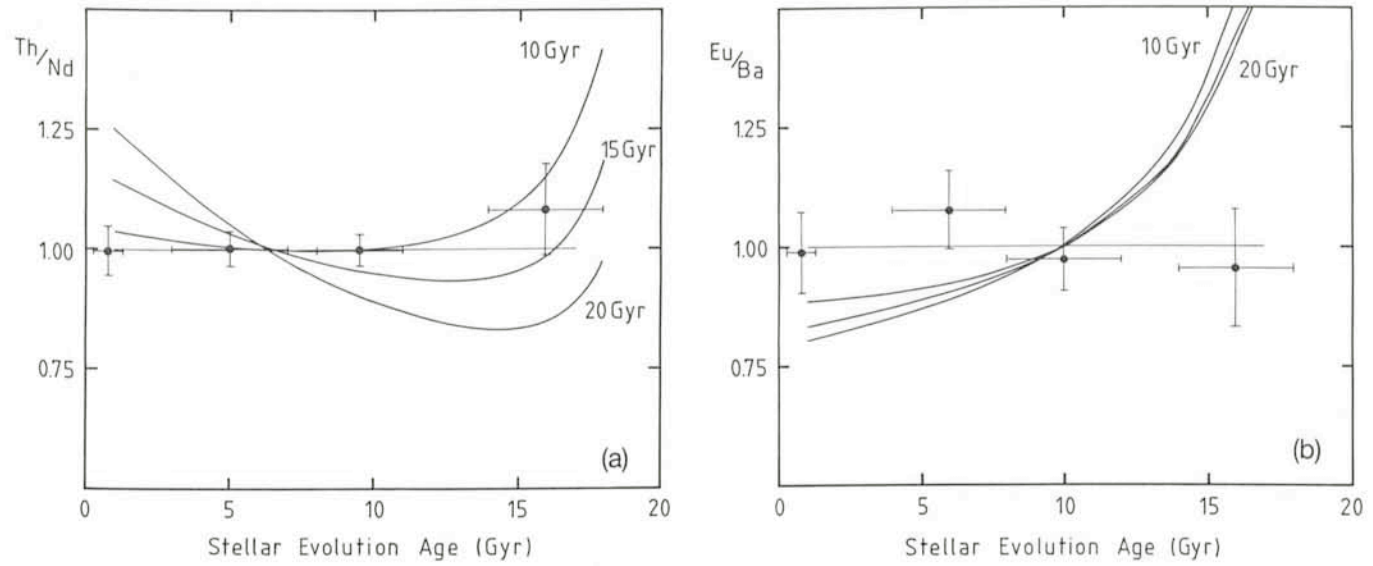


Figure 4: *Comparison of a galactic evolution model due to Mathews and Schramm with stellar abundance data. This model supposes that the r- and s-processes occur in stars of different masses, so that a gradual change in the contribution ratio for neodymium is predicted which will compensate thorium decay for ages up to 15 Gyr. The predicted Th/Nd ratio vs. age is shown in (a) for this model and three maximum ages. In (b) is shown the prediction for the stable r- and s-process elements, europium and barium. It is clear that such simple models will always have trouble providing nearly constant Eu/Ba and at the same time constant Th/Nd, unless the total age is so short that thorium has not had time to decay substantially in even the oldest stars.*

against the absence of a convincing mechanism in the traditional scenario for producing significant metallicity variations without altering the ratio of r- to s-process abundances. I suggest that all available data fit the initial spike model as well as they fit the synthesis in normal stars idea. One is then left in the amusing situation of having stars making helium, but with the vast majority of the helium around us having been produced in the Big Bang, and of supposing that although stars clearly make new elements via nuclear reactions, the majority of the heavy elements were made by some process preceding or accompanying the formation of the Galaxy. The short-lived radioactivities found in solar system material would then have their origins in such minor on-going synthesis as has taken place, and only a few species, such as the CNO isotopes, will have had their abundances measurably altered via stellar evolution.

What might the initial process be? A most exciting possibility has recently been proposed. Models concerning the quark-hadron phase transition in the Big Bang suggest that inhomogeneous conditions may have resulted during the epoch relevant to primordial nucleosynthesis (Applegate and Hogan, *Phys. Rev.*, **D 35,** 1151, 1985; Malaney and Fowler, preprint). In such conditions it appears possible to generate not only the light nuclei, but also to bridge the mass gap at atomic number 8, to produce heavy elements all the way up to U and Th. The very first generation of stars following the Big Bang would then have been responsible for the s-process elements seen in halo stars. Here is a plausible mechanism for synthesizing the r-process radioactivities which are used for cosmochronology in a single initial event. I for one will be following further studies of this idea with gleeful anticipation!

High Resolution CASPEC Observations of the z = 4.11 QSO 0000-26

J.K. WEBB, Sterrewacht Leiden, the Netherlands, and Royal Greenwich Observatory, U.K.
H.C. PARNELL, R.F. CARSWELL, R.G. McMAHON, M.J. IRWIN, Institute of Astronomy, Cambridge, U.K.
C. HAZARD, Department of Physics and Astronomy, University of Pittsburgh, U.S.A.
R. FERLET and A. VIDAL-MADJAR, Institut d'Astrophysique, Paris, France

Introduction

The QSO Q0000-26 is a newly discovered object with an emission redshift of 4.11 and a continuum magnitude at ~ 6000 Å of around 17.5. The QSO was discoverd as part of a programme to detect bright (m(R) $\lesssim$ 18.5), high redshift ($z \gtrsim 3.5$) QSOs using IIIa–F objective prism plate material taken with the UK 1.2-m Schmidt telescope at Siding Spring in New South Wales, Australia (Hazard and McMahon 1985). Q0000-26 was observed and confirmed as a high redshift QSO during an observing run on the Anglo-Australian Telescope in August last year. Fortunate timing of a run immediately following on the ESO 3.6-m telescope meant that we were able to collect the high resolution data we present here only a few days after the object was discovered.

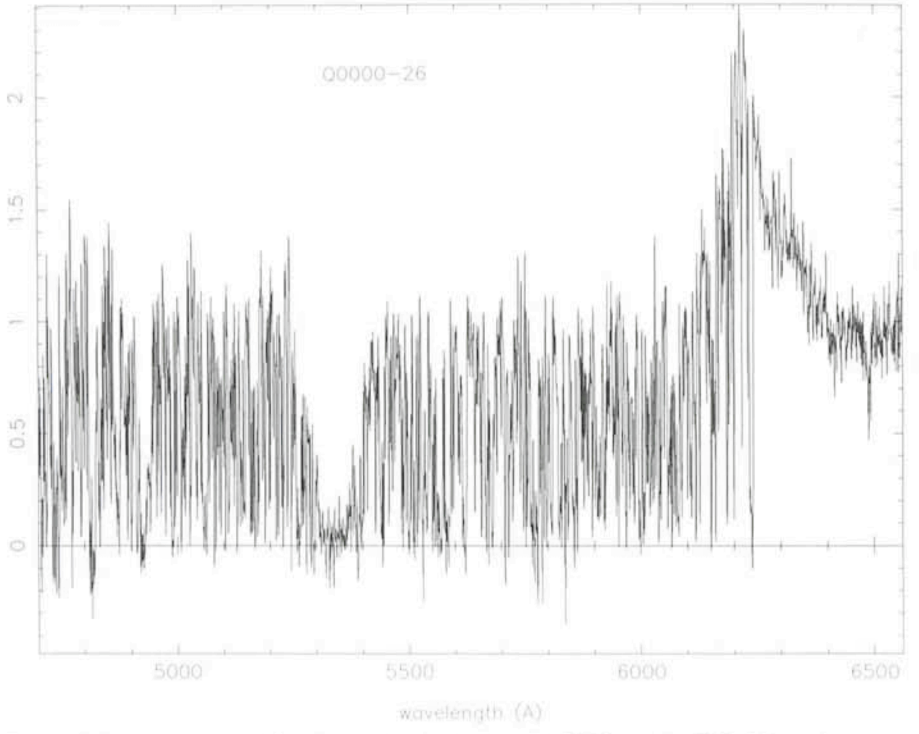


Figure 1: *The spectrum of Q0000-26 obtained using CASPEC on the ESO 3.6-m telescope. The dense Lyα forest, extending right up to the Lyα emission line at 6230 Å is clearly evident.*

The Observations

Q0000-26 was observed using CASPEC on the ESO 3.6-m telescope on the nights of the 30th and 31st August 1987. We used the 31.5 lines/mm grating to collect data in two overlapping wavelength regions: approximately 4700 to 5700 Å and 5600 to 6600 Å. Four 120-minute exposures were obtained for the first region and two for the second. For the lower wavelength exposures we binned the CCD (ESO # 3) by two pixels in the dispersion direction and for the higher wavelength exposures we binned by two pixels in both directions.

The slit lengths for the low and high wavelength exposures were 1,200 μm and 1,600 μm corresponding to about 8.6 and 11.5 arcsecs on the sky respectively. The slit width for all exposures was 280 μm, corresponding to about 2.0 arcsecs. This just about matched the seeing profile on our first night, when 3 out of the 4 lower wavelength exposures were obtained, and was somewhat less than the seeing on the second night, when the remaining lower wavelength and both higher wavelength exposures were obtained.

Data Reduction

Data reduction was carried out using the Starlink VAX 11/780 at the IOA in Cambridge. Cosmic rays were located either by subtracting two exposures (at the same wavelength setting) or simply by clipping pixel values above a suitable threshold, and were then flagged. Simple median filtering, or clipping and resetting to the local mean is undesirable because of the unpredictable effect on narrow absorption lines. The two-dimensional frames were converted from ADUs to photon counts, assuming a conversion rate of 10 e^-s/ADU. The extraction of the two-dimensional data to produce spectra was then done using an optimal, seeing profile weighted procedure to maximize signal to noise in the final spectrum. Pixels containing the flagged cosmic rays were discarded and the extracted counts rescaled appropriately. An error array was generated based on Poisson statistics. Wavelength calibration was carried out in the usual way and the r.m.s. residual on arc line positions was ~ 0.05 Å corresponding to ~ $\frac{1}{6}$ of a pixel. The final spectrum was produced by adding together the calibrated orders which had been flattened by dividing by the smoothed flat field. Calibrating in this way does not produce the correct spectral shape but this does not affect our absorption line analysis. The complete spectrum thus obtained is shown in Figure 1. There was a non-uniform increased background count present in three of the lower wavelength frames, which could mean that the zero level is slightly unreliable below 5700 Å.

To determine accurately the spectral resolution, we extracted the arc spectra, adding together the individual orders in exactly the same way as the QSO spectra. By measuring the FWHM of lines in the arc spectrum, we estimate a resolution of ~ 30 kms^{-1}.

The Lyα Forest

Given the high resolution of our CASPEC data, most of the absorption lines are resolved and we can use profile

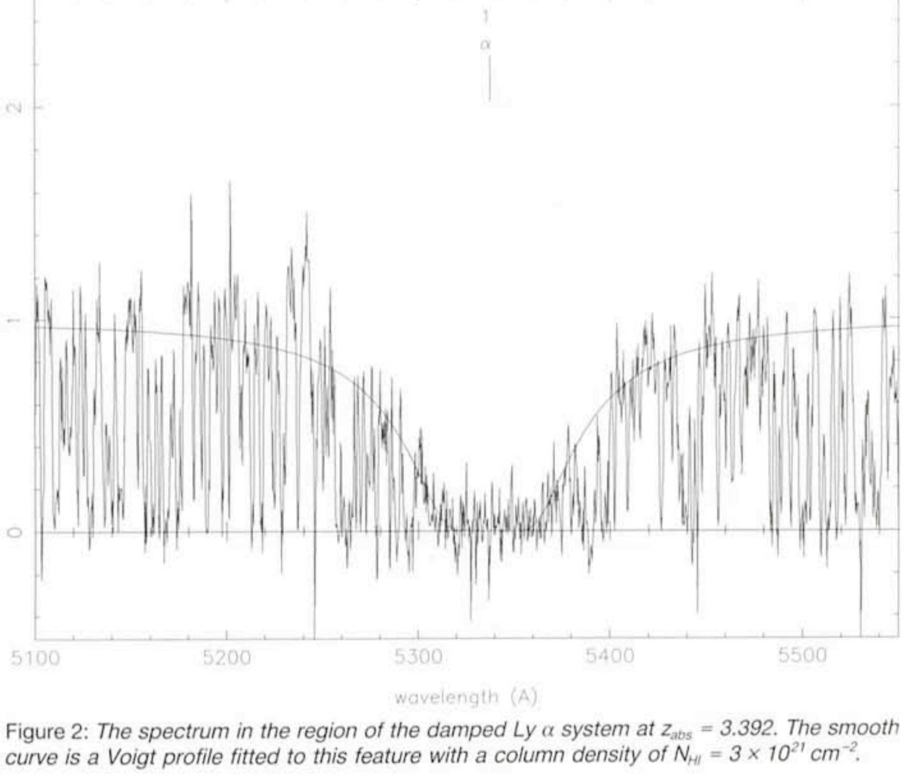


Figure 2: *The spectrum in the region of the damped Ly α system at z_{abs} = 3.392. The smooth curve is a Voigt profile fitted to this feature with a column density of $N_{HI} = 3 \times 10^{21}$ cm^{-2}.*

fitting methods to model each cloud to obtain the column density of neutral hydrogen, N_{HI}, the Doppler (velocity dispersion) parameter, b, and the redshift, z (see Carswell et al., 1987). This analysis is currently underway. Here we describe the results of a preliminary investigation of some aspects of the Lyα data.

First we fitted a single cubic spline continuum to the data using an iterative procedure which clips significant deviations below the estimated level. Clipping is carried out such that deviations in the data (excluding discarded points) about the final fit are consistent with the noise properties. The fit was done between 4700 and about 6100 Å. Over the Lyα emission line, we estimated the continuum by interpolating over regions containing absorption lines. The Lyβ emission line falls immediately shortwards of a strong damped Lyα absorption line at 5340 Å and our adopted continuum will be unreliable in that region.

Next we estimated absorption line positions (centroids) and the observed equivalent widths using an automated technique (Young et al., 1979; Carswell et al., 1982) to generate a line list containing all features which deviate from the adopted continuum level by 4 σ or more. Our rest equivalent width limit at this level is ~ 0.2 Å or better. Despite the extremely high number density of absorption lines, this procedure seems to work well. We checked this by comparing an expanded plot of the data with the appropriate entries in our line list.

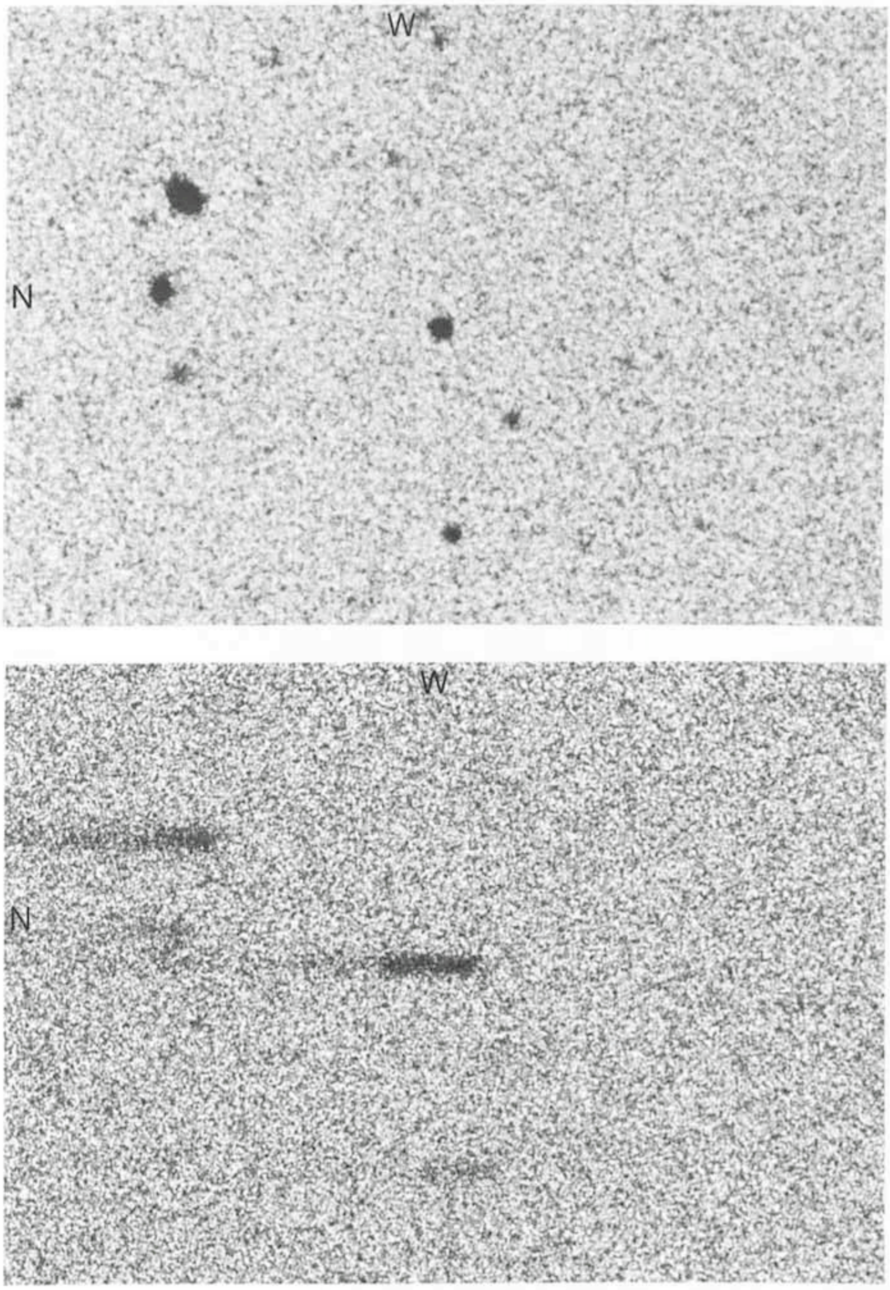


Figure 3: *(a) Image of QSO 0000-26 on IIIa-J+GG 395 plate for the ESO/SERC Atlas of the Southern Sky.*
(b) Objective prism spectrum of QSO 0000-26 on IIIa-F+GG 495 plate and 2° prism.
Both plates were obtained with the UK 48" Schmidt telescope and the reproductions were made at UKSTU, Royal Observatory, Edinburgh.

Properties of the Lyα Forest Lines

(a) Number density evolution

As shown initially by Peterson (1978), the evolution in number of Lyα lines per unit redshift interval increases with redshift at a rate significantly faster than can be accounted for purely by cosmological effects, and consequently the clouds are evolving intrinsically. This change in the number density is well approximated by

$$\frac{dN}{dz} = N_0 (1 + z)^{\gamma}. \quad (1)$$

We have estimated the parameters N_0 and γ from a sample of QSOs taken from the literature (Webb and Larsen; 1988), not including Q0000-26, and find $\gamma = 2.50 \pm 0.46$, and $N_0 = 2.53$ for lines with rest equivalent width, $W_{rest} > 0.36$ Å. These values agree with the estimates of Hunstead et al., 1987 for an overlapping QSO sample.

Counting lines in Q0000-26 between z = 3.48 (above the damped Lyα absorption and Lyβ emission lines) and up to z = 4.06 (approximately 3,000 kms^{-1} below the Lyα emission line, where the local QSO ionization probably dominates) we find 68 absorption lines with $W_{rest} > 0.36$ Å. Equation (1) predicts a count of 73 and so we find that the Q0000-26 data are consistent with a continued increase in the absorption line number density up to z ~ 4.

(b) The Inverse Effect

When considering a single QSO, there appears to be an inconsistency in the redshift distribution of lines with equation (1); the number density is seen to increase towards lower wavelengths (Carswell et al., 1982; Murdoch et al., 1986; Tytler, 1987; Webb and Larsen, 1988; Bajtlik et al., 1988). This is generally, although not unanimously, thought to be due to increased ionization levels for clouds in the vicinity of the QSO. In this preliminary investigation, we merely check as to whether or not such an effect is present in the spectrum of Q0000-26.

In the region 4.06 < z < 4.11 (i.e. within 3,000 kms^{-1} of the emission redshift) we find 4 lines with $W_{rest} > 0.36$ Å compared with 7.4 predicted by equation (1). Counting lines down to our estimated 4 σ limit of 0.2 Å, we find 8 lines in the same region and 164 in the range 3.48 < z < 4.06. The ratio of these two counts, normalized to a unit redshift interval, is 0.55 ± 0.20 and so we apparently have a significant inverse effect (at ~ 2 σ level).

(c) The velocity dispersion parameter

In order to compare our data with previous analyses of high resolution data, we selected 10 apparently unblended lines in the region $3.48 < z < 4.11$. Their mean redshift was $\bar{z} = 4.0$. These lines were then modelled by using non-linear least-squares to fit Voigt profiles. For these 10 lines we find $\bar{b} = 30.5 \pm 2.1$. This can be compared with the results of Carswell et al., 1984, for Q1101-264, and Atwood et al., 1985, for Q0420-388. For Q1101-264 $\bar{b} = 30.1 \pm 2.5$ for a sample of absorption lines with $\bar{z} = 2.0$ (this is derived from the complete sample rather than just for unblended lines; the absorption line number density is sufficiently low at $z = 2$ that this should not bias the result too much) and for Q0420-388 $\bar{b} = 30.5 \pm 2.0$ for a sample with $\bar{z} = 2.9$ (for unblended lines with log $N_{HI} > 13.75$). Our preliminary check on the Doppler parameter at $z = 4$ therefore provides no evidence for redshift evolution in this quantity.

Metal Line Systems

From this high resolution CASPEC spectrum and a low resolution (10 Å FWHM) spectrum obtained by RFC, HCP and JKW at the AAT, we have discovered two metal containing systems.

(a) $z_{abs} = 3.392$

The most prominent system is evident from the CASPEC data alone. This is associated with the strong damped Lyα line at 5349 Å. Strong C IV absorption is seen at the same redshift in our low resolution data. Profile matching to this feature, which is probably the highest redshift candidate disk galaxy yet discovered, indicates that $N_{HI} = 3 \times 10^{21}$ cm^{-2}. The Voigt profile fitted to this feature is shown in Figure 2. At this early stage, we cannot say anything about metal abundances; many of the transitions of interest (e.g. C II λ 1334, Si II λ 1260, Si III λ 1206, Si IV λλ 1393, 1402) are embedded in the Lyα forest and a detailed profile analysis is required to obtain column densities (or limits).

(b) $z_{abs} = 4.133$

This system has a redshift 1,350 km s^{-1} greater than the Lyα emission line, and so presumably resides in the same cluster of galaxies as the QSO itself. Strong C IV absorption is seen in the low resolution spectrum, although the hydrogen column density is not particularly high (probably less than a few times 10^{17} cm^{-2}). This feature is not seen in the high resolution data as it is outside the wavelength range. The higher order Lyman lines are present in the CASPEC data and they should provide an accurate column density estimate. Since this object evidently sits fairly close to the QSO, we might expect the gas to be highly ionized, and so we searched for O VI absorption. This is a doublet with rest frame wavelengths 1031.9 and 1037.6 Å. The 1031 line appears to be present but this is unfortunately ambiguous since the 1037 line is blended with the damped Lyα line.

We expect the full analysis of these data to take some time and that the results will supply new and valuable information on the nature of the Lyα clouds at the highest redshift so far available. Later this year, we aim to collect more CASPEC data on the spectrum of Q0000-26, covering wavelengths longward of the Lyα emission line. These will cover many of the metal line transitions associated with the two systems discovered and will enable us to study the abundances and ionization conditions at this early epoch.

References

Atwood, B., Baldwin, J.A., and Carswell, R.F., 1986, *Astrophys. J.*, **292,** 58.
Bajtlik, S., Duncan, R.C. and Ostriker, J.P., 1988, preprint.
Carswell, R.F., Whelan, J.A.J., Smith, M.G., Boksenberg, A., Tytler, D., 1982, *Mon. Not. R. Astr. Soc.*, **198,** 91.
Carswell, R.F., Morton, D.C., Smith, M.C., Stockton, A.N., Turnshek, D.A., and Weymann, R.J., 1984, *Astrophys. J.*, **278,** 486.
Carswell, R.F., Webb, J.K., Baldwin, J.A., and Atwood, B., 1987, *Astrophys. J.*, **319,** 709.
Hazard, C. and McMahon, R.G., 1985, *Nature,* **314,** 238.
Hunstead, R.W., Pettini, M., Blades, J.C., and Murdoch, H.S., 1987, in *IAU Symposium 124, Observational Cosmology,* ed. A. Hewitt, G. Burbidge and L.Z. Fang (D. Reidel) p. 799.
Murdoch, H.S., Hunstead, R.W., Pettini, M., and Blades, J.C., 1986, *Astrophys. J.*, **309,** 19.
Peterson, B.A., 1978, in *IAU Symposium 79, The Large Scale Structure of the Universe,* ed. M.S. Longair and J. Einasto (D. Reidel), p. 389.
Tytler, D., 1987, *Astrophys. J.*, **321,** 69.
Webb, J.K. and Larsen, I.P., 1988, to appear in proceedings of the Third IAP Astrophysics Meeting, *High Redshift and Primeval Galaxies.* (Edition Frontières)
Young, P.J., Sargent, W.L.W., Boksenberg, A., Carswell, R.F., Whelan, J.A.J., 1979, *Astrophys. J.*, **229,** 891.

Remote Observing: Nine Days in Garching

C. WAELKENS, Astronomical Institute, University of Leuven, Belgium

As announced by G. Raffi in the *Messenger* No. 49 and confirmed by P. François in the *Messenger* No. 50, the CES spectrograph equipped with CCD (using the CAT telescope) can now be operated by means of remote control from Garching. I had the chance to be the first visiting observer with these instruments in Garching, and was asked to write down my impressions for the readers of the *Messenger.*

Before leaving my home institute, I was warned by several colleagues who feared that remote control was an additional step toward a practice of observational astronomy where most of the romantic side of the job has gone away. My answer was that an observation run from Garching allowed me to stay a few days longer with my newly born son, and that there was some romanticism there too. I could also have replied how fascinating an experience it is to be in touch with one of the amazing technical developments at ESO. It surely is a remarkable achievement that, so early in the development of the remote control technique, observations could be carried out from Garching with essentially the same efficiency as at La Silla, an achievement for which G. Raffi, G. Kraus, and M. Ziebell deserve to be congratulated. My warmest thanks also go to the numerous colleagues both in La Silla and in Garching who helped in rendering the operations as efficient as possible.

My programme was an easy one for remote control, since I have been using the same spectral range throughout, watching variations of the profile of the Si III line at 4552 Å in some bright Beta

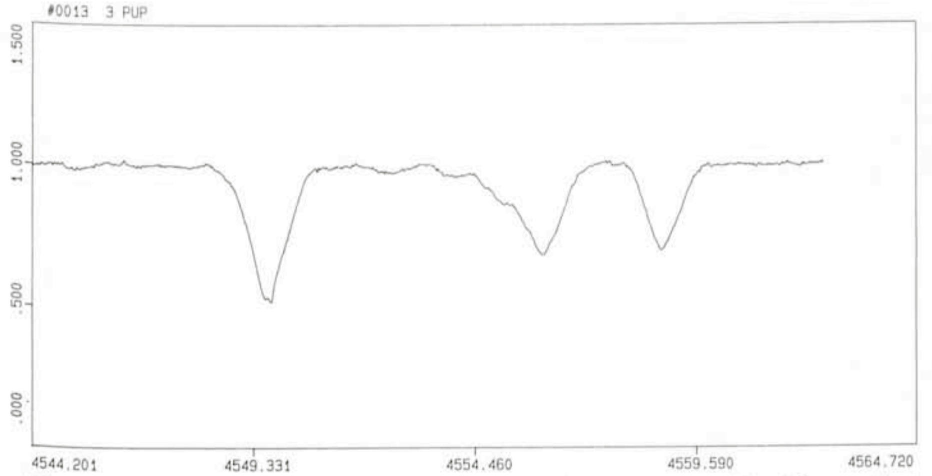


Figure 1: *Some of the stronger FeII, TiII, and CrII lines in the spectrum of the A2-supergiant 3 Puppis.*

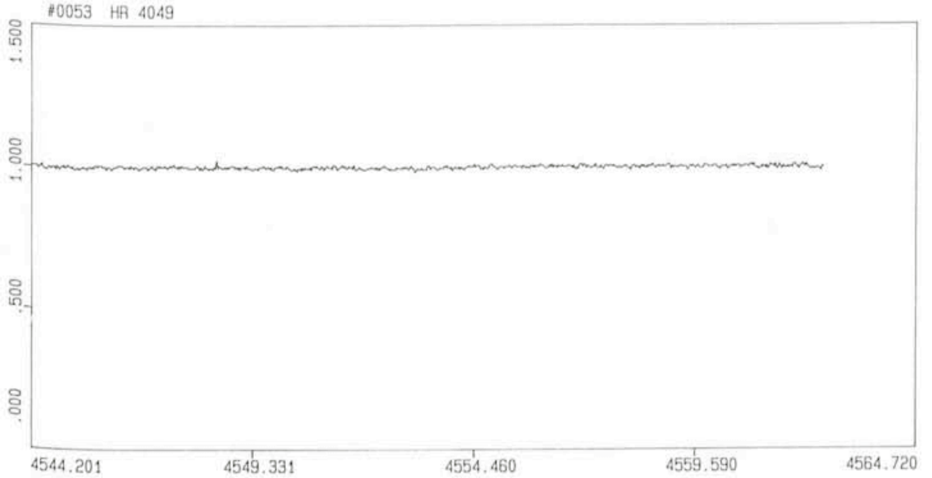


Figure 2: *The same spectral region as in Figure 1, but for the peculiar early-A supergiant HR 4049.*

Cephei stars. I could not withstand the temptation to spend some time on my favourite object, the peculiar early supergiant HR 4049. As explained in the *Messenger* 49, HR 4049 is not a normal massive supergiant, but probably an old low-mass star that is terminating its evolution from the red-giant stage toward the planetary-nebula stage. From previous optical spectra, it was clear that HR 4049 is a very metal-deficient object. It happens that the spectral region I observed contains some of the strongest lines of the iron-peak elements iron, titanium and chromium in the A2Ia supergiant standard Alpha Cygni. In Figures 1 and 2 the spectrum of HR 4049 (A0Ip) can be compared with that of another A-supergiant surrounded by a dust shell, 3 Puppis (A2Iabe). One does not have to undertake tedious calculations in order to know that the deficiency of HR 4049 is particularly severe! This star may also become an object for observers who are not interested in the subject of late stages of stellar evolution, but are just looking for early-type stars that are suitable for observations of stellar flat fields . . .

My run was rather long, nine nights, and maybe too long for remote control observations. The weather was excellent throughout at La Silla, but not so in Garching. After a few nights, it became a frustrating experience not to wake up having access to the familiar sunshine on the mountain, but instead watching the darkness of the northern winter with its fog so typical for November. This was entirely my problem, of course, since remote control is not primarily designed for such long runs. Instead, the technique is most promising for the possibility it offers to carry out shorter programmes, that presently aren't scheduled so often at the CAT, in an efficient and cost-saving way.

La Silla Snowstorm

Skiing enthousiasts among European astronomers – who have suffered because of lack of snow in the beginning of this winter – may be interested in these pictures by K. Seidensticker, obtained in late July 1987. While tall snow-drifts block the inner yard of the La Silla Hotel, a snow plough works its way along the roads under a splendid blue sky.

ESO Exhibitions

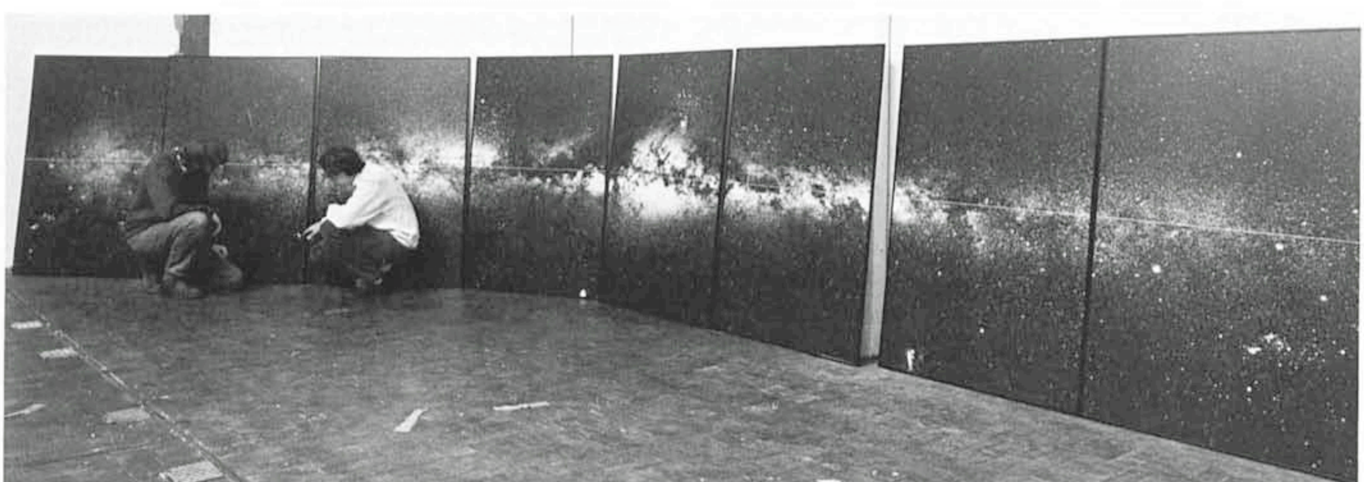
An ESO Exhibition was officially opened at the Vienna Planetarium on December 17, 1987, by the Austrian Federal Minister for Science and Research, Professor Dr. Hans Tuppy. ESO was represented by Professor Harry van der Laan, Director General elect. In the picture above, the Minister (centre) is shown the model of the ESO New Technology Telescope by the new Director General.

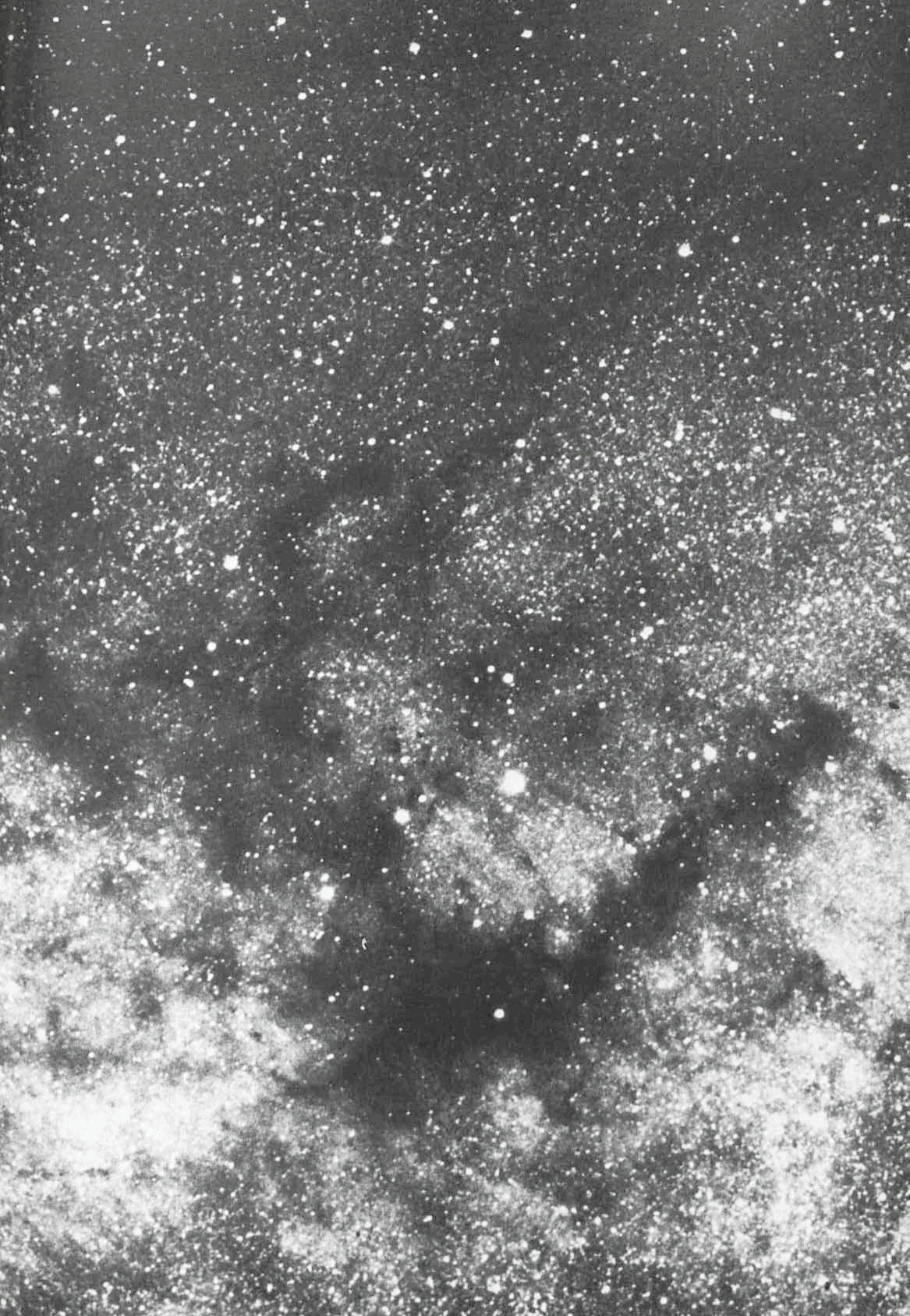
During the past year, the ESO Exhibition has grown and one more impressive item has just been added. Recently, a photographic panorama of the Milky Way was obtained by Claus Madsen and Svend Laustsen; a high-quality printed copy was published as a fold-out in the ESO Book *Exploring the Southern Sky*.

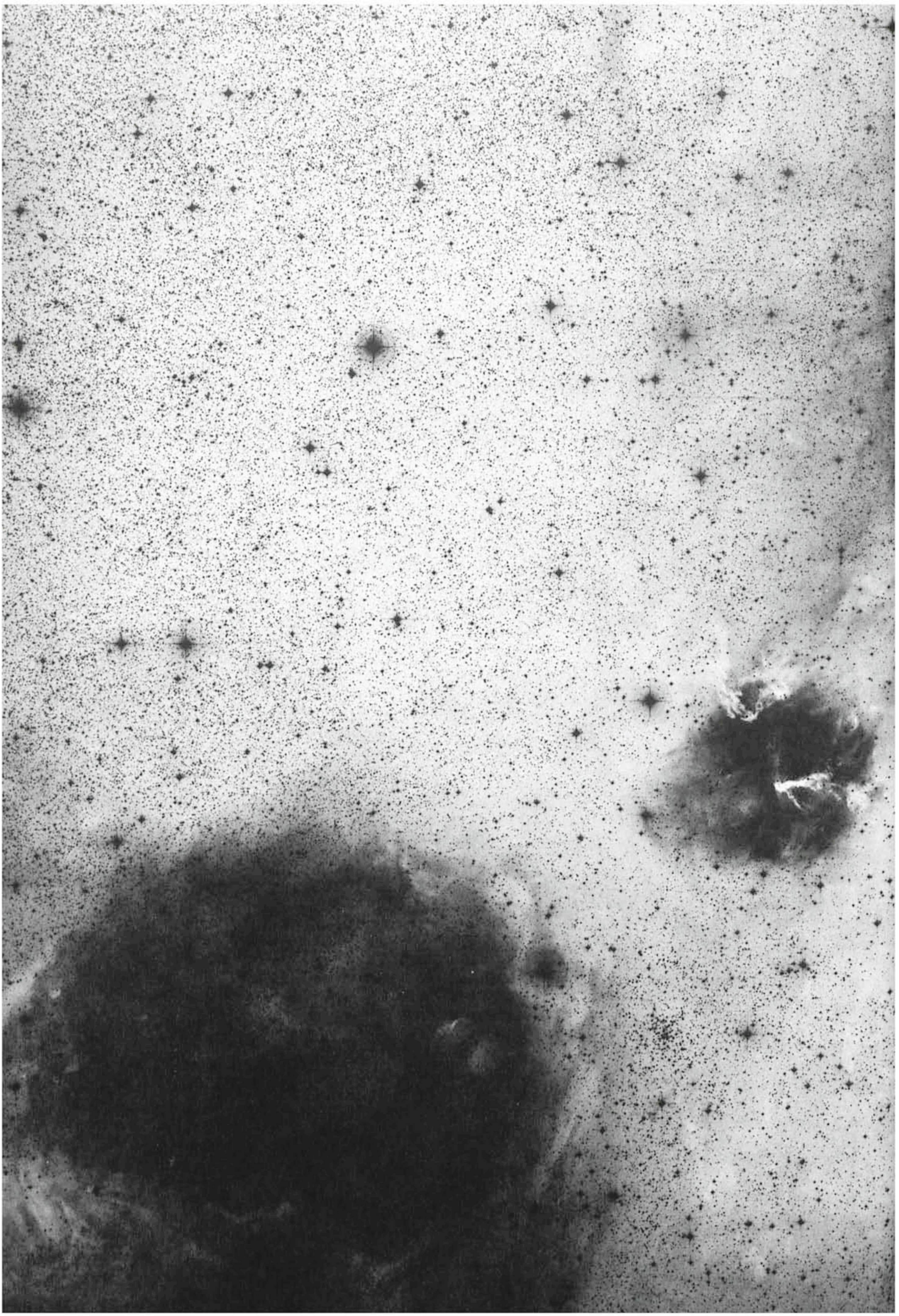
This panorama has now been photographically enlarged to fill 1.5 × 8 m. It shows the entire 360° of the Milky Way band to ± 30° latitude, i.e. about half of the entire sky, with a resolution of about 1 arcminute and down to 11th magnitude. On the photo below, it is being prepared for transport to the Madrid Planetarium, Spain, where the next ESO Exhibition will take place. The photographer points to the Andromeda Galaxy, one of the many well-known objects visible on the panorama; note also the Large Magellanic Cloud at the lower right. The picture on the opposite page is a reproduction at the panorama scale of an area near the dark clouds in Ophiochus.

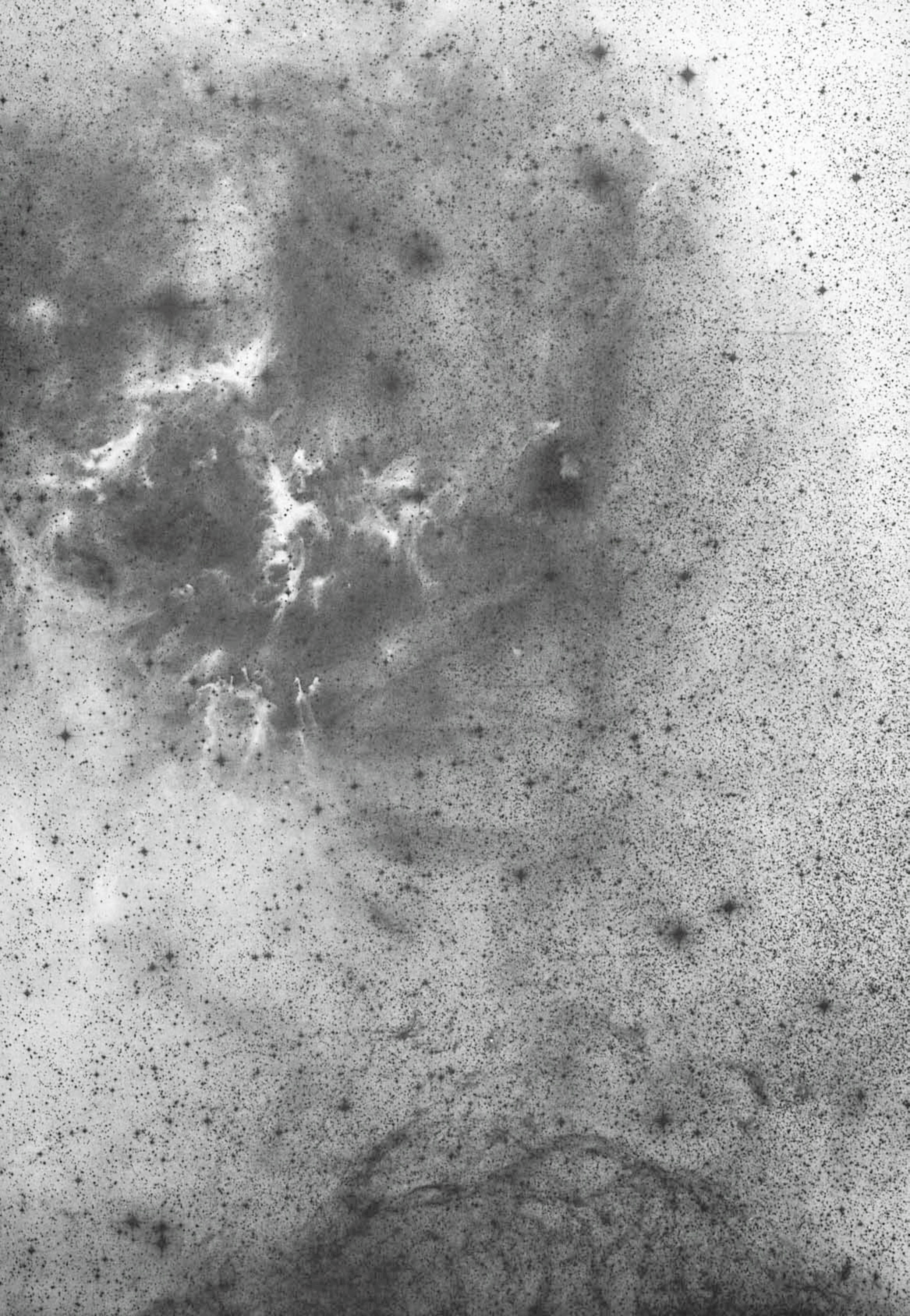
Next Locations for the ESO Exhibition:

Spain	Madrid	Planetario	March 1–April 10
Italy	Bologna	Palazzo Re Enzo	May 7–May 27
Sweden	Gothenburg	Liseberg	June 15–August









Monitoring OH/IR Stars at the 1-m Telescope

T. LE BERTRE, ESO

Variability in stars is very common. It makes observations more difficult and their interpretation more complex, but it can be useful as a mean of probing stellar properties. In particular, it can be used to derive information on stellar interiors. When a star is surrounded by circumstellar matter, variability can also be used to probe the latter.

OH/IR stars are among the most spectacular variable sources. They are primarily characterized by the coincidence of a hydroxyle (OH) maser emission with an infrared (IR) source. These stars are enshrouded in circumstellar envelopes. Dust in the shell absorbs light from the central source and re-radiates it in the IR range; OH radicals are formed by photo-dissociation of water molecules in the outer Part of the envelope, and, excited probably by 35-μm photons, produce a maser emission in the satellite line at 1612 MHz. The central stars appear to be in the late stages of stellar evolution, generally as extreme Miras, at the top of the asymptotic giant branch (AGB), or as red supergiants (1); sometimes they may be still more evolved and on their way to the planetary nebula stage (2). In this latter case, pulsations are damped out and strong variability is not observed (3).

Most OH/IR stars known in the southern hemisphere have first been discovered as OH emitters during systematic surveys made with the parkes antenna. Many have been recovered in the IR at the ESO 1-m telescope (4). Time-spread measurements have shown that these sources are variable and a systematic monitoring of a few of them was started in late 1984 with the same 1-m telescope. As OH/IR stars have periods in the range 500–2,000 days, this is a long-term programme from which only preliminary results can be given now. The monitoring is made in the J (1.25 μm), H (1.65 μm), K (2.2 μm), L (3.8 μm) and M (4.6 μm) photometric bands. Depending on circumstellar dust shell optical depth, some objects are very red and cannot be measured at short wavelengths with the 1-m. During nighttime, through a 15″ diaphragm, limiting magnitudes (S/N = 1, in 1 minute integration) are typically 14–15 in the near infrared (J, H, K); due to telescope thermal emission, they degrade at longer wavelengths, and one reaches a limit of ~ 9.5 in L and, depending on weather conditions, 7-8 in M. Thanks to the good pointing and tracking of the telescope, daytime observing is also possible. However, performances are reduced in the near infrared due to sky background; in these conditions one loses typically 3 magnitudes. Also, images are normally worse during daytime (especially in the afternoon), and one may have to use a larger diaphragm which induces, at all wavelengths, a further lowering of performances. Nevertheless, daytime observations are necessary to get a continuous coverage of the lightcurves. Except for a few cases, stars have been selected so that they could be easily measured with the 1-m anytime, at least in K, L and M.

In this sample of OH/IR sources, two objects have been studied especially in detail: OH/IR 285.05+0.07 and OH/IR 286.50+0.06. They have been selected for several reasons. Although their energy distributions (4) are similar, very early, their periods appeared to differ by a factor greater than 2. Furthermore, they are close to each other on the sky, facilitating a comparative study, and their southern position ($\delta \sim -60°$) keeps them away from the Sun all the year round, allowing, in principle, a perfectly continuous monitoring. Finally, both are bright enough so that they can almost always be measured easily in the five photometric bands. In Figure 1, the K lightcurves of both sources are presented. The coverage is almost continuous between Julian Dates (JD) 2446000 and 2447100; there is an interruption of 150 days around JD 2447000 due to the explosion of SN 1987A which obliged us to stop the programme for a while and to observe preferentially that unforeseen event.

OH/IR 286.50+0.06, with a period of ~ 550 days, appears to be an extreme member of the Mira class at the top of the AGB. Its broad-band spectrum indicates that its average total luminosity is

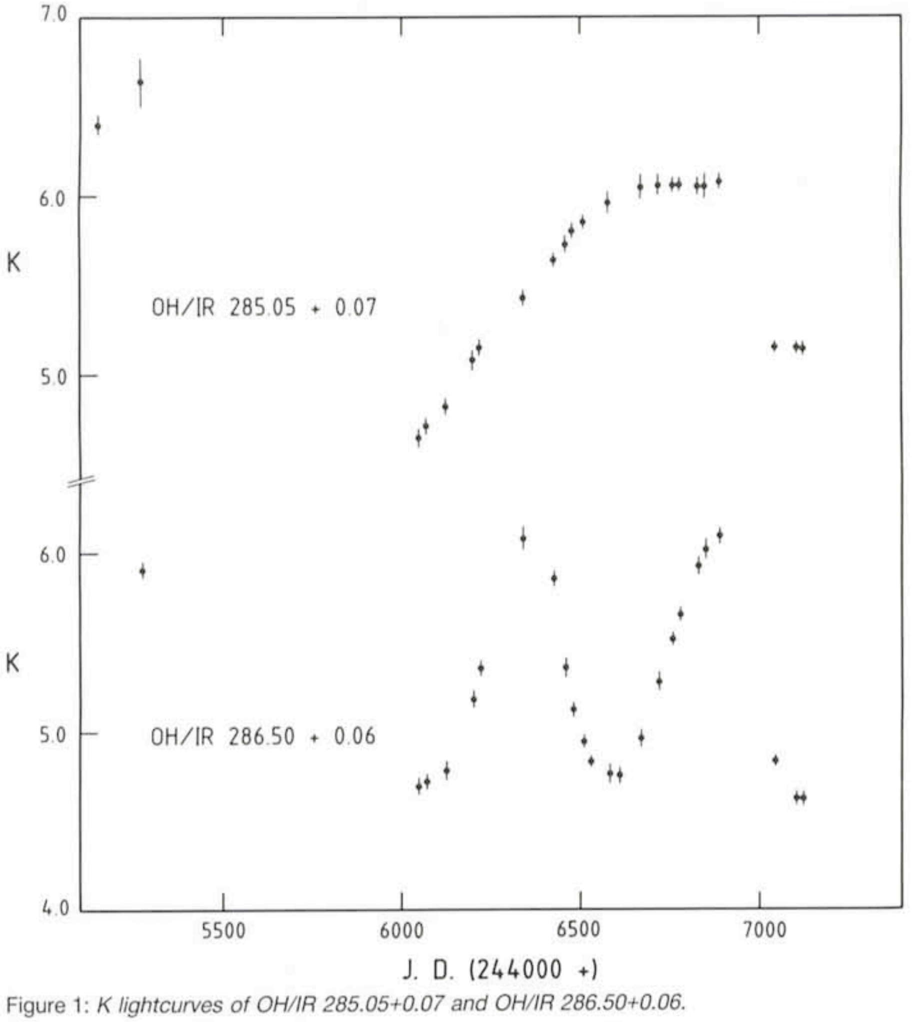


Figure 1: *K lightcurves of OH/IR 285.05+0.07 and OH/IR 286.50+0.06.*

◀ *In the central part of the Gum Nebula, just north of the Vela supernova remnant, we find several relatively unknown nebulae. The northernmost part of the filamentary Vela SNR is seen near the lower right edge of the picture, which was photographically enhanced by C. Madsen from a red plate from the ESO/SERC Atlas of the Southern Sky (IIIa–F + RG630; 120 minutes with the ESO Schmidt telescope). The large nebula to the upper right contains several areas where stars are now being born (the densest is NGC 2626). Many dust lanes are also visible in this negative picture and there are several open stellar clusters, notably NGC 2671, just to the right of the nebula in the lower left part.*

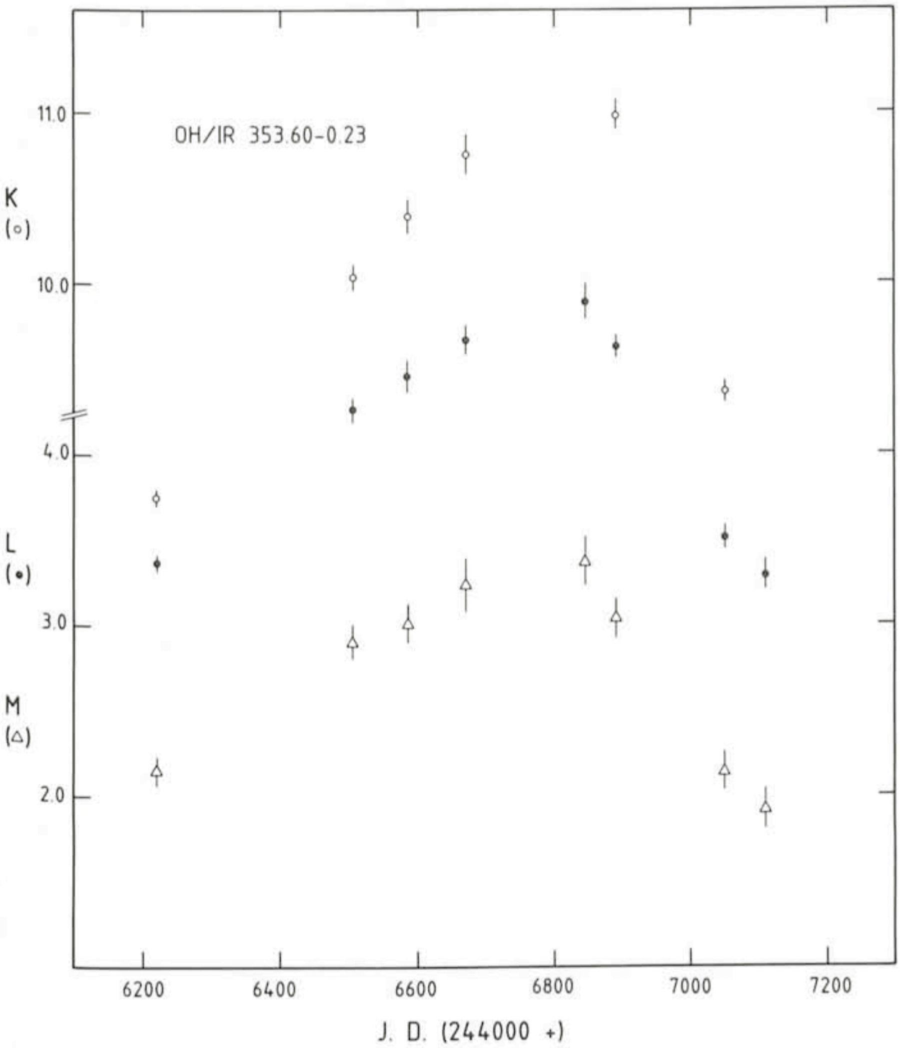


Figure 2: *K, L and M lightcurves of OH/IR 353.60–0.23.*

around 10^5 $L_\odot$, and its mass loss rate, ~ 1.5 10^{-5} $M_\odot.yr^{-1}$ (3). The case of OH/IR 285.05+0.07 is less straightforward. If periodic, its period (defined as the lapse of time between successive extrema of the same type) should be larger than 1,000 days. In fact, comparison of data acquired in this programme with earlier data (e.g. around JD 2445200) shows that the lightcurve presents irregularities. Also, one notes a strong asymmetry in the lightcurve. It exhibits a linear variation for ~ 500 days followed by a plateau lasting at least 250 days. Then, the object passed from minimum to maximum in less than 150 days. Quite surprisingly, the lapses of time corresponding to the linear part and to the plateau are wavelength dependent.

OH/IR 353.60-0.23 is another programme object. The infrared counterpart of the OH maser was also discovered at the ESO 1-m (4). Its energy distribution peaks at 10 μm (5) and is similar to that of the prototypical object, OH/IR 26.5+0.6. This kind of source is very red (K-L ~ 6); in general, they cannot be measured at wavelengths shorter than 2 μm with the 1-m telescope. The K, L and M lightcurves are displayed in Figure 2. As for OH/IR 285.05+0.07, the period is at least 1,000 days. The observed lightcurves consist of two branches in which magnitudes are varying linearly with time. The declining branches last at least 500 days and the rising ones at least 300 days; at minimum, there is no evidence for a plateau of more than 100 days. This broken line lightcurve shape, without plateau, is similar to that of OH/IR 26.5+0.6 (see Figure 5 in 1); however, the latter's lightcurve shape is symmetric, which is not the case for OH/IR 353.60-0.23. Finally, from the available data there is no evidence that the shape of the lightcurve might change with wavelength. On JD ~2446200, i.e. near maximum, an H magnitude of 14.2 ± .2 was measured at the 1-m; obviously, to study the J and H lightcurves would require a more powerful system.

As dust shells are heated by central stars, variations observed in the IR reflect, among other effects, changes in total output luminosity of the central stars. From minimum to maximum (in 150 days or less), the central source of OH/IR 285.05+0.07 is varying from 4 10^4 to 6 10^4 $L_\odot$, the one of OH/IR 286.50+0.06 from 6 10^4 to 15 10^4 $L_\odot$ (in 250 days) and, finally, that of OH/IR 353.60-0.23 from 5 10^4 to 25 10^4 $L_\odot$ (in 300 days). Such intense variations in stellar objects are surpassed only by those of novae or supernovae.

It is generally assumed that OH/IR source lightcurves are quasi-sinusoidal (1); this assumption has never been checked. Although the sample of objects that we monitor is small, it seems that strongly non-sinusoidal lightcurves are, in fact, common. Also, in some cases (e.g. OH/IR 285.05+0.07), the shapes are wavelength dependent. Clear correlations between lightcurve shapes and presence of OH (6) or H_2O (7) maser emission have been found in Mira stars; it is believed that they indicate a relation, between the pulsational properties of central stars and the physical properties of circumstellar matter, originating in the mass-loss phenomenon. Such correlations have not been established in the case of OH/IR stars for lack of data. In fact, as some lightcurve shapes are wavelength dependent, the story might be more complex; however, observations of such wavelength dependency (like observations of time variability) would be useful in providing supplementary constraints on stellar and circumstellar models.

The success of this work would not be conceivable without the efficient and friendly support of all the La Silla infrared staff. Also, I am grateful to the numerous visiting astronomers who are spending, sometimes, a large amount of their precious time in discussions with their support astronomer, and, thus, are making of La Silla a place of scientific exchange.

References

(1) Jones, T.J.: 1987, in *Late Stages of Stellar Evolution,* ed. S. Kwok and S.R. Pottasch, D. Reidel Publishing Company, 3.

(2) Le Bertre, T.: 1986, *The Messenger* **44,** 6.

(3) Le Bertre, T.: 1987, *Astron. Astrophys.* **180,** 160.

(4) Epchtein, N., Nguyen-Q-Rieu: 1982, *Astron. Astrophys.* **107,** 229.

(5) Le Bertre, T., Epchtein, N., Gispert, R., Nguyen-Q-Rieu, Truong-Bach: 1984, *Astron. Astrophys.* **132,** 75.

(6) Bowers, P.F., Kerr, F.J.: 1977, *Astron. Astrophys.* **57,** 115.

(7) Vardya, M.S.: 1987, *Astron. Astrophys.* **182,** 75.

Visiting Astronomers

(April 1–October 1, 1988)

Observing time has now been allocated for Period 41 (April 1–October 1, 1988). The demand for telescope time was again much greater than the time actually available.

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

3.6-m Telescope

April: Moorwood/Oliva, Danziger/Moorwood/Oliva, Dennefeld/Bottinelli/Gouguenheim/Martin, Reimers/Koester/Schröder, Rhee/Katgert, Cristiani/Guzzo/Shaver/Iovino, Danziger/Guzzo, Cristiani, Chalabaev/Perrier/Mariotti, Mathys/Stenflo, Moneti/D'Odorico.

May: Tapia/Moorwood/Moneti, Tapia/Persi/Ferrari-Toniolo/Roth, Miller/Mitchell, Keel, Meylan/Shaver/Djorgovski, Ilovaisky/Chevalier/Pedersen, Swings/Courvoisier/Magain/Rémy/Surdej, Husfeld/Heber/Butler/Werner, Wagner.

June: Maggazù/Strazzulla, Le Bertre/Epchtein/Perrier, Krabbe/Zinnecker/Hofmann, Buonanno/Drukier/Fahlmann/Richer/Vanden Berg/Fusi Pecci, Fort/Mathez/Mellier/Soucail/Cailloux, Herman/Smith, Chalabaev/Perrier/Mariotti, Le Bertre/Epchtein/Perrier, Richichi/Lisi/Salinari.

July: Seitter, Simon/Haefner/Kiesewetter/Ritter, Véron/Hawkins, Fosbury/Tadhunter/Quinn, Rigaut/Merkle/Kern/Léna, Brahic/Sicardy/Roques/Barucci, van der Veen/Habing, van der Veen/Habing/Geballe, Brahic/Sicardy/Roques/Barucci.

August: Brahic/Sicardy/Roques/Barucci, Waelkens/Lamers/Waters/Le Bertre/Bouchet, Chalabaev/Perrier/Mariotti, Guzzo/Collins/Heydon-Dumbleton, de Lapparent/Mazure, Bergeron/Boissé/Yee, Balkowski/Batuski/Olowin, Maurogordato/Proust.

September: Guzzo/Tarenghi, Jarvis/Martinet, Danziger/Gilmozzi, Macchetto/Turnshek/Sparks, Heydari-Malayeri, Webb/Carswell/Shaver, van Groningen, Wampler.

2.2-m Telescope

April: Prusti/Wesselius, Persi/Ferrari-Toniolo/Busso/Origlia/Scaltriti, Giraud, Rosa/Richter, Rosa/Richter, Reinsch/Pakull/Festou/Beuermann, Reimers/Koester/Schröder, Reinsch/Pakull/Festou/Beuermann, Nota/Paresce/Burrows/Viotti/Lamers, Bässgen M./Bässgen G./Grewing/Cerrato/Bianchi, Rosa/Richter, Cristiani/Gouiffes, Rosa/Richter, Reinsch/Pakull/Festou/Beuermann.

May: Reinsch/Pakull/Festou/Beuermann, Piotto/Ortolani, Miley/Chambers, Rosa/Richter, Swings/Courvoisier/Kellermann/Kühr/Magain/Rémy/Surdej/Refsdal, Rosa/Richter, Reinsch/Pakull/Festou/Beuermann, Courvoisier/Melnick/Mathys/Binette/Maeder, Reipurth/Olberg/Booth, Reipurth/Zinnecker, Reipurth/Lada/Bally.

June: Metz/Haefner/Roth/Kunze, Le Bertre/Epchtein/Perrier, Schwarz.

July: Bertola/Zeilinger, Pizzichini/Pedersen/Poulsen/Belardi/Palazzi, Melnick/Skillman/Terlevich, Ulrich, Tadhunter/Pollacco/Hill, Gottwald/White/Parmar, Melnick/Skillman/Terlevich, Joly, Habing/Le Poole/Schwarz/van der Veen.

August: Tanzi/Falomo/Treves/Bouchet, Aurière/Koch-Miramond/Cordoni, Rampazzo/Sulentic, Tadhunter/Fosbury/di Serego Alighieri, Brocato/Melnick, Capaccioli/Ortolani/Piotto, Cristiani/Gouiffes.

September: Lortet/Lindgren/Testor, Burrows/Paresce, Durret/Bergeron, Christensen/Sommer-Larsen/Hawkins, Moeller/Rasmussen.

1.5-m Spectrographic Telescope

April: Faraggiana/Gerbaldi/Boehm, Doazan/Semak/Bourdonneau, Danziger/Fosbury/Lucy/Wampler/Schwarz, Courvoisier/Bouchet, Bues/Rupprecht/Strecker, Durret/Boisson, Danziger/Fosbury/Lucy/Wampler/Schwarz, Acker/Jasniewicz/Duquennoy, Eriksson/Gustafsson/Olofsson, Danziger/Fosbury/Lucy/Wampler/Schwarz, Spite F./Spite M.

May: North/Lanz, Danziger/Fosbury/Lucy/Wampler/Schwarz, Waelkens/Lamers/Waters, Spinoglio/Malkan, Danziger/Fosbury/Lucy/Wampler/Schwarz, Heber/Hunger/Werner, Danziger/Fosbury/Lucy/Wampler/Schwarz, de Jager/Nieuwenhuijzen, Mekkaden/Geyer, Lodén LO/Sundman.

June: Kameswara Rao/Nandy/Houziaux L., Kameswara Rao/Nandy/Houziaux L., Gahm/Bouvier/Liseau, Pottasch/Pecker/Sahu, Metz/Haefner/Roth/Kunze, Courvoisier/Bouchet.

July: Major overhaul – TRS.

August: Tanzi/Falomo/Treves/Bouchet, Danziger/Fosbury/Lucy/Wampler/Schwarz, Acker/Stenholm/Lundström, Kollatschny/Dietrich, Danziger/Fosbury/Lucy/Wampler/Schwarz, Jugaku/Takada-Hidai/Holweger, Hauck/Berthet/Lanz.

September: Danziger/Fosbury/Lucy/Wampler/Schwarz, Johansson/Bergvall, Vettolani/Chincarini, Danziger/Fosbury/Lucy/Wampler/Schwarz, Balkowski/Proust/Maurogordato, Rhee/Katgert, Danziger/Fosbury/Lucy/Wampler/Schwarz, Gerbaldi/Faraggiana, Khan/Duerbeck.

1.4-m CAT

April: Molaro/D'Odorico/Vladilo, Vladilo/Molaro, Gratton/Gustafsson/Eriksson, Butcher, Artru/Didelon/Lanz, Solanki/Mathys.

May: Spite E./Spite M., Lemmer/Dachs, Waelkens, de Jager/Nieuwenhuijzen, Wilson/Appenzeller/Stahl/Henkel, Vidal-Madjar/Ferlet/Gry/Lallement, Ferlet/Vidal-Madjar/Gry/Lallement.

June: da Silva/de la Reza, Mandolesi/Crane/Palazzi, Palazzi/Blades/Crane, Crane/Palazzi/Mandolesi, Danks/Crane, Pottasch/Sahu, Benvenuti/Porceddu, Magain/Lindgren.

July: de Vries/van Dishoeck/Habing, Schwarz/Bode/Duerbeck/Meaburn/Seitter/Taylor, Crowe/Gillet.

August: Gustafsson/Edvardsson/Magain/Nissen, Waelkens/Lamers/Waters/Le Bertre/Bouchet, Magain/Lindgren, Didelon, François, Lanz.

September: Foing/Jankov/Char/Houdebine/Butler/Rodonò/Catalano S., Foing/Crivellari/Vladilo, Castelli/Beckman/Char/Jankov.

1-m Photometric Telescope

April: Courvoisier/Bouchet, Santos Friaca/Le Bertre, Le Bertre/Epchtein/Perrier, van der Hucht/Thé/Williams, Bues/Rupprecht/Strecker, Gouiffes/Cristiani, Reinsch/Pakull/Festou/Beuermann, Reipurth/Olberg/Booth, Eriksson/Gustafsson/Olofsson, Schultz, Reinsch/Pakull/Festou/Beuermann.

May: Reipurth/Zinnecker, Reipurth/Lada/Bally, Le Bertre/Epchtein/Perrier, Tapia/Persi/Ferrari-Toniolo/Roth, Spaenhauer/Labhardt, Reinsch/Pakull/Festou/Beuermann, Le Bertre/Epchtein/Perrier, Courvoisier/Bouchet, Spinoglio/Malkan, de Jager/Nieuwenhuijzen, Lorenzetti/Berrilli, Saraceno/Berrilli/Ceccarelli/Liseau/Lorenzetti, Hesselbjerg Christensen.

June: Hesselbjerg Christensen, Gouiffes/Cristiani, Gahm/Bouvier/Liseau, Antonello/Conconi/Mantegazza/Poretti, Reinsch/Pakull/Festou/Beuermann, Antonello/Conconi/Mantegazza/Poretti, Le Bertre/Epchtein/Perrier, Richichi/Lisi/Salinari, Reipurth/Lada/Bally, Courvoisier/Bouchet.

July: Reinsch/Pakull/Festou/Beuermann, Duerbeck, Barwig/Ritter/Haefner/Schoembs/Mantel, Simon/Haefner/Kiesewetter/Ritter, Brahic/Sicardy/Roques/Barucci, de Muizon/d'Hendecourt, Brahic/Sicardy/Roques/Barucci, Courvoisier/Bouchet.

August: Brahic/Sicardy/Roques/Barucci, Di Martino/Zappalà/Cellino/Farinella, Bouchet/Cetty-Véron/Véron, Johansson/Bergvall.

September: Lortet/Testor, Gouiffes/Cristiani, Liller/Alcaíno.

50-cm ESO Photometric Telescope

April: Group for Long Term Photometry of Variables, Kohoutek, Morell/Gustafsson, Kohoutek, Lemmer/Dachs.

May: Carrasco/Loyola, Mekkaden/Geyer, Lodén LO/Sundman.

June: Sinachopoulos, Metz/Haefner/Roth/Kunze.

July: Carrasco/Loyola, Beißer/Vanysek/Böhnhardt/Grün/Drechsel.

August: Group for Long Term Photometry of Variables.

September: Carrasco/Loyola, Foing/Jankov/Char/Houdebine/Butler/Rodonò/Catalano S., Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov.

GPO 40-cm Astrograph

April: Scardia.

May: Landgraf.

August: Aurière/Koch-Miramond/Cordoni.

September: Debehogne/Machado/Caldeira/Vieira/Netto/Zappalà/de Sanctis/Lagerkvist/Mourao/Protitch-Benishek/Javanshir/Wosczcyk.

1.5-m Danish Telescope

April: Ardeberg/Lindgren/Lundström, Le Bertre/Epchtein/Perrier.

May: van Paradijs/van der Klis, Leibundgut/Tammann, West, Brocato/Buonanno/Castellani/di Giorgio, Ilovaisky/Chevalier/Pedersen.

June: Haefner/Ritter/Reimers.

July: Reinsch/Pakull/Festou/Beuermann, Cristiani/Gouiffes, Piotto/King, Gottwald/White/Parmar, Azzopardi/Lequeux/Rebeirot, Beißer/Vanysek/Böhnhardt/Grün/Drechsel.

August: Ardeberg/Lindgren/Lundström, Lortet/Lindgren/Testor, Grenon/Mayor.

September: Joergensen/Hansen/Noergaard-Nielsen, Johansson/Bergvall, Gregorini/Messina/Vettolani, Fusi Pecci/Buonanno/Ortolani/Renzini/Ferraro.

50-cm Danish Telescope

May: Franco.
June: Grenon/Bopp, Ardeberg/Lindgren/Lundström, Group for Long Term Photometry of Variables.
September: Ardeberg/Lindgren/Lundström.

90-cm Dutch Telescope

June: Grenon/Lub.
July: v. Amerongen/v. Paradijs.
August: Schneider/Weiss.

SEST

May: Reipurth/Lada/Bally, Israel/de Graauw, Crane/Kutner, Lequeux/Boulanger/Cohen, Israel/Baas, Israel/Baas/de Graauw/Douglas, Heydari-Malayeri/Encrenaz P./Pagani, Garay/Rodriguez, Reipurth/Olberg/Booth, Haikala, Radford/Cernicharo/Greve, Crane/Mandolesi/Palazzi/Kutner, Wouterloot/Brand, Stutzki/Zinnecker/Drapatz/Genzel/Harris/Olberg/Rothermel.
July: Burton/Liszt, Reipurth/Olberg/Booth, Wielebinski/Mebold/Whiteoak/Harnett/Dahlem/Loiseau, Bosma/Deharveng/Lequeux, Prusti/Clark/Wesselius/Laureijs, Dettmar/Heithausen/Hummel, Henkel/Wiklind/Wilson, Loiseau/Harnett/Combes/Gérin, Henkel/Wilson, Pottasch/Pecker/Sahu/Srinivasan, Moneti/Natta/Evans, Bajaja/Hummel, Bajaja/Harnett/Loiseau, Pérault/Falgarone/Boulanger/Puget, Dennefeld/Pérault/Bottinelli/Gouguenheim/Martin.
September: Chini/Kreysa/Mezger, Gérin/Combes/Buta, Dupraz/Casoli/Combes/Gérin/Salez, Combes/Casoli/Dupraz/Gérin/Harnett/Loiseau, Combes/Casoli/Dupraz/Gérin, Gérin/Combes/Casoli/Nakai/Hummel/van der Hulst, Melnick, Lellouch/Combes/Encrenaz T./Gérin, Casoli/Combes/Dupraz/Gérin, Booth/Nyman/Winnberg/Olofsson/Sahai/Habing/Omont/Rieu.

Pre- and Post-Perihelion Spectrographic and Photometric Observations of Comet Wilson (1986 ℓ)

C. ARPIGNY, F. DOSSIN, J. MANFROID, Institut d'Astrophysique, Université de Liège, Belgium
P. MAGAIN, ESO, and
R. HAEFNER, Universitäts-Sternwarte München, F.R. Germany

Hardly had Halley's comet left our immediate vicinity when a relatively bright, "new" comet, Wilson (1986 ℓ), was discovered in the summer of 1986. The announcement of this discovery was the more exciting as early predictions gave some hope that the newcomer might become of similar brightness to Halley's in April–May 1987, just about one year after P/Halley had made its own show. As the comet would be located in the southern sky at that time, and encouraged by our successful Halley runs at ESO, we proposed a programme that would give the opportunity to make a comparison between two comets of quite different dynamical ages observed at similar distances from the sun and with similar instrumentation. Another comparison seemed interesting: to study the behaviour of the comet before and after its passage through perihelion, which occurred on 21 April, 1987. Indeed we were able to carry out observations in April and in May, both spectrographic (2.2-m ESO-MPI telescope, 1.4-m CAT + CES, and 1.5-m telescope) and photometric (0.5-m ESO telescope). Some of the most significant results of these observations will be described briefly here. They refer to spectra in the ultraviolet, blue and red regions, as well as to photometry through narrow-band filters.

Comet Wilson proved to be considerably fainter than had been anticipated on the basis of the optimistic predictions. In early April it was estimated to be roughly four times weaker than comet Halley had been one year earlier at the same heliocentric distance. However, as far as spectrography was concerned, this weakness was, in a sense, compensated by the use of CCD detectors, which had not been available during our observations of P/Halley.

This was indeed a great improvement, for CCD's are particularly suitable for the observations of extended objects: in addition to their high quantum efficiency, linearity and high dynamic range, they offer the crucial advantage of two-dimensional detectors, allowing the determination of the spatial distribution of the spectral emissions over an appreciable region of the object. Furthermore, when they are used at the Cassegrain focus, as with the 2.2-m and the 1.5-m telescopes, one avoids the loss of spatial resolution caused by the field rotation inherent to the coudé focus (where photographic plates were traditionally used in cometary spectroscopy). Knowledge of the radial profiles of the cometary emissions is absolutely necessary to analyse the physical processes responsible for the formation and for the excitation of the various emitting species, to evaluate their production rates, to construct or to test models of the coma and tail. It can also help in the identification of new spectral lines, since the extent of a given emission on each side of the comet centre is related to the nature of the particular atom or molecule involved (neutral or ionized species; short- or long-lived particle).

Ultraviolet – Blue Region

Particular emphasis was laid upon the near ultraviolet because this region has been as yet poorly explored. Besides, advantage was taken of the availability of a CCD with fluorescent coating for ultraviolet sensitivity. The importance of the UV-blue region stems also from the fact that it contains emissions of OH, CO_2^+, OH^+, CO^+, hence information related to the abundance ratios of the major constituents of the cometary material, water and the carbon oxydes.

As an example, a spectrum obtained at moderate resolution is shown in Figure 1. The heliocentric distance (r) of the comet was 1.21 A.U. pre-perihelion, and its geocentric distance (Δ) was 0.95 A.U. The upper tracing corresponds to a strip 10 arcsec or 7,000 km wide, approximately centred on the nucleus, extracted from the CCD. The flux unit is arbitrary on this and the two other plots. No correction has been applied to take out the atmospheric extinction and the instrument + detector response, in order to illustrate the tremendous attenuation produced by these effects. For instance, the difference in overall flux reduction between 387 nm and 308.5 nm amounts to about 4 magnitudes in this case: the OH (O-O) band is, in fact, appreciably stronger than the CN (O-O) band, outside the earth's atmosphere. The middle and bottom panels compare, at a magnified scale, extractions of the same width as above, but offset by about 40,000 km on each side of the

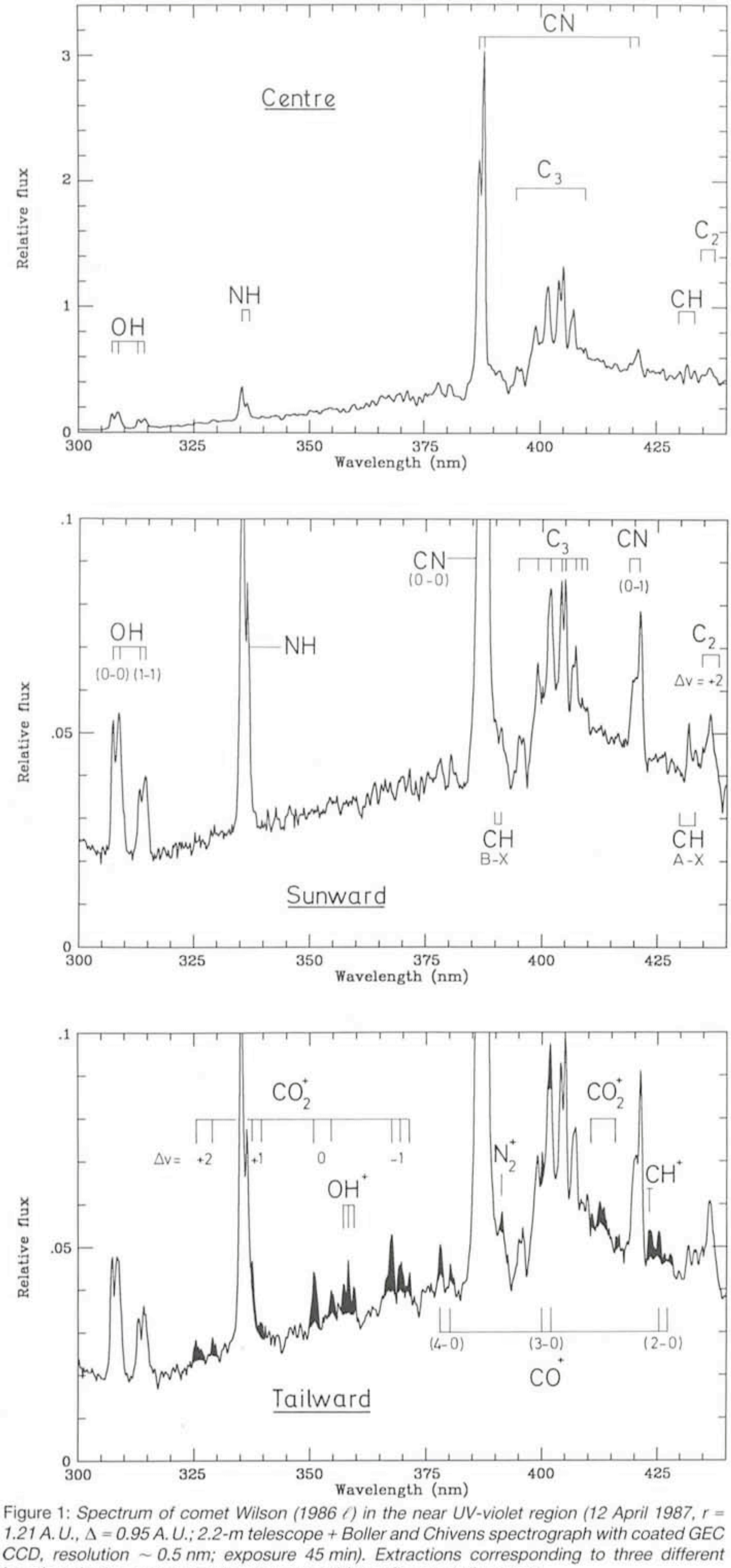


Figure 1: *Spectrum of comet Wilson (1986 ℓ) in the near UV-violet region (12 April 1987, r = 1.21 A.U., Δ = 0.95 A.U.; 2.2-m telescope + Boller and Chivens spectrograph with coated GEC CCD, resolution ~ 0.5 nm; exposure 45 min). Extractions corresponding to three different locations in the comet are shown on an arbitrary flux scale (see text).*

nucleus. While the emissions from the neutral radicals are nearly symmetrical, the ionic emissions on the contrary are present only on the side opposite to the sun, at this distance from the centre of the comet. To bring out the latter emissions, their contributions have been indicated qualitatively in black on the tailward spectrum.

A striking difference with P/Halley's spectrum in this wavelength range concerns the strength of the CO_2^+ emissions as compared to the OH^+ band, which was predominant in P/Halley near 1 A.U. from the sun after perihelion (C. Arpigny et al., 1986). This was not caused by a difference in the fluorescent excitation of the emissions and since the relative ionization efficiencies involved were probably similar as well, it appears that the proportion of released carbon dioxyde relative to water was higher in comet Wilson than in comet Halley at their respective heliocentric distances. As for the CO^+/CO_2^+ ratio, it is comparable in the two comets and we reach the conclusion that the relative abundance of carbon monoxyde too was larger in Wilson.

We note that the emission near 413 nm has been assigned to CO_2^+ on the basis of a higher resolution spectrum where we measured the same features at 410.9, 412.3, 414.6, and 416.2 nm that we had discovered in P/Halley (ibidem). The identification of these emissions was possible thanks to the kind help of S. Leach, who is currently analysing further the CO_2^+ spectrum in this region. Looking back at some older spectrograms, we found that this 413 nm feature was present in comets showing CO^+ and CO_2^+, like Bester, Humason, Bennett, West. At lower resolution it tends to be mistaken for the (4-1) CO^+ band, which has but a very small contribution in the case of Wilson.

In view of the importance of the carbon compounds, especially those containing the C-H band, as revealed by Halley's comet, the analysis of the CH emission seemed attractive. Thus, we took a spectrum of the R and Q branches of the A-X (O-O) band of this radical (Figure 2). The high resolution used (50,000, or about 0.01 nm) allows the separation of the satellite lines such as Q_{21} or R_{12} from their companion principal lines. This yields useful additional information since these lines are issued from different upper energy levels. Another unusual characteristic of this spectrum is the weakness of the R_1 (2) line. Comparing with the CH spectrum of P/Halley, for example, we see that the excitation rate of this line was indeed roughly twice as low in comet Wilson. It should be pointed out that although the

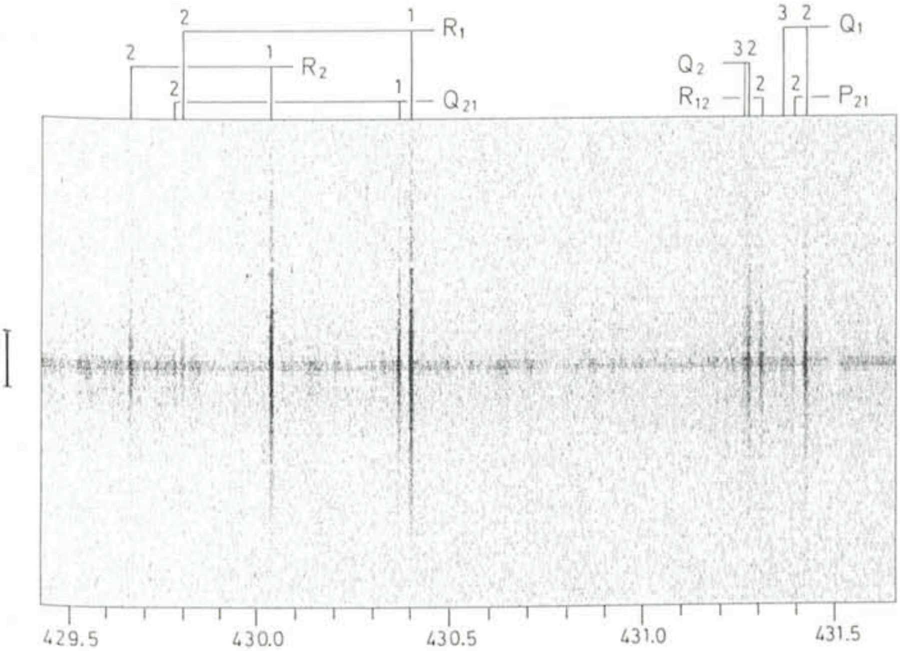


Figure 2: *High-resolution spectrum of the A $^2\Delta - X\ ^2\Pi$ (O-O) band of CH showing the complete resolution of the R and Q branches. The slit was approximately aligned (± about 10°) with the radius vector from the sun during the 70 minutes exposure obtained with the 1.4-m CAT + CES and CCD. The tail is in the upward direction on this reproduction. The vertical bar represents 10^4 km on the comet (7 April 1987, r = 1.22 A.U., Δ = 1.10 A.U.).*

electronic transitions are produced by resonance-fluorescence, collisional processes which influence the populations of the lower rotational levels in the inner coma, have to be taken into account when interpreting the spectrum of CH (C. Arpigny et al., 1987 b). On the other hand, we also draw attention to the spatial extent of the emissions. The lifetime of the CH radicals in the solar radiation field is quite short, ~ 10^2 sec (Singh and Dalgarno, 1987) and their velocity cannot be much larger than 1 km/sec. Therefore, in order to explain their presence out to more than 40,000 km from the centre, we have to assume that they are released by particles which have a much longer lifetime. The detailed study of the radial profile of the CH lines should be instructive in this respect.

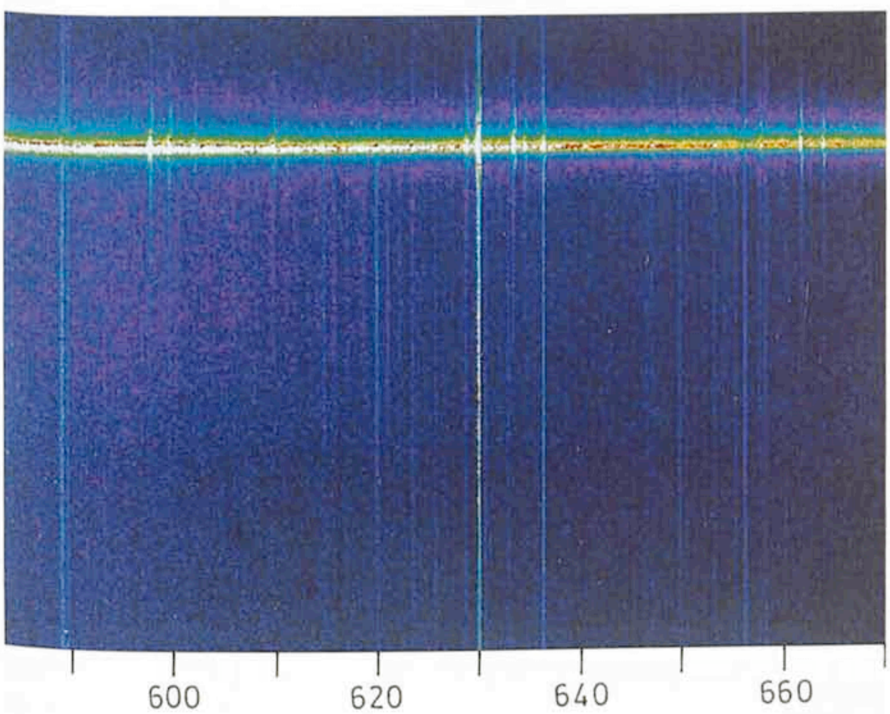


Figure 3: *Section of the spectrum of comet Wilson in the visual region (see Figure 4 for detailed identifications). (14 May 1987, r = 1.25 A.U., Δ = 0.78 A.U.; 1.5-m telescope with B & C spectrograph and CCD, resolution ~ 0.2 nm; 40 min exposure).*

Visual Region

Besides the C_2 Swan band sequences, whose interpretation still meets with difficulties, we selected another interesting wavelength interval, comprising the 9-0, 8-0, and 7-0 bands due to NH_2, the red forbidden lines of oxygen, as well as the 8-0 and 7-0 bands of the H_2O^+ ion. These emissions were monitored both before and following perihelion, the main difference between these periods being the fading of the comet after perihelion and the increase in night sky contamination in May as compared to April. The 590-670 nm region recorded after perihelion is illustrated in Figures 3 and 4, where we see that the contribution of the night sky (n.s.) is indeed quite substantial. Even the weak (9-3) and (6-1) bands of the Meinel system of the hydroxyl radical show up clearly, near 630 and 655 nm, respectively (see Kvifte, 1959, for line identifications); the red [OI] doublet is dominated by the telluric emission; at 656.3 nm the situation is rather complex, with three contributors coming in: nightglow Hα, cometary Hα, and a line of the H_2O^+ 7-0 band (which, incidentally, is quite weak compared with the 8-0 band in this spectrum).

The ionic emissions extend to distances of ~ 30,000 km on the sunward side on our different spectra, which is comparable to what we saw in P/Halley post-perihelion. This may at first appear contrary to expectation, in view of the lower gas production rate of comet Wilson. However, the solar wind conditions may have been different themselves, the relative "softness" of the cometary obstacle being, so to speak, balanced by a weaker incoming breeze in the latter case.

As far as the neutral species are concerned, the predominance of NH_2 in this spectral range is a common characteristic among comets near 1 A.U. from the sun or a little beyond. So is the weakness of the C_7 Swan Δv = −2 sequence. The Δv = −3 sequence of the same system, which should be about three times weaker still, does not appear on our spectra, although its presence on spectra for the same period has been reported by Jockers and Geyer (1987). This detection seems rather surprising, especially at a distance of 5 arcmin or 140,000 km away from the nucleus!

In April 1987 we were able to repeat on Wilson the same high-resolution observations of the [OI] + NH_2 blend we had made on P/Halley (Arpigny et al., 1987 a). The relative intensities of the various lines turned out to be similar in these two objects, although Wilson was appreciably fainter.

Photometry

Comet Wilson was observed photometrically in March, April and May 1987. The special filters defined by the IAU were used in the standard one-channel photometer of the ESO 50-cm telescope. These filters have narrow bandpasses and isolate essential information concerning several molecular emission features (OH, CN, C_3, C_2, CO^+, H_2O^+) and the continuum (ultraviolet, blue, and red). Because of the faintness of the object, only the central part of the coma could be measured. On the contrary, in the case of P/Halley (C. Arpigny et al., 1986) it had been possible to map a wide area (over about 5 arcmin).

The main characteristic of comet 1986 ℓ was its stability. While comet Halley varied by as much as a factor of 3 or 4 within one day, comet Wilson proved remarkably steady. Between March 30 and April 10, for instance, the apparent brightness increased by little more than 0.2 magnitude, although the comet was nearing both the earth and the sun. Actually, a more significant quantity can be derived by removing the effect upon the apparent brightness of the varying geocentric distance. Besides the purely geometrical dilution effect, proportional to $1/\Delta^2$, we have to take account of the fact that the fraction of the coma seen by the photometer also varies as Δ changes. The latter part of the correction can be estimated approximately by adopting a model representing the brightness distribution within the cometary disk (e.g. Haser's model, corresponding to the outflow of "parent molecules" decaying into the observed radicals, which are themselves destroyed by photodissociation). When applying the Δ-correction in this way, we find that the intrinsic brightness in the various filters remained very nearly constant as the comet approached its perihelion. There was even a tendency for the scattered continuum to weaken slightly.

When we observed the comet again, in May 1987 (4 nights), it was at about the same geocentric distance as in the beginning of April, so that the corresponding data are directly comparable. Unfortunately, the weather was very bad in May and did not allow many measurements. It seems that comet Wilson was somewhat more variable after perihelion. Comparing the fluxes in various filters, it also appears that it was intrinsically fainter by a factor of 1.5 to 2.0 postperihelion, except perhaps in the light of OH, which seemed to stay at about the same level. It should be noted that this last result is rather uncertain because the atmospheric extinction is not easily evaluated at 309 nm.

This is to be compared with P/Halley. Photometric measurements were made at approximately the same comet-sun distance (~ 1.25 A.U.), both before and after perihelion (Haute-Provence Observatory Chiran, New Zealand Mount John, ESO). The geocentric distances differed appreciably in these cases; fortunately, however, a whole series of diaphragms were used at the Chiran and in New Zealand. By interpolating between the results from the different diaphragms it was possible to derive the flux received from a given volume equi-

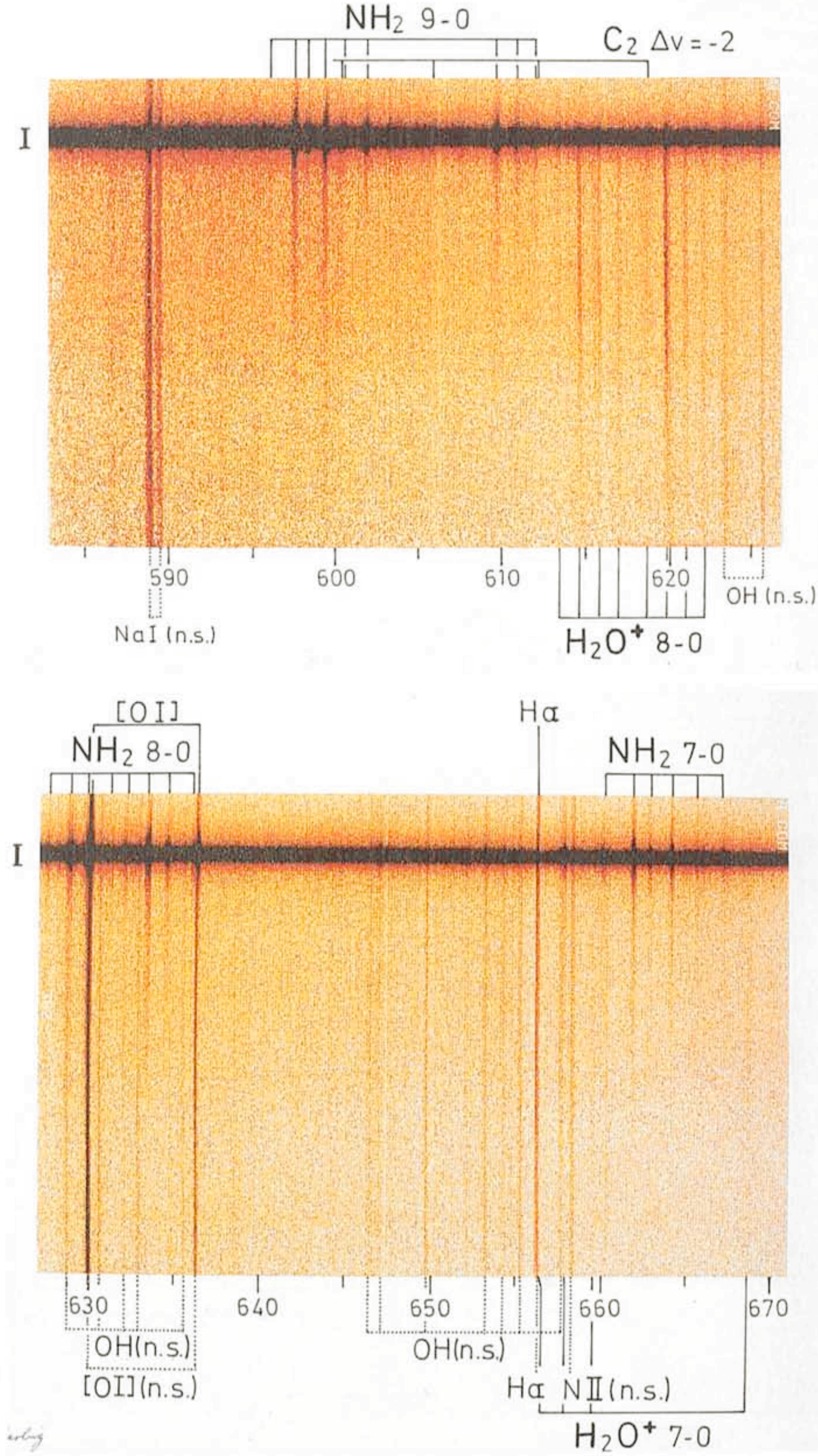


Figure 4: *Same spectrum as in Figure 3, shown here at a larger scale. Numerous emissions due to the nightglow are seen in addition to the cometary lines. The slit was set parallel to the projected sun-comet line with the comet's nucleus near one edge in order to record the tail emissions. The total height of the spectrum corresponds to ~ 2.5 × 10^5 km at the comet's distance.*

valent to that delimited by 30 arcsec at 1.24 A.U. from the earth (as for Wilson). Then, obtaining the fluxes corresponding to a fixed distance of 1 A.U. from the earth ("heliocentric" fluxes), we conclude that Halley's comet did brighten intrinsically following perihelion. It was also more variable.

To illustrate these results, Table 1 presents a comparison between the behaviours of comets Wilson and P/Halley before (b) and after (a) perihelion in two filters (Blue continuum, BC, centred at 484.5 nm, and the C_2 Swan $\Delta v = 0$

TABLE 1. *"Heliocentric" fluxes corresponding to a diaphragm of 27,000 km projected on the comet.*

Comet	Δ (A.U.)	r (A.U.)	BC	C_2
Wilson	1.24 1.23	1.24 b 1.35 a	7.1 (−13)* 4.3 (−13)	1.7 (−10)* 8.5 (−11)
P/Halley	0.82 0.46	1.27 b 1.24 a	3.4 (−13) 1.2 (−12)	1.9 (−10) 3.9 (−10)**

* The fluxes are given in ergs $cm^{-2}s^{-1}$ and the numbers between parentheses indicate the power of ten by which the entry is to be multiplied.
** This point was obtained during a minimum of activity. P/Halley was as much as 3 times brighter at other phases of its lightcurve.

We regret that due to a last minute mistake at the printer, the colour photo showing the Supernova 1987 A and the 30 Doradus nebula has been reproduced upside down. The error was discovered when this issue of the MESSENGER was delivered to ESO.

We trust that the readers will understand that under the circumstances it was not reasonable to repeat the entire printing run.

The editors

tions of SR-12 and Rox 31, two sub-arcsec pre-main-sequence binaries in the Rho Ophiuchi dark cloud (distance 160 pc). The binarity of these sources was discovered in a recent 2.2 μm lunar occultation observing programme of young stars carried out by Simon et al. (1987).

Many pre-main-sequence objects in star-forming regions are now known to be binary systems (see the review by Reipurth 1987). It is important to resolve these systems, otherwise properties such as the luminosity and the colours of young low-mass stars may be mis-

vations are required to resolve most of them into their components (judging from the statistics of binary separations of solar-type main-sequence stars for which the most frequent separation is of the order of 30 AU, corresponding to 0.2 arcsec at a distance of 150 pc). Therefore, sub-arcsec observations such as lunar occultation and speckle observations of the nearest T Tauri stars are of great interest, in the optical as well as in the near infrared. As for speckle observations, Nisenson et al. (1985) discovered an optical companion to T Tau at 0.3 arcsec separation, and Dyck et al.

speckle studies of S CrA and V 649 Ori (Baier et al. 1985) and the infrared slit scans of Elias 22 (Zinnecker et al. 1987, Chelli et al. 1988). These are young binary stars with separations in the 1−2 arcsec range. We note that infrared observations are the appropriate tool to study young stellar objects because these are fairly cool objects that have not contracted to the main sequence yet. Furthermore, there are objects still embedded in the parental molecular cloud or in their dusty circumstellar envelopes so that they can escape optical detection.

valent to that delimited by 30 arcsec at 1.24 A.U. from the earth (as for Wilson). Then, obtaining the fluxes corresponding to a fixed distance of 1 A.U. from the earth ("heliocentric" fluxes), we conclude that Halley's comet did brighten intrinsically following perihelion. It was also more variable.

To illustrate these results, Table 1 presents a comparison between the behaviours of comets Wilson and P/Halley before (b) and after (a) perihelion in two filters (Blue continuum, BC, centred at 484.5 nm, and the C_2 Swan $\Delta v = 0$ bands near 514 nm).

TABLE 1. *"Heliocentric" fluxes corresponding to a diaphragm of 27,000 km projected on the comet.*

Comet	Δ (A.U.)	r (A.U.)	BC	C_2
Wilson	1.24 1.23	1.24 b 1.35 a	7.1 (−13)* 4.3 (−13)	1.7 (−10)* 8.5 (−11)
P/Halley	0.82 0.46	1.27 b 1.24 a	3.4 (−13) 1.2 (−12)	1.9 (−10) 3.9 (−10)**

* The fluxes are given in ergs $cm^{-2}s^{-1}$ and the numbers between parentheses indicate the power of ten by which the entry is to be multiplied.
** This point was obtained during a minimum of activity. P/Halley was as much as 3 times brighter at other phases of its lightcurve.

Were the intrinsic brightness dependence upon r expressed as an inverse power law, the derived exponents would be in the range 5-8, when our measurements pre- and post-perihelion are compared. Such steep variations with r have been reported for a number of comets in the past. However, this kind of interpretation may not be very significant. Not only is our number of points post-perihelion too small, but we also have to consider that the activity of a comet, its matter and light output, may be strongly influenced by the combined effect of the inhomogeneous morphology of its nucleus and the change in orientation of its spin axis with respect to the sun, as regions of its surface with different structures and compositions are successively exposed to the solar radiation. The recent passage of Halley's comet has demonstrated this very extensively and, at times, in a spectacular manner. A possible explanation of the brightening of this comet following perihelion has been given in terms of such a "seasonal" effect (Weissman, 1986). Did, then, the fading of comet Wilson (1986 ℓ) we recorded reflect some general trend in the comet's evolution (progressive shortage of volatile material, building-up of a "crust") or was it rather the result of a geometrical effect associated with the rotation of the comet's nucleus and the presence of discrete active areas on its surface? Hopefully, more will be learned about this when we have a complete view of the various observations that were made of comet Wilson.

We are grateful to ESO and to all who helped us during our observations. In particular, the kind collaboration of D. Hofstadt and his team was greatly appreciated. Our thanks are also due to C. Sterken for communicating us the photometric data on comet Halley he obtained at Mount John Observatory, New Zealand.

References

Arpigny, C., Dossin, F., Manfroid, J., Magain, P., Danks, A.C., Lambert, D.L., and Sterken, C.: 1986, *The Messenger,* No. **45,** 8.
Arpigny, C., Manfroid, J., Magain, P., and Haefner, R.: 1987a, Proc. Symp. on the "Diversity and similarity of comets", ESA SP-278, 571.
Arpigny, C., Zeippen, C.J., Klutz, M., Magain, P., and Hutsemekers, D.: 1987b, ibid., 607.
Jockers, K. and Geyer, E.H.: 1987, *The Messenger,* No. **50,** 48.
Kvifte, G.: 1959, *J. Atm. Terr. Phys.,* **16,** 252.
Singh, P.D. and Dalgarno, A.: 1987, Proc. Symp. on the "Diversity and similarity of comets", ESA SP-278, 177.

Resolving Young Stellar Twins

H. ZINNECKER, Max-Planck-Institut für Physik und Astrophysik, Institut für Extraterrestrische Physik, Garching, F.R. Germany
C. PERRIER, Observatoire de Lyon, Saint Genis-Laval, France

Introduction

We report infrared speckle observations of SR-12 and Rox 31, two sub-arcsec pre-main-sequence binaries in the Rho Ophiuchi dark cloud (distance 160 pc). The binarity of these sources was discovered in a recent 2.2 μm lunar occultation observing programme of young stars carried out by Simon et al. (1987).

Many pre-main-sequence objects in star-forming regions are now known to be binary systems (see the review by Reipurth 1987). It is important to resolve these systems, otherwise properties such as the luminosity and the colours of young low-mass stars may be misjudged. Even for binaries in the most nearby dark clouds (with distances of the order of 150 pc), sub-arcsec observations are required to resolve most of them into their components (judging from the statistics of binary separations of solar-type main-sequence stars for which the most frequent separation is of the order of 30 AU, corresponding to 0.2 arcsec at a distance of 150 pc). Therefore, sub-arcsec observations such as lunar occultation and speckle observations of the nearest T Tauri stars are of great interest, in the optical as well as in the near infrared. As for speckle observations, Nisenson et al. (1985) discovered an optical companion to T Tau at 0.3 arcsec separation, and Dyck et al. (1982) had previously discovered an infrared companion to T Tau at 0.6 arcsec separation. We also mention the optical speckle studies of S CrA and V 649 Ori (Baier et al. 1985) and the infrared slit scans of Elias 22 (Zinnecker et al. 1987, Chelli et al. 1988). These are young binary stars with separations in the 1–2 arcsec range. We note that infrared observations are the appropriate tool to study young stellar objects because these are fairly cool objects that have not contracted to the main sequence yet. Furthermore, there are objects still embedded in the parental molecular cloud or in their dusty circumstellar envelopes so that they can escape optical detection.

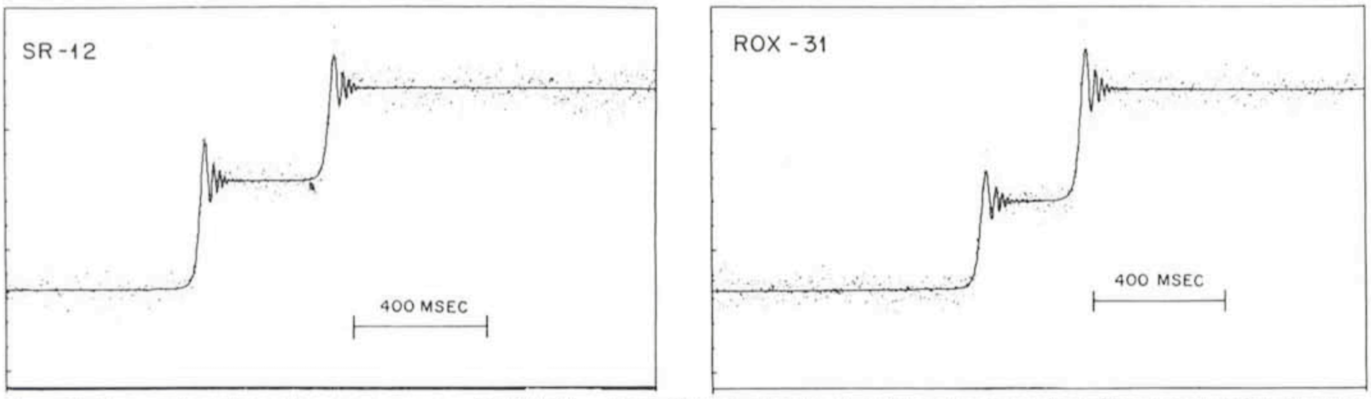


Figure 1: *Flux vs. time during the reappearance of (a) SR-12 and (b) ROX 31 behind the dark limb of the moon (from Simon et al. 1987). The dots represent the data at K (2 millisec integrations) and the solid line shows the binary model fit.*

The Objects Under Study

SR-12 is a Struve-Rudkjøbing emission line star. Its spectrum is classified as an M1 T Tauri star and its luminosity is estimated to be about 1 $L_\odot$. The object is also an X-ray source (ROX 21, Montmerle et al. 1983) suggesting that it is not too heavily obscured. It is coincident with a far infrared source in the IRAS maps presented by Young et al. (1986). ROX 31 is also a visible star and an X-ray source (Montmerle et al. 1983). There is no IRAS source clearly related with the star, but the object is known to be a weak 5 GHz radio source which on one occasion underwent a strong radio flare (Stine et al. 1988). The luminosity of ROX 31 has been estimated to be around 2 $L_\odot$, and its spectral type is K7-MO (Bouvier, priv. commun.). Bouvier also finds weak Hα emission confirming that it is a young object.

Lunar Occultation Data

In Figure 1 we reproduce the results of the lunar occultation experiment from Simon et al. (1987). The experiment was done at the IRTF on January 7, 1986. (A description of a lunar occultation experiment in the infrared done at ESO is found in the *Messenger* No. 50 (Richichi 1987)). Table 1 lists the derived parameters from Simon et al.'s work including the "separation" along the direction of the occultation.

The angular separation in the direction of the occultation follows from the time difference of the reappearances of the two components multiplied by the occultation rate of the moon at the contact point (0.43 arcsec/sec and 0.47 arcsec/sec for SR-12 and ROX 31, respectively). The flux ratios between the first (eastern) and the second (western) component of the two binary stars (0.85 and 1.29, respectively) can be read off from the levels of the flat parts of the signal after the occurrence of the Fresnel diffraction pattern. (Note that at 2.2 μm useful observations can be made only at the dark limb of the moon).

Infrared Speckle Follow-up Observations

We decided to follow up these observations by infrared speckle observations in order to confirm and to extend the lunar occultation data (particularly to obtain an infrared colour of the individual components). Our infrared speckle observations which were carried out in two orthogonal scan directions and in two infrared bandpasses (H and K) have added 3 pieces of information to the lunar occultation data:

(1) the "true" separation projected on the sky
(2) the position angle of the binaries
(3) the H-K colour of the individual components (of SR-12 only)

Let us remind the reader that, in speckle interferometry, the object is scanned across a slit at the photometer in one or more directions on the sky. The observational result is the visibility function. It is given as a function of angular frequency (cycles per arcsec) and is the square root of the power spectrum of the object's scanned signal divided by the power spectrum of the scanned signal of a point source, normalized to unity at zero frequency. The visibility of a binary star decreases from value 1 at zero frequency to a minimum and then increases; the shape of the visibility function is determined by the separation and relative fluxes of the two components. The separation is obtained from the spatial frequency at which the minimum occurs and the flux ratio is related to the depth of the minimum (for two equally bright components the value of the visibility function reaches zero).

Simon et al., in their paper, have already presented infrared speckle data (on SR-12 only, secured at UKIRT in Hawaii by Howell) which were used in conjunction with their lunar occultation data to derive further vital information on the nature of the source. We were trying to improve on their speckle data and add speckle data for ROX 31. Our data were obtained with the infrared specklograph at the ESO 3.6-m on the nights June 16 and 17, 1987 during which the seeing was rather good (1″.2). For a description of the performance of the specklograph we refer to Perrier's (1986) article in the *Messenger* No. 45. Suffice it to say that the seeing was adequate to reach the faint magnitudes of the objects (K = 8.5, K = 8.1) and – in the case of SR-12 – the S/N high enough to get convincingly over the minimum in the visibility function – a goal that the previous speckle observations of SR-12 did not achieve. As a consequence we did not have to rely on the depth of its visibility function inferred from the 2.2 μm flux ratio measured in the lunar occultation experiment to determine the projected binary separation (see Fig. 5 in Simon et al.), although we do prefer the lunar occultation flux ratio R (E/W) = 0.85 at K over the flux ratio that we obtained from our speckle data (R = 0.45 derived from the fit in Fig. 2a). It is noteworthy that Simon et al.'s computed projected separation of 0″.30 (48 AU) between SR-12E and SR-12W agrees well with our value measured directly from the speckle visibility functions in the E-W and N-S directions.

TABLE 1: *Data inferred from lunar occultation observations (from Simon et al. 1987).*

	"sep."	K (E-comp.)	K (W-comp.)
SR-12	0.19″	9.34	9.17
ROX 31	0.13″	8.72	9.00

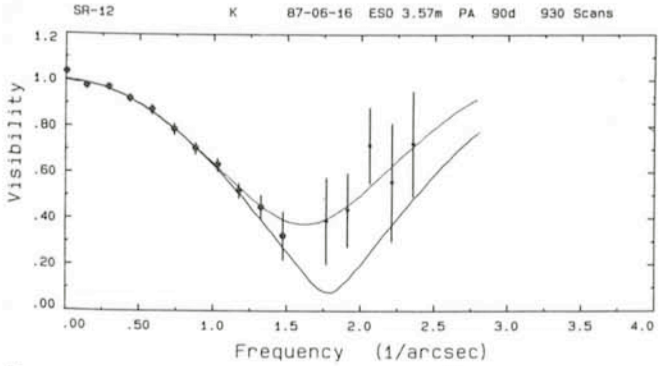


Figure 2a: *SR-12 E-W at K*
Bottom curve: fit to the data constrained by the measured lunar occultation flux ratio R (SR-12E/SR-12W) = 0.85. The resulting E-W separation is 0.28 arcsec.
Top curve: unconstrained fit to the data. In this case the resulting E-W separation is 0.30 arcsec.

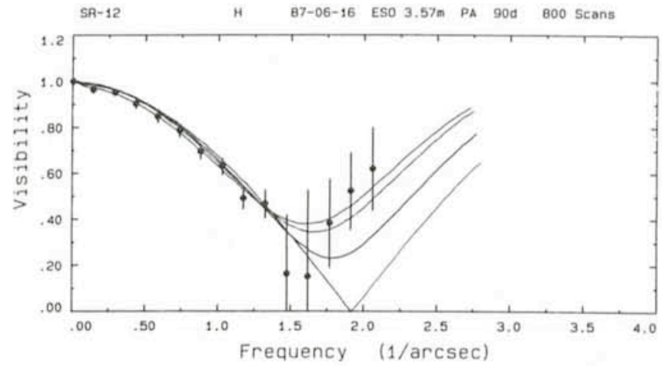


Figure 2b: *SR-12 E-W at H*
Top curve: fit where the separation was fixed at 0.30 arcsec.
Bottom curve: fit where the separation was fixed at 0.26 arcsec.
2nd curve from top: fit where both the flux ratio and the separation were free parameters.
2nd curve from bottom: fit where the separation was fixed at 0.28 arcsec (this is the value found at K under the constraint discussed in Fig. 2a/bottom curve).

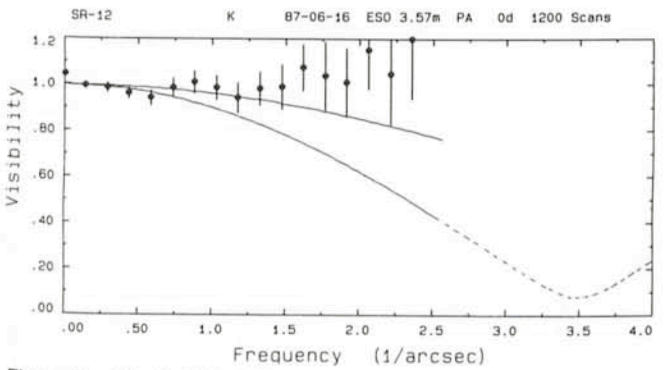


Figure 2c: *SR-12 N-S at K*
Bottom curve: fit to the data constrained in the same way as in Fig. 2a (bottom curve). The resulting N-S separation is 0.14 arcsec.
Top curve: fit to the data (unconstrained) yielding a N-S separation of 0.09 arcsec ($\chi^2 = 1$).

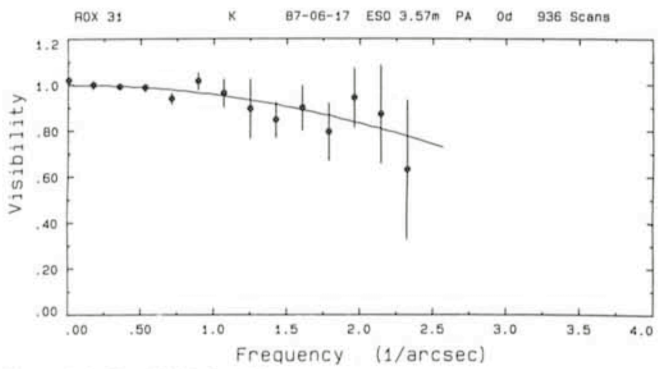


Figure 2d: *Rox 31 N-S at K*
The fit to the data gives a N-S separation of (0.09 +/– 0.05) arcsec.

Let us recall that the projected binary separation s is defined in the following way:

$$s = \left(\frac{1}{f^2_{1(E\text{-}W)}} + \frac{1}{f^2_{1(N\text{-}S)}} \right)^{1/2}$$

where f_1 denotes the spatial frequency of the minimum of the visibility function and the index E-W and N-S refers to the respective orthogonal scan directions. Figure 2 shows the 4 visibility functions that we obtained (for SR-12: K (E-W), H (E-W), K (N-S); for ROX 31: K (N-S) only). Table 2 summarizes the results.

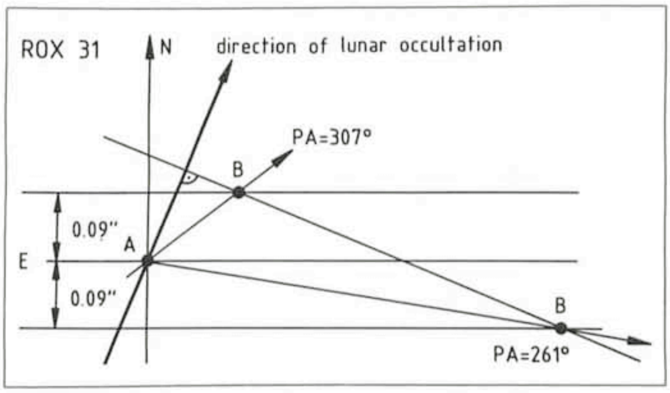


Figure 3: *The two solutions for Rox 31B The ambiguity is due to the 180° phase uncertainty for Rox 31B in the N-S speckle data, indicated by the two parallel horizontal lines 0."09 N and S of Rox 31A. Rox 31A at the origin is the brighter component at K of the Rox 31 binary system.*

TABLE 2: *Data inferred from all observations (speckle and lunar occ.)*

	proj. sep.	P.A.	K (E-comp.)	K (W-comp.)	H-K (east)	H-K (west)
SR-12	0."29	86	9.34	9.17	0.44	0.09
ROX 31	0."15*	307*	8.72	9.00	–	–

Notes to Table 2:
(i) The statistical error for the projected separations is 10%.
(ii) The position angles (east of north) should be accurate to about 10 degrees.
(iii) The K magnitudes are quite accurate (≤ 0.05 mag), while the colours are more uncertain (by 0.15–0.25 mag). The H-data for Rox 31 were too noisy to derive an H-K colour.
* There is a second (perhaps less likely) solution for Rox 31: proj. sep. = 0."55 and PA = 261 degrees (see Fig. 3).

Lunar Occultation Versus Speckle Observations

Finally we should summarize the relative merits of speckle observations versus lunar occultation observations:

(a) Lunar occultation observations can resolve binaries with separations as small as a few milli-arcsec (the limit comes from the orbital speed of the moon and the limitations of fast photometry for faint sources). It is practically an order of magnitude superior in angular resolution over speckle (speckle reaches 0.13 arcsec – the diffraction limit of a 4-m size telescope at 2.2 μm). However, it must be emphasized that higher resolution can be reached with speckle given high S/N data and a priori knowledge about the structure of the source (for example, if we knew the object was a spectroscopic binary, speckle interferometry might be capable of resolving it down to half the diffraction limit). On the other hand, it should be noted that there is an upper limit in separation (~ 0."5) for which lunar occultation yields useful results.

(b) Lunar occultation observations cannot find the projected separation since the method is intrinsically 1-dimensional while speckle observations get around this by scanning in two orthogonal directions so that the position angle and the projected separations can be found.

(c) Lunar occultation observations often cannot be repeated (for years) while speckle observations, if they fail due to poor weather, can be repeated (at most a year later). Speckle observations also can be carried out sequentially in several filters while multi-filter observations in a lunar occultation experiment must be done in parallel. As far as we are aware, such a difficult IR-experiment has not been tried yet for binaries but would be very useful since it is easier to obtain good flux ratios of the components in lunar occultation observations than from speckle data.

Acknowledgements

We would like to thank M. Simon for communicating us his results prior to publication and E. E. Becklin for drawing attention to the lunar occultation work of M. Simon and colleagues at an early stage.

Thanks also to J. Bouvier and Th. Montmerle for private communications on Rox sources, and to A. Richichi for carefully reading the manuscript. Finally we wish to thank the staff at La Silla for their efficient help.

References

Baier et al. (1985). *Astron. Astrophys.* **153,** 278.
Chelli et al. (1988). *Astron. Astrophys.* (submitted).
Dyck et al. (1982). *Astrophys. J.* **255,** L 103.
Montmerle et al. (1983). *Astrophys. J.* **269,** 182.
Nisenson et al. (1985). *Astrophys. J.* **297,** L 17.
Perrier (1986). *The Messenger* No. 45, p. 29.
Reipurth (1987). ESO preprint No. 548.
Richichi (1987). *The Messenger* No. 50, p. 6.
Simon et al. (1987). *Astrophys. J.* **320,** 344.
Stine et al. (1988). *Astron. J.* (submitted).
Young et al. (1986). *Astrophys. J.* **304,** L 45.
Zinnecker et al. (1987). IAU-Symp. No. 122, p. 117.

When Dark is Light Enough*: Measuring the Extragalactic Background Light

K. MATTILA, Helsinki University Observatory, Finland, and
G. F. O. SCHNUR, Astronomisches Institut der Ruhr-Universität Bochum, F. R. Germany

1. Introduction

The extragalactic background light (EBL) is an observational quantity of fundamental interest in several fields of cosmology. Questions involved are the decision between different cosmological models, the existence of luminous stellar matter between the galaxies, the emission by intergalactic gas, and evolutionary effects in the luminosity and the number of galaxies. Early theoretical studies of the problem by Loys de Chéseaux (1744) and Olbers (1823) led to the result which was much later coined by Bondi (1952) with the name of Olbers' Paradox: *in a static, homogeneous and infinite universe the sky background would be as bright as the Sun's surface.* Since already the crude observational fact that the sky is dark during the night has led to very deep consequences for our understanding of the universe, it is to be expected that a measurement of the intensity of the EBL will be of fundamental importance for cosmology. Such a measurement is, however, hampered by great difficulties due to the weakness of the EBL and the complexity of the composite light of the night-sky.

2. How to Separate the EBL

We have been developing for several years a method for the measurement of the EBL which utilizes the screening effect of a dark nebula on the background light (Mattila, 1976; Schnur, 1980; Mattila and Schnur, 1983). A differential measurement of the night-sky brightness in the direction of a high galactic latitude dark cloud and its surrounding area, which is (almost) free of obscuring dust, provides a signal which is due to two components only:

(1) the extragalactic background light, and
(2) the diffusely scattered starlight from interstellar dust.

The large foreground components, i.e. the zodiacal light, the airglow and the atmospheric scattered light are completely eliminated (see Fig. 1 a). The direct starlight down to ~ 21st magnitude can be eliminated by selecting the measuring areas on a deep Schmidt plate. At high galactic latitudes ($|b| > 30°$) the star density is sufficiently low to enable blank fields of ~ 2' diameter. Galaxy models show that the contribution from *unresolved* stars beyond this limiting magnitude is of minor importance. If it could be assumed that the scattered light from the interstellar dust is zero (i.e. the albedo of the interstellar grains a = 0), then the difference in surface brightness between a transparent comparison area and the dark nebula would be due to the EBL only, and an opaque nebula would be darker by the amount of the EBL intensity (dashed line in Fig. 1 c).

Unfortunately, however, the scattered light is not zero. A dark nebula above the galactic plane is exposed to the radiation field of the integrated galactic starlight, which gives rise to a diffuse scattered light (shaded area in Fig. 1 c). Because the intensity of this scattered starlight in the dark nebula is expected to be equal or larger than the EBL, its separation will be the main problem in the present method.

The separation method utilizes the difference in the shape of the spectral energy distributions of the EBL and the galactic light around the wavelength λ = 4000 Å (see Fig. 1 d).

* See Gingerich (1987)

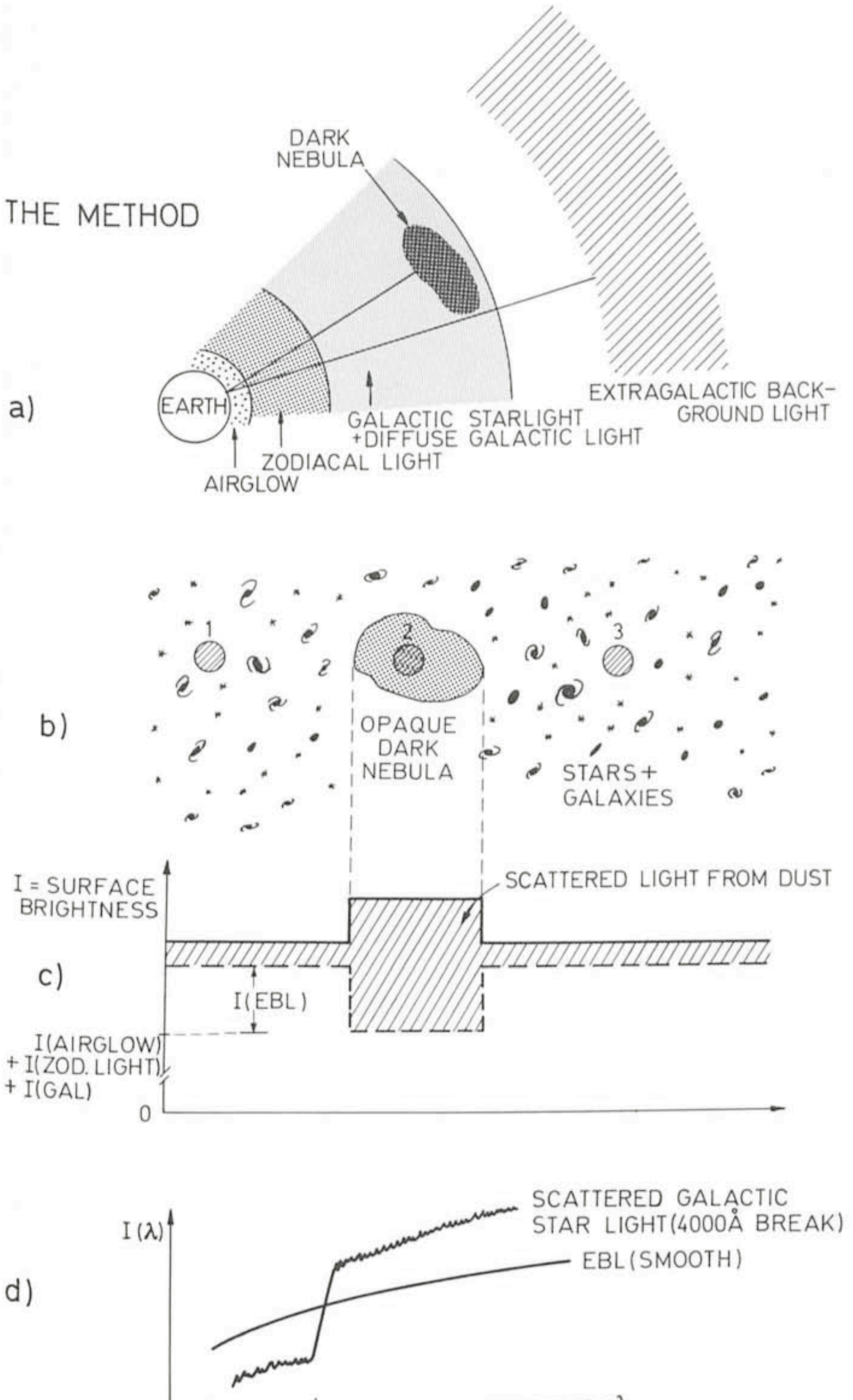


Figure 1: *(a) Principle of the EBL measuring method;*
(b) Opaque dark nebula is shown in front of a high-galactic-latitude background of stars and galaxies. Measuring positions within the nebula (# 2) and outside (# 1 and 3) are indicated;
(c) Schematic presentation of the surface brightness distribution across the dark nebula;
(d) the difference in spectral distributions of the galactic starlight and the EBL.

(1) The spectrum of the integrated starlight can be synthesized by using the known spectra of stars representing the different spectral types, as well as data on the space density and distribution in the z-direction of stars and dust. Synthetic spectra of the integrated starlight have been calculated by Mattila (1980). The most remarkable feature in the spectrum is the abrupt drop of intensity shortward of $\lambda = 4000$ Å. The shape of the integrated starlight spectrum and especially the size of the 4000 Å discontinuity have been found to depend only weakly on the galactic latitude and the imagined z-distance of the observer.

(2) It is possible to draw some conclusions about the spectrum of the EBL by using plausible theoretical arguments: Radiation from galaxies and other luminous matter over a vast range of distances, from $z = 0$ up to $z \sim 3$ at least, contribute to the EBL. Therefore, any sharp spectral features of the source spectrum – lines or discontinuities – are washed out. For the present study it is important to recognize that the discontinuity at 4000 Å, although present in all galaxy spectra, does not occur in the integrated background light.

Figure 2 illustrates how the spectral energy distribution of the observable surface brightness difference *dark nebula minus surroundings* changes for different assumed values of the EBL intensity. It can be seen that the drop at 4000 Å increases when more EBL is present. (For a more quantitative description of the method, see Mattila, 1976.)

The result of the first application of the above described method to the dark nebula L 134 gave an unexpectedly high EBL intensity of $10 \pm 4\ S_{10}$ (10^m stars per □°) at 4000 Å (Mattila, 1976). Later on, the same method was used again by Spinrad and Stone (1978) at the same nebula; they obtained an upper limit of $2.6\ S_{10}$ to the EBL.

3. Scattered and Thermal Radiation

The present authors have continued the measurements of the EBL with the dark cloud technique using the tele-

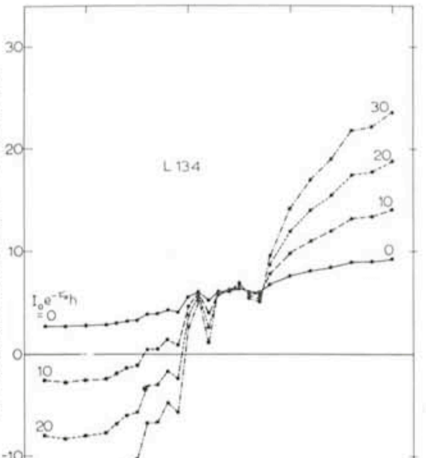


Figure 2: *Calculated spectral energy distributions of the surface brightness difference* dark nebula minus surroundings *for four different values of the EBL intensity as indicated. The numerical values refer to the observations of L 134.*

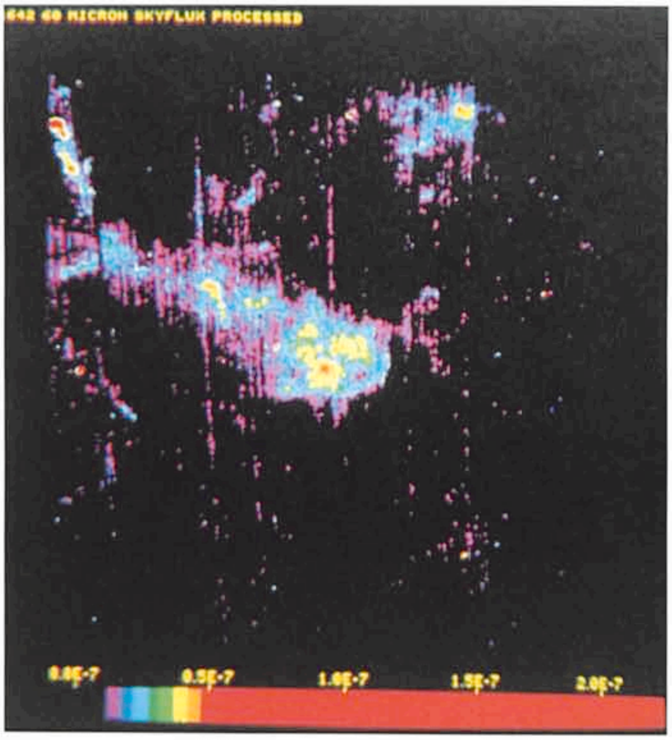


Figure 3: *Infrared (IRAS) surface brightness distribution at 60 μm in the area of L 1642. The marked area is shown in the optical image in Fig. 4. (This picture was kindly provided by R.J. Laureijs, Space Research Laboratory, Groningen.)*

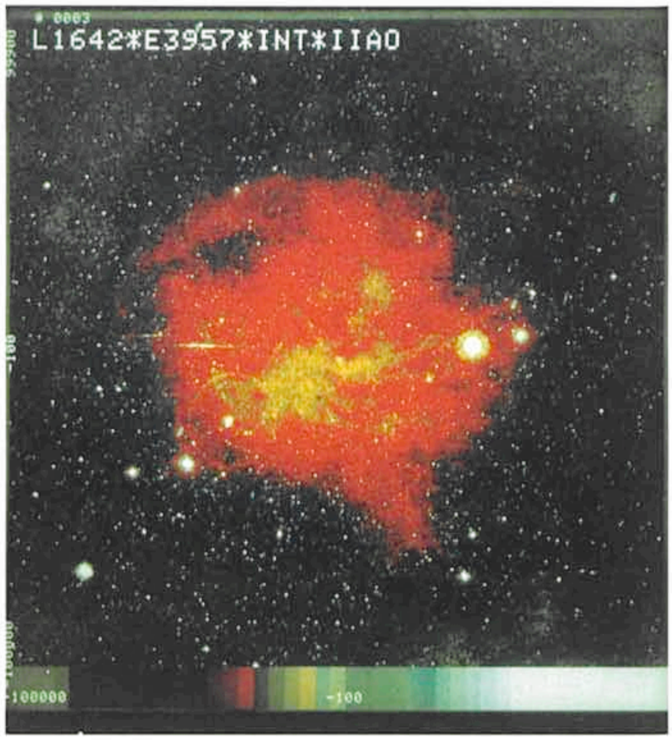


Figure 4: *Optical (blue) surface brightness distribution in the area of L 1642.*

scopes of the European Southern Observatory on La Silla since 1979. For these observations the southern dark nebula L 1642 at $l = 210^{\circ}\!.9$, $b = -36^{\circ}\!.5$ was selected in addition to L 134. Based on our observations in 1980 and data available from IRAS we have recently completed a comparative infrared and optical surface brightness investigation of L 1642 (Laureijs, Mattila and Schnur, 1987). Through the IRAS data we have a very effective method to determine the column density along each line of sight in and near the nebula. The 100 μm surface brightness distribution in the L 1642 area is shown in Fig. 3. For comparison we show in Fig. 4 the optical surface brightness distribution in the same area, measured on a blue (IIa-O) ESO Schmidt plate. It can be seen that high latitude dust clouds are effectively detected also by means of their scattered light, seen on deep photographic plates down to about the same levels as the thermal emission seen by IRAS. The lowest contours of both maps correspond to an extinction of ~ 0.2 magnitudes.

This investigation is a byproduct of the EBL measurements, but it is useful also on its own right:

From the relationship between the optical and infrared brightness in L 1642 we were able to derive e.g. the optical albedo of the dust and the ratio of visual to 100 μm opacity, which are important constraints to grain models.

4. New Measurements

In December 1987 we could spend again seven nights on L 1642 at the ESO 1-m and 50-cm telescopes under excellent sky conditions. By using the IRAS data we were this time able to considerably improve our measuring programme, since we had better means of identifying near the dark nebula regions which are free or almost free of dust. Guided by the IRAS data and our previous photometry we have also been able to locate probably the darkest and most opaque spot in the centre of L 1642 which provides the best zero point for the EBL measurement.

The photoelectric surface photometry of weak extended objects is hampered by the time variability of the airglow. One has to repeat normally in single beam photometry the ON and OFF source measurements after each other. We have been using a method in which the airglow fluctuations are eliminated by using simultaneous parallel observations with a monitor telescope (see Fig. 5). The efficient elimination of the airglow variations is demonstrated by Figs. 6a and b which show the sky brightness for a "standard position" in L 1642 as measured with the 1-m telescope through an 88″ diaphragm in u and y during the night 15/16 December 1987. Also shown is the ratio of the 50-cm signal to the 1-m signal. As can be seen the ratio remains constant to within ± 1 % of the signal, which is the pure photon noise for the 40 sec integrations at the 1-m telescope.

The reductions of the observations are still going on at the moment. How-

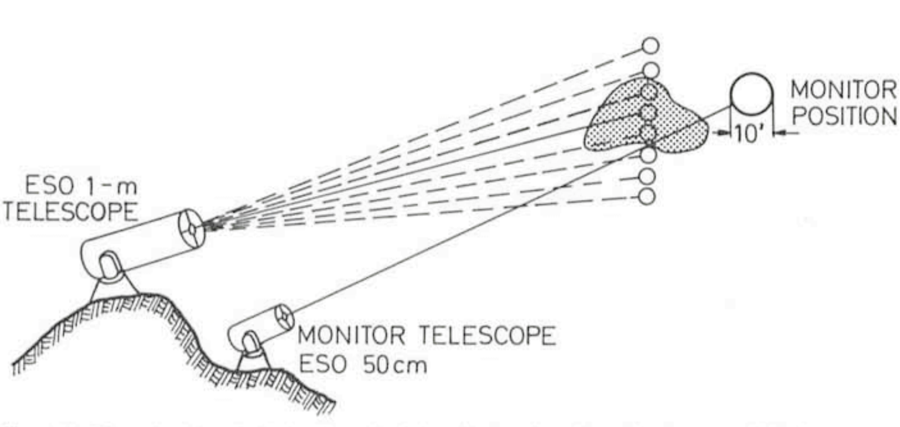


Figure 5: *The principle of elimination of airglow fluctuations by using two parallel telescopes.*

ever, thanks to the extremely good and stable sky conditions during these measurements and guided by our previous experience we are already hopeful to get this time a clearcut result on the weakness or the strength of the EBL.

References

Bondi, H.: 1952, *Cosmology*, Cambridge University Press, Cambridge.

Gingerich, O.: 1987, When dark is light enough (review of the book by E. Harrison: *Darkness at Night: A Riddle of the Universe*). *Nature* **330,** 288.

Laureijs, R., Mattila, K., Schnur, G.F.O.: 1987, *Astron. Astrophys.* **181,** 269.

Loys de Chéseaux, J.P.: 1744, *Traité de la comète qui apparut en décembre 1743,* Lausanne, p. 223.

Mattila, K.: 1976, *Astron. Astrophys.* **47,** 77.

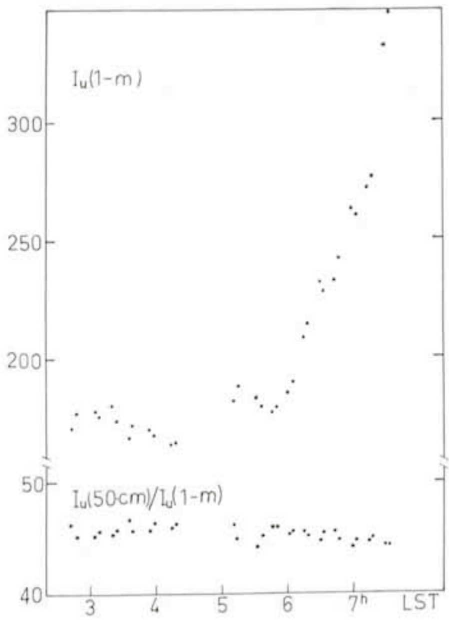
Mattila, K.: 1980, *Astron. Astrophys.* **82,** 373.

Mattila, K., Schnur, G.F.O.: 1983, *Mitteilungen d. Astron. Gesellschaft,* **60,** 387.

Olbers, H.W.M.: 1823, *Astronomisches Jahrbuch 1826* (hrsg. von J.E. Bode), p. 110.

Schnur, G.F.O.: 1980, Photoelectric Surface Photometry of Extended Sources, in ESO Workshop: Two Dimensional Photometry, p. 365, P. Crane, K. Kjär (Eds.).

Spinrad, H., Stone, R.P.S.: 1978, *Astrophys. J.* **226,** 609.



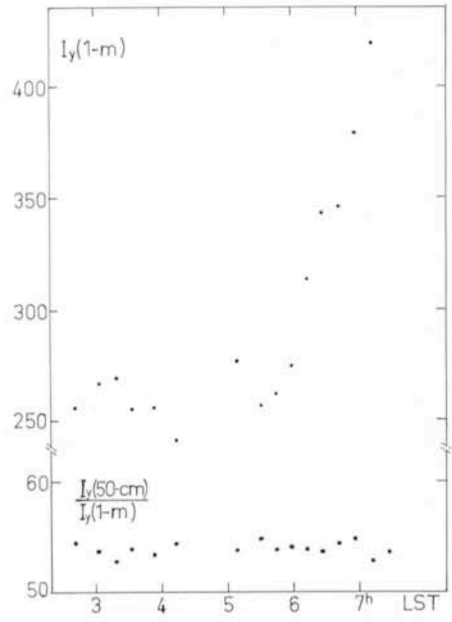


Figure 6a: *Variation of the night sky brightness in Strömgren u during the night 15/16 Dec. 1987. The upper part shows the signal measured in a fixed position at the centre of L 1642 through an 88″ diaphragm at the 1-m telescope. Units are 10^{-9} erg cm^{-2} s^{-1} sterad^{-1} Å^{-1}. The steep increase starting at LST 6^h is due to moonrise. Lower part is the ratio of the 50-cm and 1-m telescope signals.*

Figure 6b: *Same as Figure 6a, except for Strömgren y.*

MULTI-OBJECT SPECTROSCOPY WITH EFOSC:

Observations of Medium Distant Clusters of Galaxies

E. GIRAUD, ESO

1. Introduction

1.1 Context

Advances in the understanding of (a) galaxy and cluster evolution, (b) galaxy and cluster formation, and (c) their large scale distribution, have been made in the past years, but many questions are still open.

Colour variations of galaxies as a function of look-back time would arise from main-sequence turn-off points and would depend on how many stars evolve at what rate off the main sequence, on the star formation history and collapse time of galaxies. Demonstrating the evolution of galaxies (i.e. the more distant galaxies to have a younger population of stars) should be decisive for observational cosmology (see e.g. Butcher and Oemler 1978, Hamilton 1985, Spinrad 1986).

Hubble diagrams for brightest cluster members have shown a remarkably small scatter but large uncertainties due to stellar evolution are still present. Moreover the properties of these galaxies might be related to the density of the cluster core and the age through dynamical evolution (Hoessel and Schneider 1985). These evolutionary effects must be understood before any conclusion on the value of q_o and the geometry of the universe can be drawn.

Large redshift surveys (Arecibo, Harvard-Smithsonian CfA) have shown that inhomogeneities in the galaxy distribution can be characterized by voids, filamentary structures and strong clustering on small scales (e.g. de Lapparent, Geller and Huchra 1986). On large scales, inhomogeneities are still present at 100 h^{-1} Mpc. Understanding the large scale distribution of galaxies is certainly one of the fundamental problems of present observational cosmology.

Gravitational lenses with multiple imaging, due to the shear effect of a compact mass lying near the light beam coming from a distant object, have been observed (Liège Conference 1983). These spectacular gravitational mirages correspond to exceptional configurations. A more probable case corresponds to the gravitational amplification without multiple imaging by density inhomogeneities (i.e. the mean effect of several deflectors in a cluster; Weinberg 1976, Turner et al. 1986, Hammer and Nottale 1986). A rich compact cluster can be a powerful giant lens acting on the light of distant sources ideally located.

The observation of distant clusters may also give information on the geometry of the universe (Gunn and Gott 1972). For example, at $z \sim 0.9$, whether a cluster had time to form depends on H_o, q_o, and on the richness of the cluster.

For the understanding of these matters it is essential to have fair samplings of the universe. This is a long and difficult task which would require extensive observational efforts. More precisely, it would be necessary to perform a deep photometric and spectroscopic survey of distant galaxy clusters to detect evolutionary effects, and a wide angle medium deep redshift survey for the study of large scale inhomogeneities.

Figure 1: *Composite CCD image in the V-band of the central region (5.7 × 3.8 arcmin) of cluster Cl 1. North is up, east is left. The cluster core has been dimmed by ~ 1 mag in the image processing. The angular separation of the binary central system is 8 arcsec. (ESO 3.6 m + EFOSC; exposure time: 12 min).*

1.2 Photographic Surveys

A deep photographic survey of specific areas was carried out by Gunn, Hoessel and Oke (1986) with the 5-m Hale telescope and the 4-m Mayall telescope. This survey has led to the discovery of clusters up to z = 0.92. Coppi et al. reported observations of one of these clusters in the 48th issue of the *Messenger* (June 1987). They presented enlightening results on the probability to detect a cluster as a function of redshift.

A medium deep photographic survey of Abell clusters in the southern hemisphere, by Abell, Corwin and Olowin is nearly complete. In its present form, this catalogue gives information on (a) the apparent size of clusters, (b) the magnitudes of the 1st, 3rd and 10th brightest galaxies, and (c) the approximative number of objects brighter than ~ m (3) + 2 within a counting erea. These clusters should have redshifts almost entirely at z ≤ 0.4.[1] Prominent structures detected near the limit of the catalogue provide a basic list for observing medium distant (i.e. z ~ 0.2 – 0.4) southern clusters.

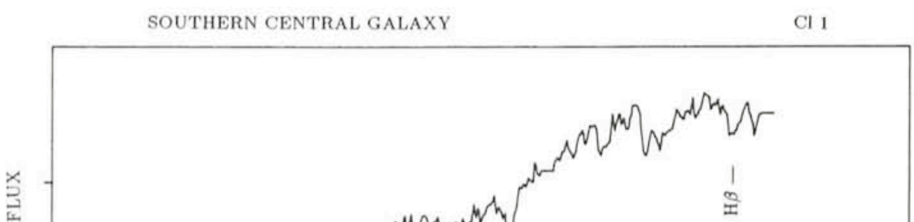


Figure 2: *A spectrum of the southern central galaxy of Cl 1, extracted from a multislit exposure with the B 300 grism. The measured redshift is z = 0.27. Spectra of 7 other galaxies were taken during this exposure. (ESO 3.6 m + EFOSC; aperture plate produced by the PUMA II machine.)*

2. Observations

Candidates were selected from this catalogue on the basis of the apparent luminosity of the first ranked object, the diameter (i.e. the compactness), and an estimate of the density enhancement over the expected background. Four superb clusters were observed with EFOSC mounted at the Cassegrain focus of the 3.6-m ESO telescope at La Silla. Photometry in B, V and Gunn I was recorded. The sky was clear and the seeing ~ 1.5 arcsec. The multi-object spectroscopic mode of EFOSC (MOS) was used to take spectra of the brightest objects. The techniques to operate the instrument and the automatic punching machine (PUMA II) are described in the Operating Manuals (Dek-

[1] Appreciable evolution is not expected in that range.

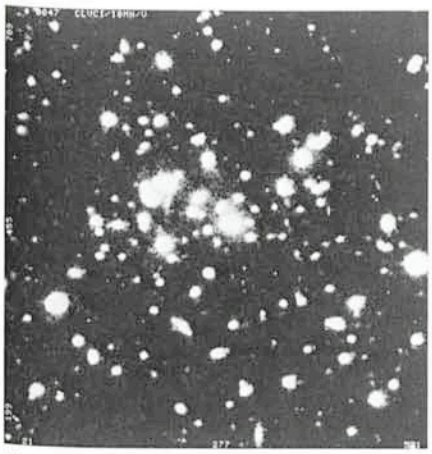


Figure 3: *CCD frame in the V band of the central part (2.8 × 2.8 arcmin) of the compact cluster Cl 2. North is up, east is left. (ESO 3.6 m + EFOSC; exposure time: 18 min.)*

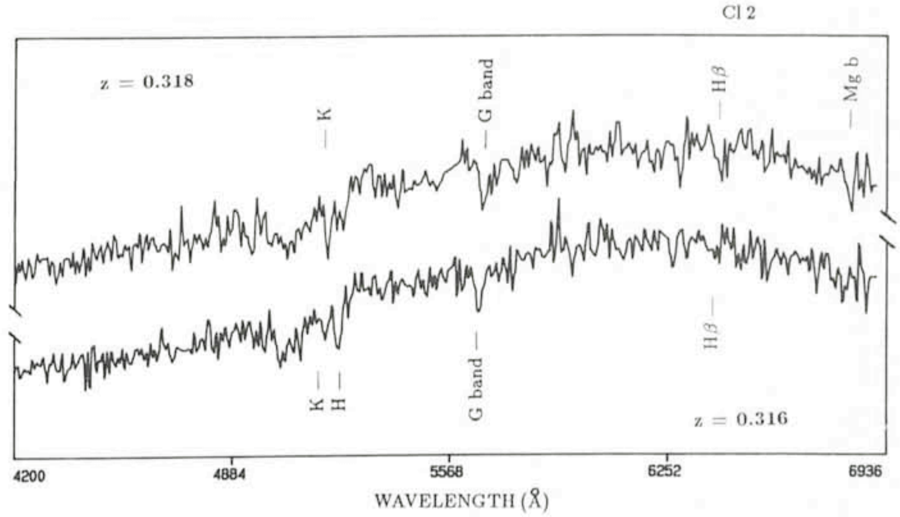


Figure 5: *Spectra of two galaxies of cluster Cl 2 extracted from the same 90-min multislit exposure as in Fig. 4. Magnitudes are V = 20.8 and V = 21.1 respectively. One of the spectra was shifted up for clarity.*

ker and D'Odorico 1985, 1986; Dupin and Dekker 1986). Results of MOS observations can be found in the Proceedings of the ESO-OHP Workshop on CCD detectors (D'Odorico and Dekker 1986) and in the *Messenger* No. 47 (Dupin et al. 1987).

The detector was ESO CCD No. 11, which is a high resolution RCA CCD (15 μm pixel). Direct images needed to prepare the masks for multi-object spectroscopy were acquired in the 2 × 2 binned mode. The masks were punched during the afternoon preceding the second observing night. Most spectra were taken through 20 arcsec slits. Round holes centred on field objects were used for the alignment of the masks on the fields. Two iterations and a final check (about 15 min) were necessary to make the alignment. The spectra were obtained with the B 300 grism, that gives a dispersion of 230 Å/mm and a total wavelength coverage of 3700–7000 Å. Wavelength calibration was accomplished with a helium lamp through the mask after each programme exposure. Spectrophotometric stars were observed for flux calibration.

The image of cluster Cl-1 presented in Figure 1 is a mosaic of CCD frames taken in the V-band. Exposure time is 12 minutes. This cluster is regular, very rich, with two giant cD type galaxies in its centre imbedded in an extended envelope and surrounded by a number of smaller elliptical or lenticular objects. The central part of the image has been dimmed by 1 mag in the image processing. Disk galaxies are found at larger angular distance from the centre. Brightest edge-on galaxies may be foreground objects. There is some evidence of subclustering around a third large galaxy 80 arcsec NNW. The apparent magnitudes of the first ranked central objects are V = 17.9 and V = 18.4. The projected separation of their centres is 8 arcsec. Reliable magnitudes can be measured down to V = 22.5. The redshift distance is z = 0.27. A spectrum of the southern central galaxy is shown in Figure 2.

This spectrum was extracted from a 75-minute multislit exposure after filtering for cosmic ray events and sky subtraction.

Cluster Cl 2 (Fig. 3) is regular, rich, compact, and has a triple core. The central galaxy (V = 19.3) is surrounded by a corona of E or S0 galaxies (V ~ 21). It has a redshift of z = 0.315 (Fig. 4). The similarity in redshift and the angular separation of CL 1 and 2 (60–70 h^{-1} Mpc) could infer that they belong to the same large-scale structure.

The central galaxy is very red (B–V = 1.6 mag). This is partly intrinsic (large 4000 Å break amplitude) and partly due to the shift of the spectral energy distribution (K term). A large amplitude of the 4000 Å break is generally suggestive of no ongoing star formation. Low val-

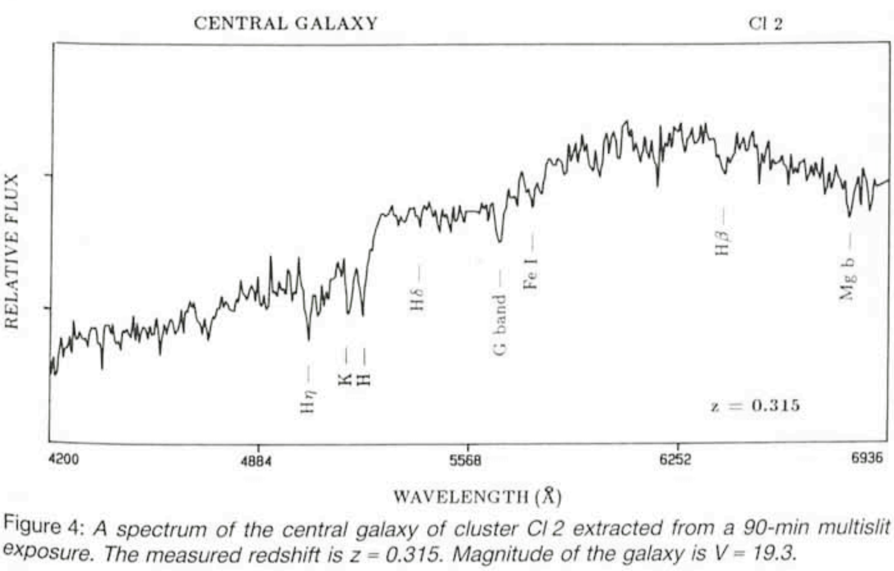


Figure 4: *A spectrum of the central galaxy of cluster Cl 2 extracted from a 90-min multislit exposure. The measured redshift is z = 0.315. Magnitude of the galaxy is V = 19.3.*

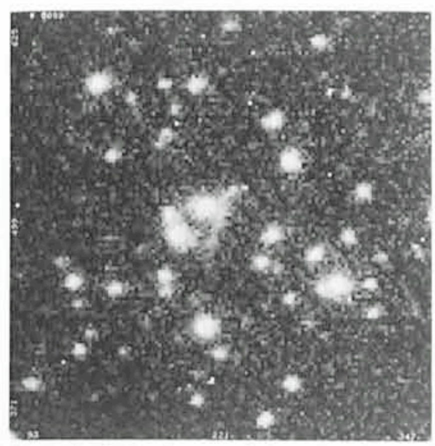


Figure 6: *A blue image of the central part of cluster Cl 2, showing an elongated structure near two large elliptical galaxies. The projected angular distance between these two galaxies is 7.5 arcsec. The arc-like structure and the centre of the nearest galaxy are separated by 2.8 arcsec in projection.*

ues of the 4000 Å break amplitudes are mainly due to present or recent star formation, or dilution by the continuum of an active nuclear region (Dressler and Shectman 1987). Spectra of galaxies extracted from the same MOS exposure are shown in Figure 5.

Examination of blue images of cluster Cl 2 shows an elongated feature near two large elliptical galaxies (Fig. 6). In the V band, the images of the northern galaxy and of this possible arc-like structure are blended. The B band, that corresponds roughly to ultraviolet wavelengths in the rest frame of the cluster, is well suited to register arc structures located near an old-populated elliptical galaxy. The present structure is bluer than most cluster galaxies and, in that sense, is similar to other discovered giant arcs (Soucail et al. 1988, and further references therein).

The proximity of two large galaxies, probably interacting, suggests an interpretation in terms of enhancement of star formation. On the other hand the compactness of the cluster would be favourable to the observation of gravitational lensing phenomena. High resolution imaging in subarcsec seeing and spectroscopy are needed to pursue these possibilities.

Results based on the photometry of these cluster and on first spectroscopic measurements will be published in forthcoming papers.

Acknowledgements

I would like to express my thanks to ESO for the observing time allocated to the project, to Dr. H. Corwin for communication of his list of clusters, and to Dr. H. Arp for his suggestions. I thank Dr. P. Magain for the introduction at the various modes of EFOSC.

References

Butcher and Oemler, 1978, *Ap. J.*, **219,** 18.
de Lapparent, Geller and Huchra, 1986, *Ap. J.*, **302,** L 1.
D'Odorico and Dekker, 1986, in ESO-OHP Workshop: The Optimization of the Use of CCD detectors.
Dressler and Shectman, 1987, MWLCO preprint.
Gunn and Gott, 1972, *Ap. J.*, **176,** 1.
Gunn, Hoessel and Oke, 1986, *Ap. J.*, **306,** 30.
Hamilton, 1985, *Ap. J.*, **297,** 371.
Hammer and Nottale, 1986, *Astron. Astrophys.*, **167,** 1.
Hoessel and Shneider, 1985, *A. J.*, **90,** 1648.
Soucail et al., 1988, *Astron. Astrophys.* Letter, in press.
Turner et al., 1986, *Nature*, **321,** 142.
Weinberg, 1976, *Ap. J.*, **208,** L1.

STAFF MOVEMENTS

Arrivals

Europe:

GUIRAO SANCHEZ, Carlos (E), Associate
LONGINOTTI, Antonio (I), Fellow
RUPPRECHT, Gero (D), Physicist-Astronomer
WEIGLE, Renate (D), Secretary/Administrative Assistant to the Director General

Chile:

GREDEL, Roland (D), Fellow

Departures

Europe:

MATTEUCCI, Maria Francesca (I), Fellow

Transfers

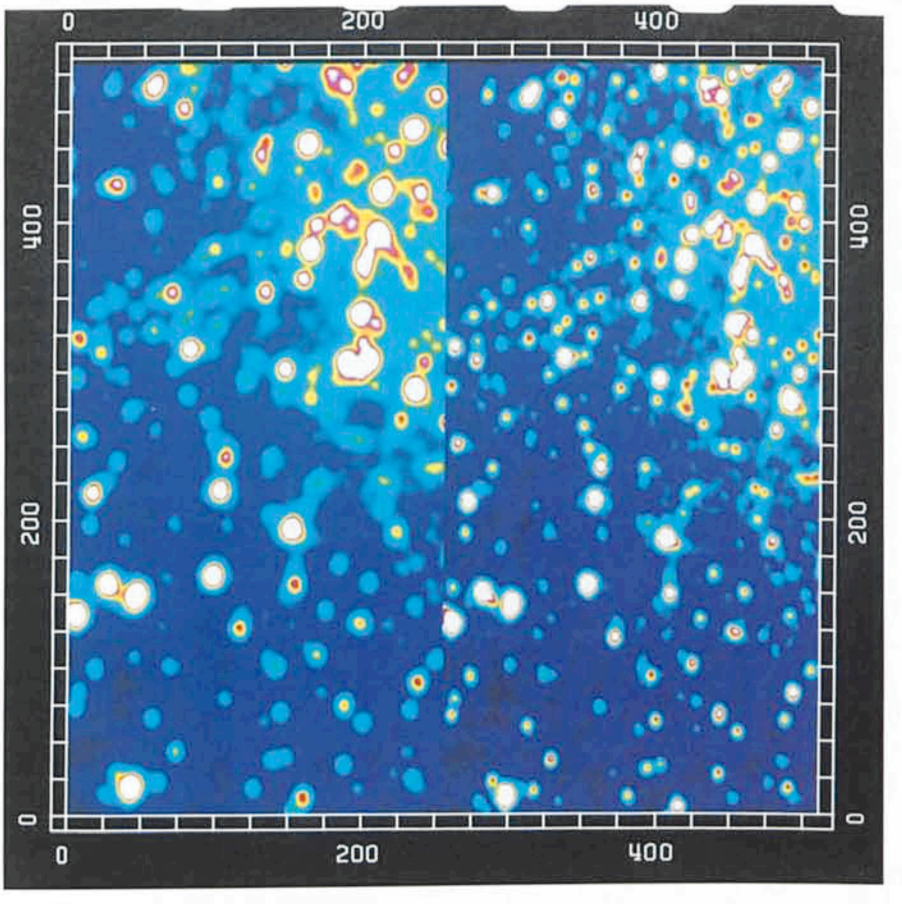
MELNICK, Jorge (RCH), Associate (from Europe to Chile)

Wirtschafts-Attaché-Club Bayern Visits ESO Headquarters

On November 25, 1987, a visit was paid to ESO by the Wirtschafts-Attaché-Club Bayern, headed by Mr. P. Grillet from the Belgian General Consulate. The commercial attachés from more than 15 countries were given a general introduction to ESO and an overview of the scientific and technological research carried out at this organization. After the formal session in the auditorium during which many questions were asked, in particular about the VLT project, a light lunch was served, later to be followed by a tour of the Headquarters. The photo was taken in the foyer, at the moment of arrival of the officials.

First Observing Run with DISCO was Successful

F. MAASWINKEL, S. D'ODORICO, F. BORTOLETTO, B. BUZZONI, B. GILLI, C. GOUIFFES, G. HUSTER, and W. NEES, ESO



The Direct Image Stabilized Camera Option DISCO was tested for the first time from 29 November to 5 December at the 2.2-m telescope with a CCD camera. The instrument was described in *Messenger* **48,** p. 51. It comprises a new adapter for the 2.2-m telescope with a newly designed XYZ offset guider. It offers the possibility to observe at the conventional f/8 focus, or alternatively at an f/20 focus. In the latter mode it is possible to correct the motion of the astronomical image 50 times per second. DISCO was mounted at the telescope with the precious support of the TRS group and operated without problems from the first night. The aim of the run was in particular the test of the image correction system (fast tilting mirror, ICCD camera, VME based microprocessor). As had been expected, the system gave only minor improvement in mediocre seeing conditions; during very good seeing, however, it provided a rather impressive image improvement. As an illustration, Figure 1 shows a comparison of two exposures of 47 Tuc made *without* (left picture) and *with* (right picture) image stabilization. The exposure time was 45 sec for both and a red gunn filter (λ_c = 668 nm) was used. The stellar image diameters without stabilization were 1".2 FWHM, with stabilization 0".9 was achieved. Thanks to the superior light concentration the stabilized image reveals more details and reaches fainter magnitudes. During part of a night the seeing was so good that it was possible to improve the FWHM of the stellar images in long integrations from 0".85 (non-stabilized) to 0".66 (stabilized). The possibility to switch remotely in a few minutes from the f/8 to the f/20 mode was found particularly useful, as the seeing was observed to change on a rather short timescale (~ 1 hour).

A more detailed report on this test will be given at the Very Large Telescope Conference at ESO in March.

New Operational Limits for 1.5-m Danish Telescope

A 14.5 cm thick spacer ring has been installed between the mirror cell and the instrument adapter. Its purpose is to eliminate residual spherical aberration. Recently analysed Schack-Hartman tests have shown the correction to be complete.

The longer focal length of the telescope has changed the focal plane scale from 16.07 to 15.83 +/− 0.02 arcsec/mm.

Unfortunately, the extra length below the mirror cell implies restrictions for the use of certain pieces of auxiliary equipment, in addition to those described in ESO Users Manual No. 3 "Danish 1.5-m telescope and Auxiliary equipment", pages 4–7. Observers are urged to take these into account, when planning their programme.

As the telescope can be used either west or east of the base, there are two sets of limits; they are however symmetric. Telescope operation west of the base has the advantage that tracking (but not presetting) can be done into part of the "danger" zone; the observer may override a first warning signal.

The inaccessible corner for the CCD camera is h.a. > +01 : 10, decl. < −47 (telescope west) and h.a. < −01 : 10, decl. < −47 (telescope east). In the west position, tracking is allowed to decl. −53, for h.a. > +01 : 10. It is not feasible to reverse the telescope during the night, as the CCD electronics would have to be disconnected.

For Coravel, the corner is at h.a. > +00 : 10, decl. < −43 (west) and h.a. < −00 : 10, decl. < −43 (east). These limits appear more restrictive than those mentioned above. However, the control cable for the Coravel permits the observer to reverse the telescope at night. Objects which are inaccessible from one side of the base, can therefore be observed from the other.

A two-channel and a six-channel photometer have limits which are rather similar to those of the CCD camera, and telescope reversal is possible.

Mr. P. Nørregaard, Brorfelde, has reprogrammed the microprocessor-based safety-system so that physical collisions between telescope base and auxiliary equipment remain impossible.

H. Pedersen, ESO

MIDAS Memo

ESO Image Processing Group

1. Application Developments

An extended CCD reduction package made by S. Jörsäter, Stockholm Observatory, has been implemented in MIDAS. This package includes tools for standard reductions of CCD frames such as dark current and sensitivity corrections. A set of sophisticated routines also allows the user to make mosaics of several frames including photometric adjustments of the individual exposures.

A calibration directory structure is being created. This will contain general calibration data useful for reduction of data from La Silla. The first data to be included are tables of spectral lines, flux of standard stars, and extinction data. Information on filter transmission curves, performance of ESO CCD chips, gratings efficiencies, etc. will be added later.

2. Portable MIDAS

The developments of the portable version of MIDAS are proceeding according to schedule. The portable monitor has been tested successfully on a μ VAX ULTRIX system while internal verifications on a SUN and Bull SPS 7 system are in progress. The full Table File System has been ported using the new set of table interface routines. The Fortran application code has been converted from VAX/VMS Fortran to standard Fortran with 5 simple extensions (i.e. INCLUDE, IMPLICIT NONE, !-comments, ENDDO and long internal names). A preprocessor was made for Fortran compilers which do not support these extensions.

We are also happy to announce that a new UNIX system programmer, Carlos Guirao Sanchez, has joined the IPG. One of his main responsibilities is to develop and maintain the system dependent interfaces of MIDAS. He will therefore be strongly involved in the implementation of MIDAS on new systems.

3. MIDAS Workshop

The next Data Analysis Workshop, arranged by the ST-ECF, will be held on the 26th and 27th April, 1988. For the convenience of people who also want to participate in the MIDAS workshop, the Image Processing Group has scheduled this workshop for 28th April, 1988. The programme will include sessions on general developments and new applications. Since the Portable version of MIDAS will be made available during this summer, a significant part of the MIDAS Workshop will be devoted to this topic. We anticipate giving a demonstration of a prototype of the Portable MIDAS during the workshop. A tentative agenda will be sent out to all MIDAS sites together with other material for the Data Analysis Workshop. People interested in participating in the Workshop should contact either the IPG or the ST-ECF.

4. MIDAS Hot-Line Service

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

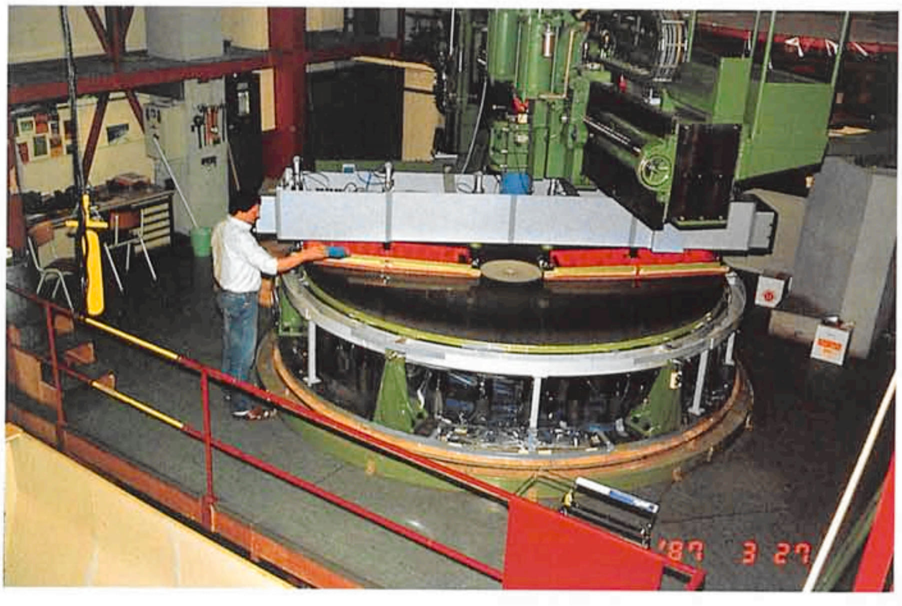
- EARN: MIDAS@DGAESO51
- SPAN: ESOMC1::MIDAS
- Tlx.: 528 282 22 eso d, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

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.

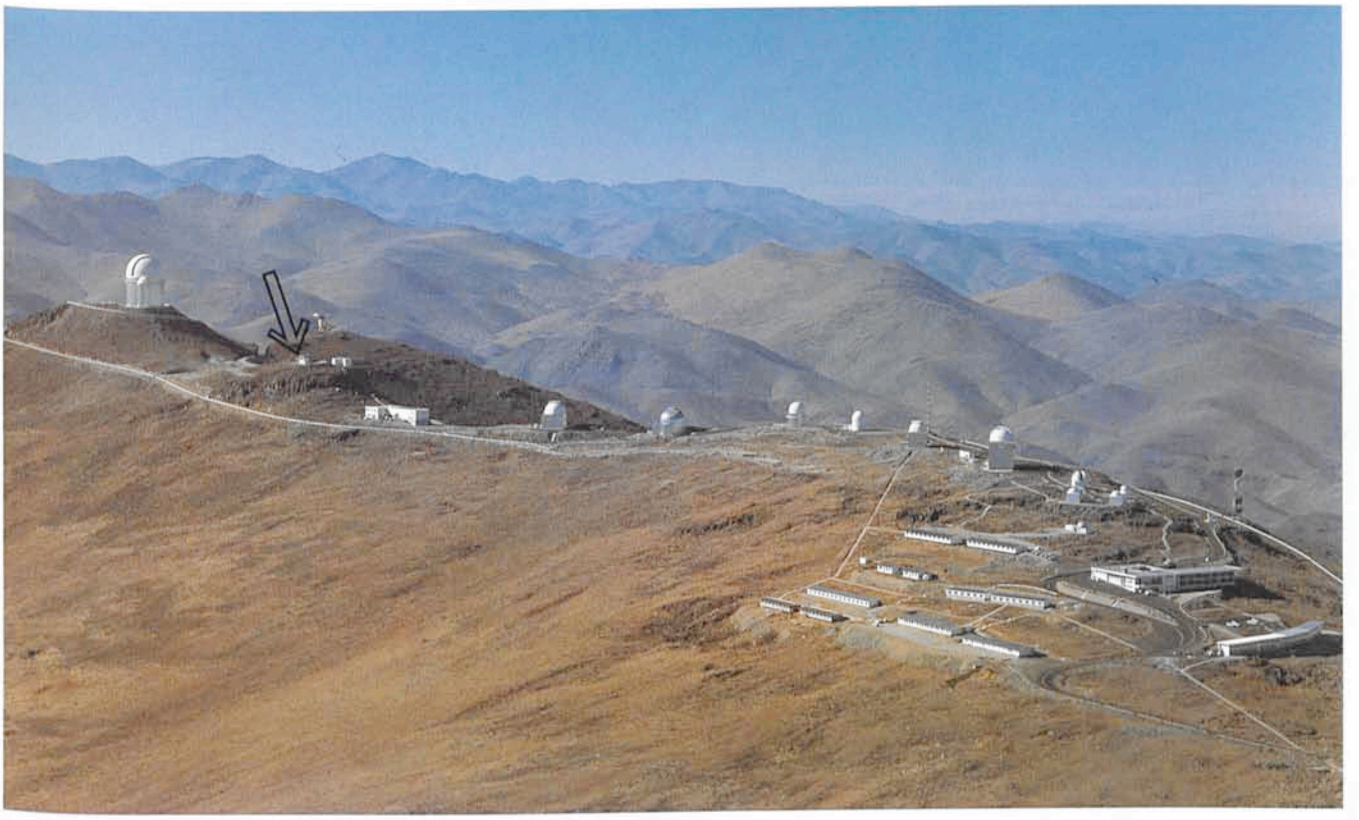
Unusual Building for the ESO NTT Arrives at the La Silla Observatory

Early in February, M/S *Cervo* arrived in the harbour of Valparaiso, Chile, with the packaged parts for the building which will house the ESO New Technology Telescope (NTT). Soon thereafter, the 350 ton load was hauled by road to the ESO La Silla observatory in the Atacama desert, some 600 km north of Santiago de Chile. Here, at one of the best astronomical sites on earth, the giant mechanical puzzle will now be put together to form one of the strangest telescope domes ever seen.

The NTT will be mounted in a rotating building with an unusual octagonal shape. It has been designed to ensure maximum exposure of the telescope to the external environment during observation, while protecting the structure from strong winds and dust. Furthermore, the floor of the building is actively cooled and the temperature in the telescope room and in the instrument rooms is maintained at the level of the



The 3.58-m NTT main mirror being polished at Zeiss, Oberkochen, F.R.G.



Aerial view of La Silla. The site for the NTT building is indicated by an arrow. Photograph by C. Madsen, February 1987.

outside temperature at night. These features will improve the NTT performance, as compared to other telescopes, since there will be less turbulence in the surrounding air and the images of astronomical objects will therefore be sharper.

The exact shape of the building was determined by wind tunnel tests at the Technical University of Aachen.

The building was conceived at ESO and designed and manufactured by a consortium of Italian companies (MECNAFER, Mestre, ZOLLET, Belluno, and ANSALDO Componenti, Genova) in close cooperation with a number of European industries. One of these is RKS France who manufactured an extremely precise roller bearing with diameter of no less than 7 m, a key component of the rotating system.

It will take almost six months to complete the erection of the rotating building at La Silla.

The NTT itself has now been dismounted and will be shipped to Chile with arrival in the course of May 1988. It will then be erected inside the rotating building and it is expected that the first sky observations begin at the end of 1988.

Here are some data for the NTT project:

Estimated price of the NTT project: 25 million DM
Size of NTT building: 18 m (high) × 17 m × 17 m
Weight of building: 250 tons
Length of telescope tube: 8 m
Weight of telescope: 125 tons
Main mirror material: Zerodur
Size of main mirror: Diameter 3.58 m; Thickness 24 cm; f/2.2
Weight of main mirror: 6 tons
Foci: 2 Nasmyth platforms, f/11, with fixed infrared and visual multi-function instruments.

ALGUNOS RESUMENES

Observaciones infrarrojas de estrellas variables, con el telescopio de un metro.

Muchas estrellas son variables. El primer observador de estrellas variables fue el holandés Fabricius, quien a fines del siglo XVI descubrió, en la constelación de la Ballena (Cetus), un objeto estraño que aparecía y desaparecía, con un período de un año. Este fenómeno estaba en plena contradicción con el dogma clásico que establecía que las estrellas eran objetos perfectos que no pueden cambiar. Entonces, Fabricius llamó a este objeto Mira Ceti (la maravilla de la constelación de la Ballena). Posteriormente, se descubrieron muchas estrellas variables y aquellas que, como Mira Ceti, tienen un período de un año o más y son rojas, fueron apodadas Miras. Hoy sabemos que ellas son gigantescas: su radio mide entre cien y mil veces el radio del Sol, lo que las hace entonces más grandes que la órbita de la Tierra. Su luminosidad es mil a cien mil veces la del Sol. Las teorías de evolución estelar predicen que, en algunos billones de años, el Sol también será una Mira por un millón de años antes de extinguirse definitivamente.

La superficie de estas estrellas no está bien definida, y contínuamente ellas pierden material. A grandes distancias, este material se enfría lo suficiente como para condensarse y luego formar una especie de polvo. Este polvo absorbe la luz estelar y la reemite en la gama infrarroja. La densidad del polvo puede aumentar a tal punto que la totalidad de la luz de la estrella central es absorbida; en este caso detectamos solamente una fuente infrarroja.

Muchos de estos objetos infrarrojos fueron descubiertos por el astrónomo francés N. Epchtein, utilizando el telescopio de un metro, en La Silla. Ahora, después de tres años, algunas de esas fuentes son observadas regularmente con el mismo telescopio para apreciar los cambios de luminosidad. Se puede hacer este tipo de observaciones infrarrojas tanto de día como de noche; pero, por supuesto, es más fácil de noche. Los períodos son a veces mucho más largos que el de Mira Ceti. Por ejemplo, la estrella designada por OH/IR 286.50+0.06 (Fig. 1, pág. 24) tiene un período de 550 días y las estrellas OH/IR 285.05+0.07 (Fig. 1, pág. 24) y OH/IR 353.60–0.23 (Fig. 2, pág. 25) de más de tres años (todavía no se conoce su período con precisión). Estos objectos son sitios donde ocurren cambios fenomenales; la estrella OH/IR 285.05+0.07 estuvo estable durante 200 días, con una luminosidad 40 mil veces la del Sol y, en menos de 150 días, su luminosidad creció hasta llegar a ser 60 mil veces la del Sol. En el caso de OH/IR 353.60–0.23, en 300 días la luminosidad cambió de 50 mil a 250 mil la del Sol. En tales condiciones, es muy importante tener permanentemente telescopios e instrumentos en condiciones perfectas para poder observar estos fenómenos cuando ocurren.

El autor agradece a todas las personas que en La Silla se esfuerzan para que el Observatorio, los telescopios y los instrumentos funcionen óptimamente.

T. Le Bertre (trad. R. Huidobro)

Noticias del Gran Telescopio (VLT)

Después de que fue aprobado el proyecto el día 8 de Diciembre, se está constituyendo progresivamente la estructura del manejo del proyecto.

Se establecerá el plan final del proyecto tan pronto se tome la decisión sobre el material del cual será confeccionado el espejo. Por el momento se encuentran en competencia dos tecnologías: Zerodur de Schott y sílice fundida de Corning. Se decidirá cuando se reciban las propuestas finales de las dos firmas. En ambos casos se ha fijado el espesor del espejo en 175 mm. Esto parece ser un compromiso aceptable entre el coste y la rigidez. Como alternativa se está desarrollando la tecnología de aluminio y se fabricará un espejo de prueba de 1.8 m. Una pieza de aluminio de 8 m podría construirse en menos de dos años, en caso de que se presentaran (inesperadas) dificultades con los espejos de vidrio.

Se está preparando un prediseño mejor elaborado del edificio (ver dibujo CAD en pág. 5). El presente concepto del esquema está basado en el cobertizo inflable (se está montando un modelo a media escala en Chile). El centro de la cúpula estará ubicado en el nivel de la base del telescopio, y así el espejo primario estará siempre protegido del viento directo. Aperturas en la base del edificio permitirán una ventilación controlada de la superficie del espejo. Se están haciendo pruebas de este concepto en el túnel de viento del Politécnico de Lausanne. *D. Enard*

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.

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

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

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

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

ISSN 0722-6691

Contents