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Portugal and ESO Sign Cooperation Agreement

To some of the experienced diplomats in the attentive audience, the festive ceremony on July 10, 1990, may have been just another of the steps towards European integration, now being taken all over the continent. But for the astronomers from Portugal and ESO, this official act was much more than that; it was a joyous event that marked the beginning of a new, interactive era with high expectations.

On a hot summer's day in Lisbon, the Republic of Portugal and the European Southern Observatory signed a Cooperation Agreement which is aimed at *full membership of Portugal in ESO within the next ten years.*

During this period, the Portuguese Government "will allocate an amount equivalent to a percentage of the annual contribution Portugal would have to pay, if it was already a member of ESO, to the development of research in the field of contemporary Astronomy, so as to permit a future efficient usage of ESO's facilities by Portuguese astronomers". This amount will be spent

At the signing ceremony in Lisbon. From left to right: Professor Teresa Lago (Astrophysical Centre, Porto), Professor Harry van der Laan (ESO Director General), Professor José Pedro Sucena Paiva (Portuguese Secretary of State for Science and Technology), Professor Carlos Salema (President of JNICT), Mr. Fernando Gonçalves (Chief of Cabinet of the Secretary of State).

on a number of infrastructures necessary for the development of Astronomy in Portugal and on technological and scientific training actions related to ESO's activities.

In return, Portuguese astronomers will have access to ESO's facilities during the pre-accession period under scientific conditions similar to those of Member Countries. It is expected that the OPC will soon receive the first proposal(s) from Portugal, and that some joint programmes with astronomers from ESO member countries will be worked out before the end of the year.

A Joint Portuguese/ESO Advisory Body is being set up to monitor the development of Portuguese astronomy and its interaction with ESO.

The Agreement was signed on behalf of the Portuguese Government by His Excellency, Secretary of State for Science and Technology, Prof. Dr. José Pedro Sucena Paiva, and for ESO by its Director General, Prof. Dr. Harry van der Laan. Among the invited guests were high government officials, quite a few Portuguese scientists representing other scientific fields, as well as many media representatives who reported extensively about this event in TV, radio and newspapers.

Joining the Secretary of State and the Director General on the platform were the President of Junta Nacional de Investigação Científica e Technológica (JNICT: National Board for Science and Technological Research), Prof. Dr. Carlos Salema, and Prof. Dr. Teresa Lago, Astrophysical Centre of the University of Porto, both of whom played key roles during the extensive preparations that preceded the conclusion of this Agreement, which was approved by the ESO Council in December 1989.

The ceremony commenced with the showing of a short video film about ESO and its role in European astronomy. Professor Lago then commented on the present situation in Portuguese astronomy. It is in a critical period of growth, for which the association with ESO will be a great support and stimulus. The full text of the speech is reproduced on the next page; see also the summary on page 4.

Following the solemn act of signature, Professor van der Laan expressed his great pleasure in connection with the new association between Portugal and ESO. He expressed his conviction that the ancient astronomical tradition in Portugal, particularly evident at the famous naval institute founded by Henry the Navigator and of such a great importance for the far-reaching expeditions of that time, will continue and be strengthened by the interaction with ESO. He surveyed the ESO facilities and the importance of astronomy, not just as a science in its own right, but also as a driver for new and advanced technology which may be of great use in many other fields as well. He looked forward to the day when a new generation of Portuguese astronomers will be able to make full use of their new opportunities within the European astronomical community and when Portugal will become a Member State of ESO.

In his discourse (English translation hereafter), the Secretary of State emphasized the rapid progress in astronomy, in particular because of modern technology. He stressed the importance attached by his country to the furthering of scientific and technological projects within a European framework. In this connection, significant support is now becoming available, especially after Portugal became a full member of the European Community. In its present quest for development, Portugal can draw inspiration from the Great Maritime Discoveries in earlier centuries.

In the afternoon, the Director General and his small ESO delegation went to Porto to visit the University and its Centre for Astrophysics, which was officially started here last year. Since 1984, when a programme for astronomical studies was first developed in Porto, there has been an increasing interest and a steadily growing number of students in this discipline. Several Master's degrees have been gained abroad and presently, a number of PhDs are well under way. In a few years, the Porto group can be expected to reach the critical mass, needed to introduce more, high-level courses. For the time being, there is a special interest in stellar studies and cosmology. The Astronomy Centre is neighbour to the University's Computing Centre and many of the students have become involved in image processing; MIDAS is being implemented. Some students have already made short visits to the ESO Headquarters.

It is obvious that Portuguese astronomy is in a phase of rapid and well considered expansion. With access to the ESO telescopes, more young astronomers in this country will be drawn towards observational studies and their possibilities for fruitful interaction with astronomers in other places will increase. And in ten years' time, or perhaps even before, the formal adherence of Portugal to ESO will follow naturally, with the full, mutual benefits.

The Editor

Speech by Professor José Pedro Sucena Paiva

It is indeed a great pleasure and privilege for me to sign on behalf of the Portuguese Government the Cooperation Agreement between the Republic of Portugal and the European Organization for Astronomical Research in the Southern Hemisphere – ESO –, a prestigious international organization devoted to scientific research in the field of Astronomy.

I firmly believe that this Agreement, which sets the conditions for Portugal's adhesion to ESO within a ten-year period, will prove to be a decisive milestone for the development of Astronomy and Astrophysics in this country.

During this period Portugal will reinforce its scientific capability in this field, namely through advanced training of human resources, so that the number of Portuguese astronomers becomes, in proportion to the scientific community, comparable to that of the ESO Member States. ESO will provide access to its facilities to Portuguese scientists and graduate students under scientific conditions similar to those of the Member States.

Man has always endeavoured to study the objects outside planet Earth and its immediate environment, including the Moon, Sun, planets, stars, the Galaxy and similar external star systems, interplanetary and interstellar matter, and the Universe as a whole.

Until the 17th century, astronomy was largely concerned with the measurement of the positions and motions of the Sun, Moon, planets, and apparently fixed stars visible to the unaided eye. Then the laws of planetary motion were discovered, the telescope was invented, and the laws underlying motion and gravitation were formulated.

In the 18th century the first ideas based on extensive observations of the structure of the Galaxy that contains the Earth and of the Universe were put forward.

The 19th century brought the introduction of two basic techniques, spectroscopy and photography, which led to new and quantitative methods for measuring the quantity and quality of light and enable physical studies to be made of the brightness, temperatures and chemical nature of the stars and nebulae.

Theoretical analysis of the contribution of the stars advanced enormously in the 20th century through the development of quantum theory and other branches of physics, leading to a new discipline: astrophysics.

Astronomy now flourishes as never before: quasars and pulsars have been discovered and there are hopes that answers to problems such as the origin of the Universe, of chemical elements, of the Earth, and of life itself may be found.

The present development of Astronomy is to a large extent due to the use of modern technology, namely advanced telecommunications, electronic computers, precise timekeeping and rocketry.

This is also the case in other areas of fundamental research, the advance of which in effect many times requires the development of advanced technologies, which can partly justify the heavy investment necessary to provide the adequate facilities.

The risks involved in big science projects are not negligible, as the recent mishap with the Hubble Space Telescope well demonstrates. However, the potential rewards are enormous, since the intrinsic value of knowledge itself is invaluable and priceless.

The sight of our beautiful planet from space has made us fully aware of its smallness and fragility. Technology can in some way be defined as the means through which man manipulates the environment. This definition clearly shows that, despite its tremendous achievements, technology must be used in a way compatible with the survival of Earth for the benefit of ourselves and the future generations. No generation has a freehold on this planet, all we have is a life tenancy, with a full repairing lease.

Science and Technology are now being seriously considered in this country at the political level. After many years of relative neglect, our scientific community is now the object of considerable attention and care. Conditions for scientific research and technological development have considerably improved in recent years, especially since Portugal's integration in the European Community in 1986.

At the turning point that Portugal is now, Science and Technology are key ingredients for our development and full participation in the construction of Europe.

International contacts are being strengthened rapidly and our scientists and engineers are involved in a sizable number of multinational R & D projects, namely in the context of the European Community Framework Programme.

The scientific communities of the different countries are certainly among the most internationalized bodies of the society, for obvious reasons. Science has always cut across barriers and frontiers and international contacts are instrumental for its development. Internationalization and mobility of scientists is therefore a cornerstone of our scientific policy.

The Portuguese Scientific Community is still relatively small – about 5000 full-time equivalent scientists – but young, competent and dynamic. This number has to be rapidly increased, both by new entry-level recruits and also by attracting senior foreign scientists.

At this stage, our infrastructures – buildings, equipment and support personnel – are still insufficient, limiting many times the efforts of our scientists and making their life somewhat difficult. But there are some good prospects on the horizon to overcome this solution.

In the framework of the Structural Funds Reform of the EC, Portugal has submitted a Programme – emblematically named the Science Programme – designed to create new scientific infrastructures, reinforce existing ones and train new scientists. The programme, which was extremely well received by the EC Commission and approved with minor alterations, is now in the first stage of execution.

The articulation of this Programme with the new EC Framework Programme 1990/94 will certainly provide the stage for a rapid development of Portuguese Science and Technology. It is up to the scientific community to seize the opportunities available to them. The government should only create the right environment and of course adequate conditions and then step aside and in due time evaluate the results.

The private sector should be called upon to participate more actively in the R & D activities. We understand that for a small or medium enterprise, R & D is a very expensive activity. That is why University-Industry partnerships should be strongly encouraged and it pleases me to say that some encouraging examples have already flourished in this country.

In its present quest for development, Portugal can draw inspiration to the Great Maritime Discoveries of the 15th and 16th centuries, which were possible by the conjugation of four factors: (1) political will; (2) rigorous and methodic scientific knowledge; (3) enterprising spirit and the capacity of taking risks; (4) mastery of the technological systems of that time, navigation and weaponry.

The challenges which confront us nowadays require the same ingredients for an adequate response.

Speech by Professor Teresa Lago

I believe today is indeed an important mark in the development of Astronomy in Portugal. In the present times of awareness for Science and Technology, today's events are of indisputable importance for the future of Astronomy, both in research and education.

They come in the sequence of an initiative taken by JNICT in 1987, and the subsequent proposal for a nationwide programme for the development of Astronomy/Astropysics. JNICT's initiative was then very important for Astronomy, always forgotten or merely tolerated both by research planners and university authorities. Astronomy was, for the very first time, considered as one of the areas that should be developed.

Of equal importance was the simultaneous survey of the situation at the Portuguese Observatories – the first done in modern times – including a full enquiry on the facilities, personnel, activity (teaching and research), programmes and projects being carried out at the three University Observatories (Porto, Coimbra and Lisboa) and at the National Observatory (Lisboa). The conclusions of this survey gave a realistic image of the situation at the, until then, unique State- or University-financed Institutions for astronomical activity. Although this is neither the place nor the time to comment on those results, they should, even today, be given serious and urgent attention. Qualified human resources are the crucial component, otherwise all efforts are condemned to failure.

The situation of Astronomy in Portugal remains very worrysome: instead of the "European average" of 10 to 20 astronomers/1,000,000 inhabitants, we are still short by a factor of 10! And the lack of long tradition of research work in the field has made recovery more difficult.

The situation has substantially improved over the last two years. Some investment has been made. However, any programme for the development in Astronomy must necessarily include simultaneous components, risking to compromise the objectives aimed at, would any of them be neglected. These components are

(i) the education of a new generation of astronomers, both at University level and at doctoral level. At the doctoral level this should preferably take place abroad or through international collaborative projects, until a "critical mass" is achieved; this implies a steady number of grants for some period of time,

(ii) the support of a small number of infrastructures, providing the necessary facilities for research and education, and the support to those fields where competitive work is already being done, in order to avoid dispersion of the available resources,

(iii) the establishment of a small number of temporary positions, both at the technical support level and post-doctoral level (national and/or foreign) so that research teams can be provided with acceptable working conditions; at a more advanced phase an adequate number of permanent research positions for Astronomy should also be considered,

(iv) finally the access to adequate observing facilities for Portuguese astronomers and postgraduate students.

The signature of this agreement with ESO is an event of great importance for the development of the astronomical research in Portugal. Not only does it fulfil some of our needs – the access to adequate observing facilities – but it also allows the collaboration and, at some level, participation with ESO at an exciting time – the time in which a very large telescope of a new generation and the important related instrumentation are being developed at ESO.

I believe this agreement constitutes the undeniable proof that the decision makers in Science and Technology in Portugal finally give to Astronomy the credit it fully deserves and receives in other countries in Europe. I take this ceremony as a real commitment for a continuous and serious effort to develop Astronomy in Portugal. A commitment to provide conditions that allow the Portuguese astronomy to grow to levels comparable to the European ones over a period of time of 5 to 10 years.

I want to thank the Secretary of State for Science and Technology for his decisive support and involvement at the crucial stages of the negotiations with ESO. And to express to the ESO Director General my gratitude for his comprehension and understanding, that has been so important for the conclusion of such an advantageous agreement for us. I feel that Prof. van der Laan's attitude during the whole process was closer to the fellow astronomer and well beyond the negotiator's job.

Of course, years of low profile take time and an enormous effort to be replaced. Mentalities probably take even longer to change. But as an astronomer I must say this is a time of optimism and strong hopes for a brighter future.

A Short Summary of Astronomy at "Centro de Astrofísica da Universidade do Porto"

M. T. LAGO, Astrophysical Centre, University of Porto, Portugal

In 1988 JNICT (the national research council) took the decision to finance the first research centre in Astrophysics in Portugal, the "Centro de Astrofísica" at the University of Porto.

Although in activity since 1988 the Centro was officially created in May 1989 as a financially autonomous association within the University and is housed since October 1989 at the new building of the University Computer Centre.

As personnel it involves

- 2 University staff (Ph.D. in Astronomy, 1979, 1982),
- 8 Ph.D. Students (1 M.Sc. in Applied Statistics, 1988; 2 M.Sc. in Astronomy, 1989, 1990; 1 M.Sc. in Astronomical Technology, 1989; 3 D.E.A. in "Astrophysique et Techniques Spatiales", 1989, 1990; 1 "Licenciado" in Surveying Engineering, Univ. Porto, 1984) and
- 2 temporary staff (1 "Licenciado" in Physics/Applied Mathematics [Astronomy, University of Porto, 1989] in charge of the computer management and assistance to users, general administrative activities and part-time research, and 1 secretary/librarian).

It also involves several undergraduate students of Astronomy (terminal year).

Because of the particular situation of Astronomy in Portugal, we believe that any programme aimed at the development of Astronomy must necessarily include five simultaneous components. There would be a risk of compromising the objectives if any of them would be neglected; the "Centro de Astrofísica" therefore includes all of these components in its objectives:

1. The education of a new generation of astronomers – the shortage of adequately trained and active prospective supervisors in Astronomy in Portugal implies that, at this initial stage, the majority of the doctorates must be prepared abroad, and those to be prepared at home also need to benefit from a close and continuous collaboration with scientists from well-known foreign institutions; therefore the Centro has been trying to guarantee a continuous and equilibrated scheme of grants as well as the necessary contacts.

At the same time, the Centro provides conditions for its visitors to collaborate in the undergraduate teaching and to involve the terminal year students in its projects. Therefore the Centro's support for education comes,

– *at university level:* through support to the only undergraduate degree in the country aimed at the education of the new astronomers, at the School of Sciences of the University of Porto; this interdisciplinary degree was set up in 1984 and is jointly offered by the Physics and Applied Mathematics Departments. It has a four-year plan of studies, a *numerus clausus* of 15 students per year and is structured in course units of which 37% are in Physics, 32% in Mathematics, 25% in Astronomy and 6% either in Chemistry, Geology, Mathematics or Physics. The initial three years providing basic training in Mathematics and Physics, except for an introductory course (first year) intended as an overview of modern Astronomy and aiming at keeping alive the student's enthusiasm. The 3rd year offers a general Astronomy course and finally the 4th year includes 5 options from an annual list of various topics in Astronomy, naturally strongly dependent on the availability of lecturers (local and visiting). An example of such a list includes Astrometry, Cosmology, Extragalactic Astronomy, Formation and Evolution of Stars and Stellar Structure. Some of these courses are fully delivered (or include units of 10 to 15 hours) by visiting professors or researchers; this has proven to be very stimulating, exposing the students to different people and also helping to compensate for the lack of "people around", considering that the number of astronomers in Portugal is presently so reduced – well below the European average of 1 to 2 astronomers per 100,000 inhabitants;

– *at a younger level:* taking Astronomy to the Schools through a programme involving the Centro, the Regional Education Authority and the Government Local Authority; this includes sessions with a portable planetarium „Starlab" donated to the Centro by the Government Local Authority (the planetarium sessions are prepared for age groups 5–7, 8–10 and 10–12), talks on various topics of Astronomy and the preparation of slide sets with explicative texts to be lent to teachers at various levels.

The Centro has also been involved in the planning of the Master's degrees for students connected with it; several students from the Centro have successfully completed their degrees at various Astronomy departments with the following thesis:

– "The Solar-Stellar Connection", University of Sussex (1989),

– "Evolution des Etoiles Bleues et Lumineuses aux Environs de la Limite de Humphreys-Davidson", Universités Paris VII et Paris XI (1989),

– "IRIS – A Project on Infrared Image Sharpening", University of Edinburgh (1989),

– "La Fonction de Luminosité des Nébuleuses Planétaires", Universités Paris VII et Paris XI (1990),

– "L'^{3}He dans le Soleil, Étude Analytique de la Diffusion Microscopique", Universités Paris VII et Paris XI (1990),

– one thesis to be completed soon, Queen Mary and Westfield College – University of London (1990).

The University of Porto is also the national node for the European Astrophysics Doctoral Network, a consortium which today federates 21 European Universities all having a graduate programme in Astrophysics, ESA and ESO. This Network has continuously benefited from national, European Community (ERASMUS) and European Science Foundation support.

2. The Centro is the institutional structure providing support for the development of research projects, adequate postgraduate education, undergraduate education, the promotion of Astronomy (through the organization of conferences, courses, etc.) and the stimulation of science popularization.

The ongoing research projects at the Centro are in the following areas:

(a) – "Classification of Observed Astrophysical Structures"

(b) – "Cosmology – Jordan-Thiry theories and models of galactic formation",

(c) – "Stellar Astrophysics".

These areas have been selected because they were already active research areas at the University of Porto and all have research projects where Ph.D. work is carried on, namely:

(a) – "Classification of Observed Astrophysical Structures" – the quantitative analysis and application of statistical methods to the study of large structure and their origins, a collaborative project with people at ESO and the ST-ECF involving one Ph.D. student,

(b) – "Cosmology" – the study of dark matter in the Universe, involving one Ph.D. student at the Centro,

(c) – "Stellar Astrophysics"

– the modelling of winds in young stars, a collaborative project with people at the University of Sussex involving one Ph.D. student at the Centro (1990),

– the study of the evolution of pre-main-sequence stars, a collaborative project with people from the Astrofysisch Instituut, Vrije Universiteit Brussel, involving one Ph.D. student (1989),

– the study of MHD outflows from astrophysical objects, a collaborative project with people from the Department of Mathematical and Computational Sciences, University of St. Andrews (1989),

– the study of the interaction between young stars and molecular clouds, involving one Ph.D. student from the Centro at the Department of Astronomy of the University of Edinburgh (1989),

– two other Ph.D. students are expected to start in October Ph.D. projects within Stellar Astrophysics.

We are also working in order to try to guarantee that at a more advanced stage temporary post-doctoral positions (2- to 3-year contracts) are available not only at the Centro but also at other national Institutions. Furthermore, we are also trying to draw attention to the fact that if all this effort is to be fully explored it should involve a real commitment by the universities and national research authorities towards the opening of permanent positions in Astronomy at the various Institutions.

3. The Centro provides the local infrastructure to support research, through

3.1 – library facilities (a collection of back numbers of the most relevant journals was generously offered by some Institutions such as ESA, ESO, Utrecht Laboratory for Space Research, Observatoire de Meudon, Royal Greenwich Observatory and astronomers working there),

3.2 – computer facilities for data analysis, access to networks, data banks, data bases and larger computers existing in the country, as well as adequate software; the Centro is equipped with a μ Vax 3400, 700 MB in disk TK 70 and accessories such as graphic terminals, printer, Image Display device and adequate software is also available (Starlink, Nag, Matlab and MIDAS being installed); some Mackintosh are also available.

4. Observing facilities – the availability of observing facilities, either national or on a collaborative basis with international observatories, for the Portuguese astronomers and post-graduate students is vital; besides the existence of potentially very good sites on the national territory, such as Madeira, and the possibility of building a national observatory being very attractive and not to be excluded in the long run, the alternative of the participation in existing international facilities seemed to be more advantageous. People from the Centro were deeply involved in all the negotiations process that successfully ended in the present agreement with ESO.

5. Promotion of the popularization of Astronomy – the Centro has had various initiatives during the current year, namely through activities such as

– the local organization of the ESO exhibition in Porto (October 1990) including organized visits for students in the terminal years of Secondary Schools,

– the organization of a series of public conferences on several topics of Astronomy simultaneously with the ESO exhibition,

– various popular-level talks on Astronomy.

Most of these activities also involve the Astronomy students.

New ESO Scientific Preprints

(June–August 1990)

705. E. Gosset et al.: A Search for Quasars in a Field Around NGC 520. *M.N.R.A.S.*
706. P. Magain and G. Zhao: Empirical Study of Departures from the Excitation

Equilibrium of FeI in Metal-Poor Stars. *Astrophysical Journal.*

707. D. Hutsemékers and J. Surdej: Formation of P Cygni Line Profiles in Relativistically Expanding Atmospheres. *Astrophysical Journal.*

708. T. Baribaud and D. Alloin: On the Use of [OIII] Narrow Line Emission for Scaling Spectrophotometric Data in Active Galactic Nuclei. *Astronomy and Astrophysics.*

709. A.M. Lagrange-Henri et al.: Search for Beta Pictoris-Like Stars. *Astronomy and Astrophysics, Suppl.*

710. L.B. Lucy, I.J. Danziger and C. Gouiffes: Excitation by Line Coincidence in the Spectrum of SN 1987A. *Astronomy and Astrophysics.*

711. J.S. Chen, X.-W. Liu and M.-Z. Wei: CCD Photometry of Unclassified Cataclysmic Variable SS UMi (PG 1551+719). *Astronomy and Astrophysics.*

712. D. Baade, W. Schmutz and M. van Kerkwijk: Short-Term Activity in the γ^2 Velorum System: The O-Type Supergiant is a Nonradially Pulsating Star. *Astronomy and Astrophysics.*

713. A.F.M. Moorwood and E. Oliva: H_2 Emission in Galaxies: Observational Constraints on Ultraviolet Excitation. *Astronomy and Astrophysics.*
A.F.M. Moorwood and L. Origlia: IR Images of the Circinus Galaxy and NGC 4945. To appear in Proceedings of the NOAO/KPNO Conference on Astrophysics with Infrared Arrays.

714. E. Oliva, A.F.M. Moorwood and I.J. Danziger: Infrared Spectroscopy of Supernova Remnants. II. A Detailed Study of RCW 103. *Astronomy and Astrophysics.*

715. Proceedings of the ESO-CERN Topical Workshop on "LEP and the Universe". April 5 and 6, 1990. CERN, Geneva, Switzerland. Organized by J. Ellis, P. Salati and P. Shaver.

716. D. Hutsemékers and E. van Drom: The Supergiant Bep Star CD −42°11721 and Its Surrounding Nebula. *Astronomy and Astrophysics.*

717. WW. Zeilinger et al.: NGC 5084: A Massive Disc Galaxy with a Tilted Ring. *M.N.R.A.S.*

718. G. Zhao and P. Magain: The Chemical Composition of the Extreme Halo Stars. III. Equivalent Widths of 20 Dwarfs. *Astronomy and Astrophysics Suppl.*

719. A.F.M. Moorwood: Infrared Capabilities of Very Large Groundbased Telescopes. Invited paper presented at the COSPAR XXVIII Symposium "The Infrared and Submillimeter Universe at High Redshifts". To be published in Advances in Space Research (Pergamon, Oxford).

720. P. Crane et al.: The Interstellar $^{12}C/^{13}C$ Ratio Toward μ Normae. *Astrophysical Journal.*

721. M. Mariani and S.A. Bonometto: Thermal Evolution of Phases During the Cosmological Quark-Hadron Transition. *Astrophysical Journal.*

722. A. Sandage and G.A. Tammann: Steps Toward the Hubble Constant IX: The Cosmic Value of H_0 Freed from All Local Velocity Anomalies. *Astrophysical Journal.*

723. P.A. Shaver: Active Galactic Nuclei in Cosmology (A review of literature published from July 1987 to June 1990, for 1991 IAU Transactions XXIA, Commission 47).

724. P. Molaro and P. Bonifacio: Chemical Abundances of Two New Extreme Metal Poor Giants. *Astronomy and Astrophysics, Letters.*

ESO FELLOWSHIPS 1991–1992

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

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

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

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

Fellowships are to be taken up between January and October 1991.

Most of the scientists in the Centre come from the member States of ESO, but several are from other countries. The Member States of ESO are: Belgium, Denmark, the Federal Republic of Germany, France, Italy, the Netherlands, Sweden, and Switzerland. In addition to regular staff members, the Centre comprises visiting scientists, post-doctoral fellows, and graduate students.

ESO facilities include the La Silla Observatory in Chile with its eight telescopes in the range 0.9 to 3.6 m, as well as a 1-m Schmidt, the 15-m SEST and smaller instruments. In Garching, extensive measuring, image processing and computing facilities are available.

Applicants normally should have a doctorate awarded in recent years. The fellowships are granted for one year, with normally a renewal for a second year and occasionally a third year. Applications should be submitted to ESO not later than October 15, 1990. Applicants will be notified in December 1990. The ESO Fellowship Application form should be used. Three letters of recommendation from persons familiar with the scientific work of the applicant should be sent to ESO directly. These letters should reach ESO not later than October 15, 1990.

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

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

Visiting Astronomers

(October 1, 1990–April 1, 1991)

Observing time has now been allocated for Period 46 (October 1, 1990–April 1, 1991). As usual, the demand for telescope time was much greater than the time actually available.

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

3.6-m Telescope

Oct. 1990: Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Gratton/Sneden, Moehler/de Boer, Mazure et al. – 1-014-43K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Turatto et al. – 4-004-45K, de Lapparent et al. – 1-003-43K, Shaver, Macchetto/Turnshek, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Turatto et al. – 4-004-45K.

Nov. 1990: Mariotti/Cuby/Lacombe/Léna/Merkle/Perrier/Rigaut, Gallais/Alloin/Rouan/Lançon/Léna/Rigaut/Merkle, Combes M./Léna/Rigaut/Merkle/Cuby/Tomasko/Saint-Pé, Ögelman/Gouiffes/Melnick/Augusteijn/Hasinger/Pietsch/Pedersen, Ögelman/Gouiffes, Danziger/Bouchet/Lucy/Fransson/

Mazzali/Della Valle/Gouiffes, Guzzo/Collins/Nichol/Lumsden, Warren, Chambers, Marano/Mignoli/Zamorani/Zitelli, Danziger et al. – 6-003-45K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Simon/Husfeld/Kudritzki/Voels, Kudritzki/Voels/Husfeld/Gabler/Pauldrach/Puls, de Boer et al. (Spite F.) – 3-003-43K.

Dec. 1990: de Boer et al. (Spite F.) – 3-003-43K, de Boer et al. (Molaro) – 3-003-43K, Reimers et al. – 2-009-45K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Soucail/Mathez/Mellier/Le Borgne, Giraud/Infante, Turatto et al. – 4-004-45K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Meylan/Dubath/Mayor, Dubath/Melnick/Mayor, de Boer et al. (Wolf) – 3-003-43K.

Jan. 1991: Dougados/Rouan/Léna/Merkle/Rigaut, Malbet/Bertout/Léna/Rigaut/Merkle/Cuby, Léna/Dougados/Merkle/Monin/Perrier/Rigaut/Ridgway, Ögelman/Gouiffes/Melnick/Augusteijn/Hasinger/Pietsch/Pedersen, Ögelman/Gouiffes, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, de Boer et al. (Azzopardi) – 3-003-43K, Beuermann/Trümper/Thomas/Reinsch/Simon, Wampler et al. – 2-010-45K, Schmutz/Nussbaumer/Vogel, Hensberge et al. – 5-005-45K, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund.

Feb. 1991: Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Turatto et al. – 4-004-45K, Reimers/Koester/Chanmugam, Danziger et al. – 6-003-45K, Turatto et al. – 4-004-45K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Turatto et al. – 4-004-45K.

March 1991: Zamorani/Vettolani/Zucca/Scaramella/Chincarini/Burg, Bertola et al. – 1-008-43K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Danziger et al. – 6-003-45K, Böhringer/Seitter/Schuecker/Horstmann/Cruddace/Kowalski/Wallin/Pierre/Voges/MacGillivray/Collins, Ögelman/Gouiffes/Melnick/Augusteijn/Hasinger/Pietsch/Pedersen, Ögelman/Gouiffes, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Perrier/Mariotti/Mayor/Duquennoy.

3.5-m NTT

Nov. 1990: Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Arp/Danziger/Giraud, Fusi Pecci/Ferraro/Brocato/Cacciari/Clementini/Buonanno/Zinn, Surdej et al. – 2-003-43K, Ellis/Fosbury/Hook/Colless/Broadhurst, Tarenghi/D'Odorico/Wampler/Peterson/Yoshii/Silk.

Dec. 1990: Butcher/van Rossum, Brocato/Castellani/Ferraro, Giraud, de Boer et al. (Dennefeld) – 3-003-43K, Paresce/Clampin/Moneti/Golimowski/Nota, Lagrange-Henri/Maillard/Vidal-Madjar/Ferlet/Beust.

Jan. 1991: Lagrange-Henri/Maillard/Vidal-Madjar/Ferlet/Beust, Boisson/Joly/Moorwood/Oliva/Ward, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Gilmozzi/Blades/Madau, Bignami et al. – 6-002-45K, Fort et al. – 1-015-45K, Reipurth.

Feb. 1991: Poetzel/Ray/Mundt, Della Valle/Capaccioli/Piotto/Wagner, Macchetto/di Serego Alighieri/Trinchieri/Sparks, Falomo/Tanzi/Tarenghi, Bender et al. – 1-004-45K, Origlia/Brocato/Oliva.

March 1991: Hainaut/Jarvis, Krautter/Starrfield, Tarenghi/D'Odorico/Wampler/Peterson/Yoshii/Silk, Bergeron et al. – 1-012-43K, Surdej et al. – 2-003-43K, Miley et al. – 2-001-43K, Danziger/Bouchet/Lucy/Fransson/Mazzali/Della Valle/Gouiffes, Danziger/Moorwood/Oliva, Moorwood/Oliva.

2.2-m Telescope

Oct. 1990: Goudfrooij/de Jong T./Joergensen H.E./Norgaard-Nielsen/Hansen, Barbieri et al. – 2-007-43K, Zeilinger/Buson/Galletta/Saglia, Turatto et al. – 4-004-45K, Zeilinger/Buson/Galletta/Saglia, Barbieri et al. – 2-007-43K, Miley et al. – 2-001-43K, Test – Moorwood.

Nov. 1990: Test-Moorwood, van der Kruit/de Jong R.S., Mirabel/Lagage/Cesarsky, de Boer et al. (Koornneef) – 3-003-43K, Dettmar/Becker, Surdej et al. – 2-003-43K, Bergvall/Rönnback/Johansson, Seggewiss/Feinstein/Vazquez, Christensen/Sommer-Larsen/Hawkins/Flynn, Westerlund/Azzoppardi/Rebeirot/Breysacher, Turatto et al. – 4-004-45K.

Dec. 1990: Chiosi/Ortolani/Bertelli/Bressan/Vallenari, Bhatia/Chiosi/Piotto/Prugniel/MacGillivray, Chiosi/Ortolani/Bertelli/Bressan/Vallenari, de Boer et al. (Seggewiss) – 3-003-43K, Dennefeld/Boulanger/Fruscione/Moshir, Polcaro/Giovannelli/Manchanda/Norci/Pollock/Rossi/Viotti, Westerlund/Azzopardi/Rebeirot/Breysacher, de Boer et al. (Wolf) – 3-003-43K, MPI time.

Jan. 1991: MPI Time, Test-Moorwood.

Feb. 1991: Danziger/Liu/Dalgarno, Bender et al. – 1-004-43K, Sabbadin/Cappellaro/Turatto/Salvadori, Melnick/Böhringer/Giraud/Voges/Peters/Zimmermann, Piotto/Capaccioli/Ortolani, Blommaert/Habing/v.d. Veen, Groenewegen/de Jong T./Hu.

March 1991: Krautter/Ögelman/Starrfield/Williams, Tapia/Schwarz/Roth/Ruiz, van Haarlem/Katgert, Surdej et al. – 2-003-43K, Miley et al. – 2-001-43K, Danziger et al. – 6-003-45K, Turatto et al. – 4-004-45K, Danziger/Moorwood/Oliva, Schwarz/Moneti.

1.5-m Spectrographic Telescope

Oct. 1990: Pallavicini/Tagliaferri/Gahm/Pasquini, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Kjaergaard Rasmussen/Joergensen I., Barbieri et al. – 2-007-43K, Dettmar/Koribalski/Krenz/Barteldrees, Proust/Mazure/Capelato/Sodre, Renzini/Greggio/Bragaglia.

Nov. 1990: Gehren/Axer/Fuhrmann/Steenbock/Reile, Paturel et al. – 1-017-45K, Danziger et al. – 6-003-45K, Jasniewicz/Thévenin, Reimers et al. – 2-009-45K.

Dec. 1990: Bues/Pragal, Lub/de Ruiter, de Ruiter/Gregorini/Parma/Vettolani, Calvani/Marziani/Acosta, Courvoisier/Bouchet/Blecha, Gerbaldi et al. – 5-004-43K.

Jan. 1991: Gerbaldi et al. – 5-004-43K, Sauvageot/Rothenflug/Dubreuil/Ballet, Pakull/Motch/Bianchi, Walsh/Walton/Pottasch S.R., Kohoutek, Hensberge et al. – 5-005-45K.

Feb. 1991: Lodén L.O./Sundman, Gahm/Lodén K., Falomo/Maraschi/Tanzi/Treves, van Genderen/van der Hucht/Schwarz, Bianchini/Della Valle/Ögelman/Orio/Bianchi.

March 1991: Gerbaldi et al. – 5-004-43K, Thé/de Winter/Bibo/Hu, Thé/de Winter/Hu, Danziger et al. – 6-003-45K, Durret/Petitjean, Rifatto/Buson/Zeilinger, Rafanelli/Padrielli/Gregorini/Marziani, Courvoisier/Bouchet/Blecha.

1.4-m CAT

Oct. 1990: Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Lagrange-Henri/Jaschek M./Jaschek C., Reimers/Toussaint/Hansen, Pasquini/Saar/Restaino, Gehren/Axer/Butler/Fuhrmann/Steenbock/Reile.

Nov. 1990: Gehren/Axer/Butler/Fuhrmann/Steenbock/Reile, Pols/Waters/Verbunt/van Paradijs/Coté/v. Kerkwijk/van den Heuvel, da Silva/de la Reza, Vladilo/Centurion/Molaro/Monai, Maceroni/van't Veer/Vilhu, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Clausen, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter.

Dec. 1990: Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Fibre link – 3.6-m telescope, Lagrange-Henri/Beust/Vidal-Madjar/Ferlet, Benvenuti/Porceddu/Krelowski, Cayrel de Strobel, Pols/Waters/Verbunt/van Paradijs/Coté/van Kerkwijk/van den Heuvel.

Jan. 1991: Pols/Waters/Verbunt/van Paradijs/Coté/van Kerkwijk/van den Heuvel, Kürster/Schmitt, Reimers/Toussaint/Hansen, Nissen/Edvardsson, Boffin/Arnould/Abia/Isern/Forestini/Canal/Rebolo.

Feb. 1991: North, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, North, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Grenon/Barbuy, Barbuy/Maeder/Medeiros, Sembach/Danks/Crane/Savage, Reimers/Toussaint/Hansen.

March 1991: Reimers/Toussaint/Hansen, Hu, Lanz/Mathys/Gerbaldi/Faraggiana, Lanz/Mathys/Megessier/Landstreet, Waelkens/van Winckel/Lamers/Trams, Boffin/Jorissen/Groenewegen.

1-m Photometric Telescope

Oct. 1990: Tagliaferri/Cutispoto/Giommi/Pallavicini/Pasquini, Fulchignoni/Barucci/De Angelis/Burchi/Dotto/Ferrari/Foryta/Roques, Cacciari/Clementini/Fernley, Pols/Waters/Verbunt/van Paradijs/Coté/v. Kerkwijk/van den Heuvel.

Nov. 1990: Pols/Waters/Verkunt/van Paradijs/Coté/v. Kerkwijk/van den Heuvel, Prugniel/Rampazzo/Combes F., Di Martino/Mottola/Gonano/Neukum, Gieren/Moffett/Barnes, Bouvier/Martin E./Malbet/Menard/Fernandez/Matthews/Terranegra/Alcala.

Dec. 1990: Bouvier/Martin E./Malbet/Menard/Fernandez/Matthews/Terranegra/Alcala, Liller/Alcaíno/Alvarado/Wenderoth, Vidal-Madjar/Lagrange-Henri/Beust/Ferlet/Foing/Char, Giard/Bernard/Dennefeld/Sales, Le Bertre et al. – 5-006-45K, Arlot/Descamps/Thuillot/Colas/Vu, Le Bertre et al. – 5-006-45K.

Jan. 1991: Le Bertre et al. – 5-006-45K, Courvoisier/Bouchet/Blecha, Pols/Waters/Verbunt/van Paradijs/Coté/van Kerkwijk/van den Heuvel, Sterken/Longo/Busarello, Arlot/Descamps/Thuillot/Colas/Vu, Le Bertre et al. – 5-006-45K, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Le Bertre et al. – 5-006-45K.

Feb. 1991: Le Bertre et al. – 5-006-45K, Courvoisier/Bouchet/Blecha, Hoffmann/Geyer, Groenewegen/de Jong T./Hu, Arlot/Descamps/Thuillot/Colas/Vu, Lorenzetti/Molinari, Courvoisier/Bouchet/Blecha, Thé/de Winter/Hu.

March 1991: Thé/de Winter/Hu, Robberto/Busso/Guarnieri/Scaltriti/Silvestro/Persi, Manfroid/Vreux, Arlot/Descamps/Thuillot/Colas/Vu, Catalano F.A./Leone/Kroll, Courvoisier/Bouchet/Blecha.

50-cm ESO Photometric Telescope

Oct. 1990: Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Surdej/Detal/Hainaut/Pospieszalska-Surdej, Catalano F.A./Schneider H./Leone.

Nov. 1990: Catalano F.A./Schneider H./Leone, Schober, Maceroni/van't Veer/Vilhu, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Arlot/Thuillot/Descamps/Vu/Colas, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter.

Dec. 1990: Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Gochermann/Grothues, Mantegazza/Antonello/Poretti, Arlot/Thuillot/Descamps/Vu/Colas, Mantegazza/Antonello/Poretti.

Jan. 1991: Mantegazza/Antonello/Poretti, Kohoutek, Arlot/Thuillot/Descamps/Vu/Colas, Kohoutek, Arlot/Thuillot/Descamps/Vu/Colas, Kohoutek, Schmutz/Nussbaumer/Vogel, Arlot/Thuillot/Descamps/Vu/Colas, Schmutz/Nussbaumer/Vogel, Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund.

Feb. 1991: Foing/Collier-Cameron/Vilhu/Gustafsson/Ehrenfreund, Char/Jankov/Foing/Neff/Fernandez/Rodono/Crivellari/Walter, Debehogne/Di Martino/Zappalà/Lagerkvist/Hahn/Magnusson/de Campos/Cuypers/Cutispoto, Arlot/Thuillot/Descamps/Vu/Colas, Debehogne/Di Martino/Zappalà/Lagerkvist/Hahn/Magnusson/de Campos/Cuypers/Cutispoto, Arlot/Thuillot/Descamps/Vu/Colas, Debehogne/Di Martino/Zappalà/Lagerkvist/Hahn/Magnusson/de Campos/Cuypers/Cutispoto.

March 1991: Thé/de Winter/Bibo/Hu, Arlot/Thuillot/Descamps/Vu/Colas, Thé/de Winter/Bibo/Hu, Cutispoto/Giampapa/Pasquini/Leto/Pagano, Arlot/Thuillot/Descamps/Vu/Colas, Cutispoto/Giampapa/Pasquini/Leto/Pagano, Peres/Cutispoto/Reale/Serio/Leto/Pagano.

GPO 40-cm Astrograph

Nov. 1990: Elst/Hoffmann/Shkodrov.

Dec. 1990: Vidal-Madjar.

Feb. 1991: Munari/Lattanzi/Massone, Massone.

March 1991: Debehogne/Machado/Caldeira/Vieira/Netto/Zappalà/de Sanctis/Lagerkvist/Mourao/Protitch-Benishek/Javanshir/Wosczcyk.

1.5-m Danish Telescope

Oct. 1990: Ardeberg/Lundström/Lindgren, Caon/Capaccioli, Danziger/Bouchet/Gouiffes/Lucy/Fransson/Mazzali/Della Valle, Capaccioli/Bresolin/Ortolani/Piotto, Mazure et al. – 1-014-43K, Athanassoula/Bosma/Buta/Crocker, Saust, Andersen/Nordström/Mayor/Olsen.

Nov. 1990: Danish time, Mayor et al. – 5-001-43K.

Dec. 1990: Mayor et al. – 5-001-43K, Lortet/Lindgren/Martin N., Vio/Cristiani/Della Valle/La Franca, Danziger/Bouchet/Gouiffes/Lucy/Fransson/Mazzali/Della Valle, Surdej et al. – 2-003-43K, Quintana/Ramirez, Vidal-Madjar, Prugniel/Bhatia/McGillivray/Piotto, Danziger/Bouchet/Gouiffes/Lucy/Fransson/Mazzali/Della Valle, Danish time.

Jan. 1991: Danish time, Mayor et al. – 5-001-43K.

Feb. 1991: Mayor et al. – 5-001-43K, Gahm/Lodén K., West, Bender et al. – 1-004-43K, Caon/Capaccioli/Ferrario, Groenewegen/de Jong T./Hu, Danziger/Bouchet/Gouiffes/Lucy/Fransson/Mazzali/Della Valle, Waelkens/Mayor, Mermilliod/Mayor.

March 1991: Mermilliod/Mayor, Danish Time, Ardeberg/Lundström/Lindgren.

50-cm Danish Telescope

Oct. 1990: Group for Long Term Photometry of Variables, Ardeberg/Lundström/Lindgren, Group for Long Term Photometry of Variables.

Nov. 1990: Group for Long Term Photometry of Variables, Danish time, Einicke/Fabricius/Helmer, Group for Long Term Photometry of Variables.

Dec. 1990: Group for Long Term Photometry of Variables.

Jan. 1991: Group for Long Term Photometry of Variables, Danish time, Group for Long Term Photometry of Variables.

Feb. 1991: Group for Long Term Photometry of Variables, Olsen, Maitzen/Leone/Catalano F.A./Jenkner.

March 1991: Franco, Ardeberg/Lundström/Lindgren, Catalano F.A./Leone/Kroll.

90-cm Dutch Telescope

Oct. 1990: van Genderen.

Nov. 1990: van Genderen, Dutch time.

Dec. 1990: Dutch time, van Genderen, Lub/de Ruiter.

Jan. 1991: Dutch time.

Feb. 1991: Ferrari/Bucciarelli/Massone/Koornneef/Lasker/Postman/Siciliano/Lattanzi, van Genderen/van der Hucht/Schwarz.

March 1991: Dutch time.

SEST

Nov. 1990: Chini, Casoli, Bresolin, Combes, Becker, Kazes, Dettmar.

Jan. 1991: Wielebinski, Loiseau, Oosterloo, Huchtmeier, Dennefeld, Wild/Eckart, van der Hulst, Israel, Rothermel, de Graauw, Israel.

March 1991: Tacconi, Beckman, Cameron, Gérin, Wild, Cox, Lequeux, Cox, Stark, Henkel, Arnal, Groenewegen, Hu, Foing.

During 2nd ESO/OHP Summer School in Astrophysical Observations:

Observatoire de Haute-Provence Becomes a European Northern Observatory

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D. BAADE, ESO

There is a strong trend towards an ever tighter correlation between the quality of the equipment of an astronomical observatory and the remoteness of its site. There are good reasons for this. But it has the negative side effect that students find it more and more difficult to get adequate training in the usage of up-to-date instruments and the handling of the data they provide. This simple recognition led the European Southern Observatory and the Ob-

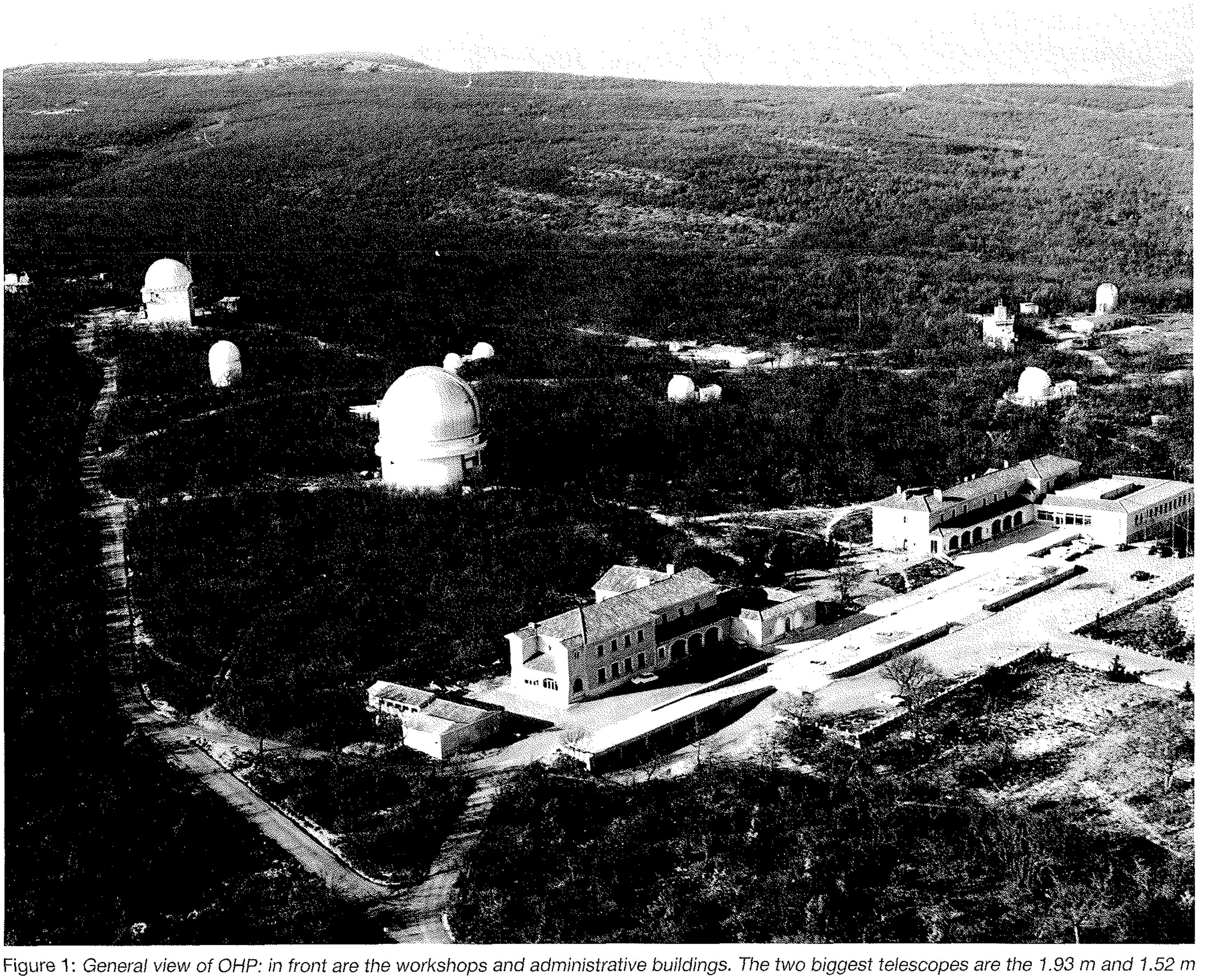

Figure 1: *General view of OHP: in front are the workshops and administrative buildings. The two biggest telescopes are the 1.93 m and 1.52 m telescope.*

servatoire de Haute-Provence (OHP) to organize a first joint Summer School in Astrophysical Observations which was held in July 1988 at OHP (see the report by A. Chalabaev and S. D'Odorico in the *Messenger* No. **53,** p. 11).

Since all involved felt that this first experiment was very successful, it was decided that now, 2 years later, organizing a second Summer School was very timely. In fact, the number of more than 50 applications convincingly confirmed this view. Unfortunately, the capacity of the facilities of OHP and the intended character of the Summer School limited the number of participants to eighteen. The selection process was, therefore, a very difficult one because we could accept only a fraction of the candidates which we should have liked to invite.

All participants arrived at OHP in the morning of July 16. After lunch, they met to form six teams of three students and one tutor each (their names are given in the separate box accompanying this article) and to plan and prepare the work to be done during the next ten days. For the Summer School, the OHP had set aside three nights at the 1.93-m telescope for low-resolution spectroscopy with the CARELEC spectrograph, three nights at the 1.52-m telescope with its high-resolution spectrograph AURELIE, and 6 nights for direct imaging with the 1.20-m telescope. All three instruments are equipped with CCD detectors. Three groups observed with the 1.93-m and

List of courses:

R. Wilson (ESO):	Modern telescope layout
M. Dennefeld (IAP, Paris):	High-sensitivity detectors
J. Wampler (ESO):	High-throughput optical instruments
F. Rufener (Geneva):	Photo-electric photometry
S. Ilovaisky (OHP):	Photometry with CCDs
D. Gillet (OHP):	High-resolution spectroscopy
F. Merkle (ESO):	High-resolution imaging
C. Vanderiest (Meudon):	Low-resolution and multi-channel spectroscopy
F. Sibille (Lyon):	Infrared observations
D. Baade (ESO):	Introduction to MIDAS
M. Véron (OHP):	Introduction to IHAP

Tutoring astronomers: D. Baade (ESO), E. Brocato (ESO), M. Dennefeld (IAP), D. Gillet (OHP), S. Ilovaisky (OHP) and P. Véron (OHP).

Students: J.-L. Beuzit (ESO), N. Caon (Padova, Italy), M. Cassiano (Göttingen, Germany), P. Cruzalèbes (Nice, France), R. den Hartog (Leiden, the Netherlands), J. Eislöffel (Heidelberg, Germany), F. Guglielmo (Meudon, France), F.G. Jensen (Arhus, Denmark), L. Kaper (Amsterdam, the Netherlands), A. Klotz (Toulouse, France), A. Lançon (Paris, France), X. Liu (ESO), J. Meijer (Münster, Germany), O. Moreau (Paris, France), C. Pichon (Meudon), France), A. Smette (ESO), M. Vestergaard (Copenhagen, Denmark), T. Zwitter (Trieste, Italy).

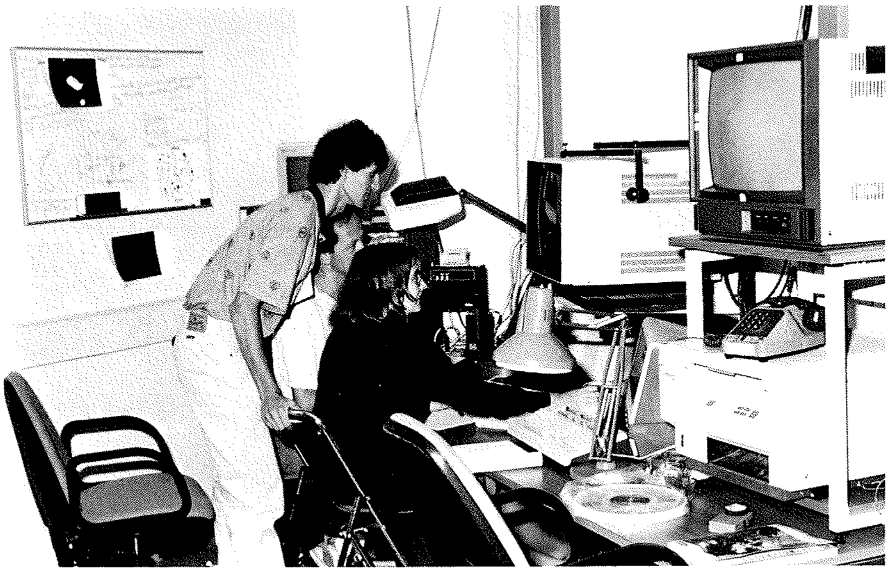

Figure 2: *A group of students (A. Lançon, N. Caon and J. Eislöffel) reducing CCD direct images at the IHAP station of the 1.20-m telescope.*

days at OHP for in-depth discussions. Indisputable highlight was a joint, unscheduled presentation by Joe Wampler and Ray Wilson (both from ESO) which they had offered in order to bring the students up to date on the symptoms and interpretation of the optical anomalies of the Hubble Space Telescope.

The programme was rounded of by a visit of Ray Wilson to one of the telescopes where he explained what can be inferred about the aberrations of a telescope from the image of its pupil. Finally, through the kind invitation of Prof. Michel Mayor of the Observatoire de Genève, the students had the opportunity to complement their experience with modern instruments by watching CORAVEL being used at the Swiss 1-m telescope.

In many of the applications received for the Summer School, a strong interest was expressed in working with colleagues from other countries in an international environment. With nearly a dozen different nationalities, this desire was well satisfied. So, at least for the duration of the Summer School, one could speak of the OHP as a European Northern Observatory. The enthusiasm and good spirit of the students, the untiring efforts of the tutors, the helpfulness of numerous OHP technical staff, and the skill of the lecturers in explaining complex subjects made this Summer School a very rewarding experience for the organizers. We cordially thank them all.

the other three with the 1.52-m telescope for one night each whereas all groups had one night at the 1.20-m telescope. With only minor exceptions, the weather cooperated during all nights.

The observing programmes had mostly been worked out by the group tutors but in some cases also included proposals made by the students. The targets ranged from IRAS galaxies over open star clusters to β Cephei stars, close X-ray binaries, OB supergiants, and FU Ori stars. The scientific subjects helped to provide a realistic background to the practical work done. But the main emphasis was on the latter: How does one select targets? Where do coordinates and finding charts come from? What other information is needed at the telescope? How does one estimate exposure times? What calibration sources are available; which ones are required for a given programme? How many different instrument set-ups can I handle in one night? In short, all the do's and don'ts of astronomical observations on which standard text books but also many user guides quit. Most programmes were on purpose not very ambitious in order to leave sufficient room for (minor) errors which so often are the most efficient teachers.

One of the lessons which every student learned (and even some of the tutors were reminded of it) is that the time required for the proper reduction of data exceeds the time for their acquisition by a large factor. The students responded to this challenge with considerable diligence. All computers were given a hard time, often nearly round the clock. The observations were tested for instrumental defects, calibrated and counter-checked, compared to literature data, and eventually put into the form of scientifically meaningful and esthetically pleasing viewgraphs. In this way, the students were exposed to a fairly broad range of applications software in MIDAS as well as IHAP.

The only major break was on Sunday, July 22, when an excursion to the nearby town of Forcalquier and its citadelle and a picnic close to the old monastery of Ganagobie provided a welcome opportunity to rest for a while.

On the last day, July 26, each group presented their work and results in a short talk of about 20 minutes duration to the other participants. Although rumours had it that some groups hardly saw their beds in the preceding night, the presentations made were without exception of a very high standard and well reflected the intense learning process of the past ten days.

Since OHP could provide state-of-the-art instruments with modern computer-based user interfaces plus both MIDAS and IHAP for data reduction, every student should now be in a good position to conduct observing programmes at La Silla or elsewhere on his/her own. This we had defined as the primary scope of the Summer School.

As stated above, the tutors guided and supervised the work of their respective groups. But there should also be a more systematic introduction to the physical basis and the practical design and operating principles of the types of facilities the students were using. This was provided by a series of eleven one-and-a-half hour lectures which were given by various renowned experts (see box). The students interacted with the speakers in lively conversations, and most lecturers kindly spent some extra

Selection of the VLT Site

The readers of the *Messenger* may wonder how the selection of the site for the Very Large Telescope (VLT) is proceeding. The interest in this important matter seems to be rising; hardly a day passes without a corresponding request for information to the ESO Information Service.

Here is a short summary of the current situation.

The Site Selection Working Group (SSWG phase I: Chairman J.-P. Swings) delivered its final report about the meteorological conditions in the Paranal and La Silla areas in early May this year. This report was thoroughly discussed by the Scientific Technical Committee (STC) during its meeting on May 10–11. The STC passed a resolution, which endorsed the SSWG I recommendation to establish the VLT Observatory in the Paranal area and recommended that the ESO Executive work out and present a viable operational model of ESO/Chile with the Observatory on La Silla and the VLT Observatory in the Paranal area to the STC, the Finance Committee and Council in November/December 1990.

In its meeting in Sweden on June 7, the ESO Council passed the following resolution: "Council, taking note of the superior scientific qualities of the Paranal area, asks the ESO Executive to work out financial, technical and research policy implications and operational models of ESO/Chile for the Paranal area option as well as for the Vizcachas option."

This work is now under way at ESO. At the same time, a modified Site Selection Working Group has taken up its work during a first meeting at the ESO Headquarters on July 25. Whereas in the first phase, the SSWG mainly looked into the scientific aspects of the site choice, the terms of reference for SSWG phase II, as defined already in December 1988, also include the operational and financial pros and cons of the site options. J.-P. Swings (Belgium) continues as Chairman; other members are I. Appenzeller (F.R. Germany), A. Ardeberg (Sweden), G. Lelièvre (France) and S. Ortolani (Italy).

The SSWG II will have the important function of providing guidelines for and running criticism of the in-house study by the ESO management, before it is finalized and presented to the ESO Committees and Council later this year.

In this connection, a completely independent line of approach to the question of the long-term climatic stability in Northern Chile has become available. Dr. Michel Grenon of the Geneva Observatory, a regular visiting astronomer to La Silla during the past two decades and a botanist with strong interests in biogeography, has recently submitted a report on the climate in and around the Atacama desert, as deduced from sources, not considered in the SSWG study, but indicative of the climatic conditions in the past and the present around the possible VLT sites.

We are very pleased that Dr. Grenon has agreed to the publication of a popular account of this most interesting biogeographical study in this issue of the *Messenger.* We warmly commend it to the attention of our readers.

In accordance with the original planning, it is hoped that it will be possible to decide about the future VLT site before the end of the current year. In that case, the ground preparation (blasting, etc.) will start on-schedule in early 1991.

The Editor

The Northern Chile Climate and Its Evolution

A Pluridisciplinary Approach to the VLT Site Selection

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1. Introduction

The selection of an optimum astronomical site in northern Chile, undertaken by ESO for several years now, is a very complex task. The location of the VLT will effect the efficiency of the European astronomical community for the next 30 to 50 years. Therefore, it is of prime importance that the selected site optimizes the quality and the quantity of the collected data for the whole range of wavelengths being of interest now and in the future. At least four different parameters have to be considered:

1. the quality of the images (seeing);
2. the quality of the atmospheric transparency, namely the amount of aerosols and of the precipitable water and their time variation;
3. the annual distribution of photometric and spectroscopic nights;
4. the intermediate and long term evolution of climate with local response to global climatic changes.

Several factors complicate the selection of the site. A major problem is the scarcity of meteorological stations in northern Chile, as they are mainly located along the coast, below the inversion layer, or distributed in the main valleys. Little is known about the Andean or the precordillera area climate, south of 23 °S. The rather short duration of continuous records of half a century or less, depending on the measured quantities, make the definition of mean meteorological values and trends uncertain. Another important problem is the vastness of the domain to be investigated, i.e. about 1000 km in latitude and 200 km in longitude in which the potential sites are located in non-populated areas and hence have no meteorological or historical records. In the southern part of the Atacama desert, the occurrence of quasi periodic wet episodes separated by series of dry years, makes the comparison between sites difficult and possibly meaningless unless it is synchronous. With a semi-periodicity of 8 to 12 years, cf. section 3, measurements over 30 to 40 years are necessary to characterize the local mean climatic conditions.

The aim of this report is to provide information on the existing and anticipated sites, complementary to that collected by ESO investigators during the site testing campaign.

The present approach utilizes biogeography as a tool to define with a high spatial resolution the integrated climatic properties over various time scales depending on the life duration and propagation times of living beings considered. The data used here are either compiled from specialized literature or are the results of mainly botanical observations, made by the author in Chile since 1971. The connection with meteorological and climatical parameters will be made in order to define the astronomical properties of northern Chile sites, in comparison with Cerro Tololo and La Silla sites.

The sensitivity of local conditions to small and large amplitude climatic changes will be explored, using data from the fields of palaeobotany, glaciology, and geology.

2. The Origin of the Atacama Desert

The Atacama desert is, geologically speaking, a rather young feature. Its development started during the Miocene, about 12 Myr ago, when the uplifting of the Andes Central Cordillera progressively interrupted the zonal circulation at low altitudes. Erosion and canyon cutting on the western flank ceased at the Miocene-Pliocene boundary, about 5.3 Myr ago, as a consequence of the intensification of the Humboldt current, and of the regression of the counter-running warm current. During the lower Pliocene, the Atacama climate remained warm but not arid. It is only from the lower Pleistocene on, during glacial and interglacial episodes, that the colder humid periods started to alternate with warm and dry ones. The aridity was intensified at each interglacial period as a result of the height increase of the Andes through intense andestic activity (Arroyo et al. 1988). The present day extreme arid condition was reached only at the end of the Pleistocene about 10,000 years ago.

Nowadays, the wet continental tropical air masses are stopped east of the Andes and may cross the Andes only in southern summer, during the so-called Bolivian winter, when the Pacific anticyclone is moving southwards, cf. Fuenzalida (1983). But even if saturated when crossing the Andes, the adiabatic warming of the air by 10 to 30 degrees leads to a relative humidity of less than 30% at low altitudes.

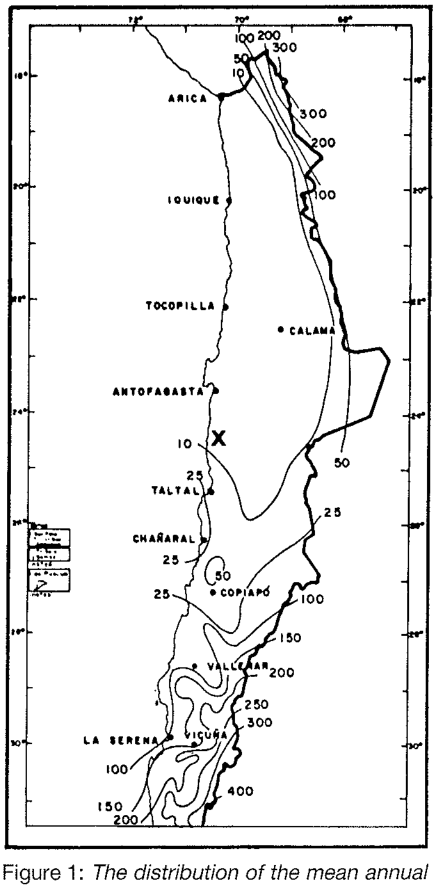

Figure 1: *The distribution of the mean annual precipitation over northern Chile in units of mm H_2O. The cross indicates the site of Paranal (Huber, 1979). The nucleus of the Atacama desert, i.e. the orographic depression between 19° and 25°S is the most arid desert of the Earth with annual precipitation as low as 3.1 mm at Pintados (20°27 S, 69°29 N) and a daily amplitude of the temperature exceeding 25 °C during more than 9 months per year (Weischet, 1966). Along the northern coast, precipitation is even less, e.g. 0.6 mm at Arica or 2.2 mm at Antofagasta, but the relative humidity is high.*

On the western side, the Pacific anticyclone prevents the penetration of polar air masses over the continent at latitudes approximately north of 25 °S. The presence of cold waters of the Humbolt current at tropical latitudes induces temperature inversion at an altitude of 900 m near La Serena to 1300–1500 m between Taltal and Antofagasta. This inversion, with its associated quasi-permanent sea of clouds, inhibits the sea evaporation as well as the vertical atmospheric turbulence. The Pacific humid air masses penetrate into the continent only when the coastal Cordillera is depressed, or through the main valleys, pumped by local thermal winds.

Between the latitudes 19°30 S and 25 °S there is no significant discontinuity in the western mountain range and so, for about 600 km, the Pacific air mass is completely blocked over the sea and the narrow coastal strip. As a consequence, one of the most arid deserts of the Earth was able to develop over the coastal Cordillera and in the central depression. In stable conditions, the atmospheric transparency corresponds to the properties of a modified tropical maritime air mass, dry and with a low aerosol content.

3. The Climate of Atacama

Although arid climate prevails from 15 °S to 28 °S in Chile, the climatic conditions are distinct in the northern, eastern and southern borders of the desert. The extension of the extreme arid conditions, defined by precipitation less than 10 mm/y, may be seen in Figure 1. The limits of absolute desert are narrower, with a maximum altitude ranging from 1500 m east of Arica to 3000 m east of Antofagasta.

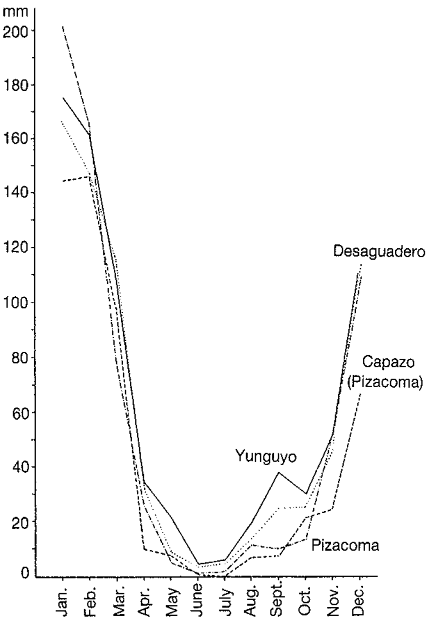

Figure 2: *The annual distribution of precipitations at different sites close to the Chilean-Peruvian border east of the main Cordillera (Rodriguez, 1988). Measurements of annual rain precipitation show that precipitations induced by easterlies are regular, cf. Figure 3, and allow the development of a rich flora and fauna. An increase of moisture in the atmosphere in northern Chile is to be expected from December to March.*

The northern part is a cold air and rain shadow desert with a climate determined by the yearly latitudinal oscillation of the intertropical convergence. The pluviosity shows a steep increase towards the east. Up to 4000 m, regular precipitation as rainfall occurs between November and April with annual maxima reaching 300 mm to 400 mm at the Bolivian border, see Figures 2 and 3.

South of 24–25 °S the precipitations are due to the polar front activity bringing moisture from the south-west. Here, between April and September, the rise of cool moist air produces condensation as rainfall or, if above 3000 m, as snowfall over the precordilleras and cordilleras.

The occurrence of fronts is controlled by the latitudinal yearly oscillation of the South Pacific anticyclone centred at about 27 °S in winter and 30 °S in summer. The virga phenomenon, i.e. the evaporation of rain drops in low altitude dry air layers, is frequent. That is why rain over the central depression and the coastal mountains is so scarce and irregular. The warm tropical desert ends at latitude 27 °S, about 50 km north of Copiapo.

4. The Transition Zone

The transition zone is of particular interest since it contains the three major

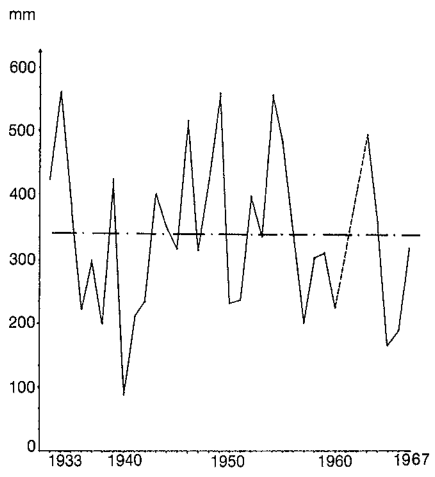

Figure 3: *Annual precipitation at Parinacota station, latitude 18°12, longitude 69°20 W and altitude 4360 m. Notice the limited range of year-to-year variation. Adapted from Niemeyer (1968).*

astronomical sites now operating in Chile. It is also the zone where the biogeography allows a very detailed analysis of the past and present climatic conditions. Since it is a comparison zone for the northern sites of Paranal and Armazoni, its properties will be more extensively described.

This zone, between 27 °S and 34 °S, has a typical Mediterranean climate characterized by sporadic winter rains occurring when the anticyclonic conditions are briefly interrupted by short-lived cyclons, and followed by a dry summer and autumn. The amount of precipitation, as well as the duration of the wet season, steeply declines when moving to the north, see Figure 4 from Caviedes (1990). The number of cyclonic transits also declines towards the North. At the latitude of La Serena, there are about 3 to 4 bad weather episodes with a marked variability in intensity and number per winter.

At La Silla, the frontal activity is the cause of a serious degradation of the observing conditions in winter and spring. The highest percentage of non-photometric nights also occurs when the nights are the longest, it is therefore more realistic to consider the monthly number of lost hours of observation. In Figure 5 we give the total number of hours lost during non-photometric nights at La Silla for the period 1966–1972 which includes only one wet episode, see Figure 7. In Figure 5, lost hours during partially photometric nights, i.e. with at least 6 hours of observation, are not taken into account.

Thus, Figure 5 gives only the lower limits of lost observing hours. Monthly precipitation in central Chile and loss of observing hours show a clear correlation, see Figures 4 and 5, for the greater part of the year, except for spring months when fronts normally produce not rain but only cloudiness at La Silla. The dotted area in Figure 5 is indicative of the number of hours which could be gained by moving the observatory to the North.

Between the Elqui and Copiapo valleys, winter precipitation is highly irregular and, north of Vallenar, totally dry years may occur. The total annual precipitation at La Serena (lat. 29°54 S), Vallenar (lat. 28°34 S) and Copiapo (lat. 27°20 S), for the years 1970–1984, are shown in Figure 6. The decrease of the precipitation, over these 250 km only, is as spectacular as the increase of the variability from year to year.

In order to study the intermediate time scale climatic variations, longer series have to be considered. In the absence of a dense net of nivo- and pluviometers in the transition zone, the mean flux of the major rivers and their affluents are used as indicators of the mean precipitations in their basin. Fluxes are monitored in the area since 1942 and the most relevant data are the hydrograms of Rio Huasco and of its affluent Rio Carmen alimented by precipitation fallen just east of La Silla, see Figure 7.

The most evident pattern is the recurrence of wet episodes with a semi-regular periodicity. Severe winters occur every 7 to 12 years followed by progressive return to dry conditions. The flux distribution is somewhat smoothed by the delay between snowfall and melting at high altitudes about four months later, and by the low velocity of underground water. The volume of water measured in El Carmen correlates very well with the amount of precipitation observed in the Vallenar area. Nevertheless, flux measurement appears to be a better indicator of the winter severity at Las Campanas and La Silla than the pluviosity at Vallenar since it is not affected by the virga effect and thus represents the true frontal cloudiness over La Silla.

The hydrograms of Elqui, Hurtado and Limari rivers, characteristic of the winter

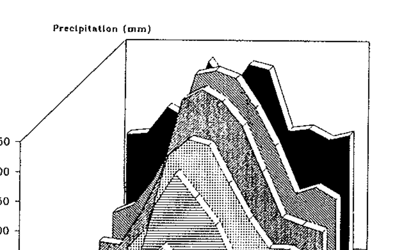

Figure 4: *Monthly precipitation at different coastal stations of central Chile, from Caviedes (1990).*

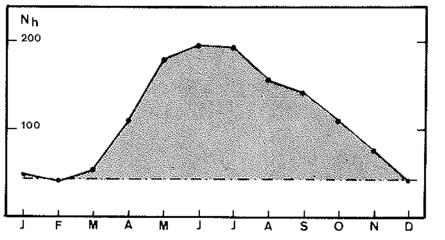

Figure 5: *The monthly number of lost photometric hours during non-photometric nights for the period 1966 to 1972 at La Silla.*

conditions prevailing at Cerro Tololo, show similar patterns but with more pronounced and frequent secondary peaks. The regularity of rainy years is increasing towards the South whereas in the intermediate zone there appears to be a quasi biblical alternance of rich and poor harvests.

When compared during dry years, the mountain sites between Elqui and Copiapo valleys would show little difference in their quality as astronomical sites. This may be the reason why La Silla mountain was selected after a series of tests performed in that area during the dry years 1961–1962. In Figure 7, the peak in 1965 also explains why the first measurements at La Silla that year were somewhat disappointing.

The transition zone is indeed the most sensitive to climatic changes and consequently the southern limit of the Atacama desert is expected to vary by several hundred kilometres.

5. The Biogeography as a Site Testing Tool

The distribution of living beings, in particular that of plants, is the result of geological, biological and climatic evolution. Various time scales are involved, from several million years for the families and genera differentiation, few thousand years for major climatic changes to one year for blossoming of annuals.

At the present time the observed distribution of plants, insects, reptiles, etc., has almost reached a new equilibrium after major changes of the last ice age. Living species develop in well-defined biotopes. Plants in particular are adapted to more or less restricted ranges of temperature, total amount of precipitation, soil acidity, insolation and hygrometry. In the semi-arid and arid zones plants are characterized by their capability to absorb water, to store it for the dry months or years and to resist desiccation. This desiccation, due to low relative humidity, effect of the solar radiation and that of surface evaporation reinforced by wind, is the limiting factor of major importance for the vegetal development.

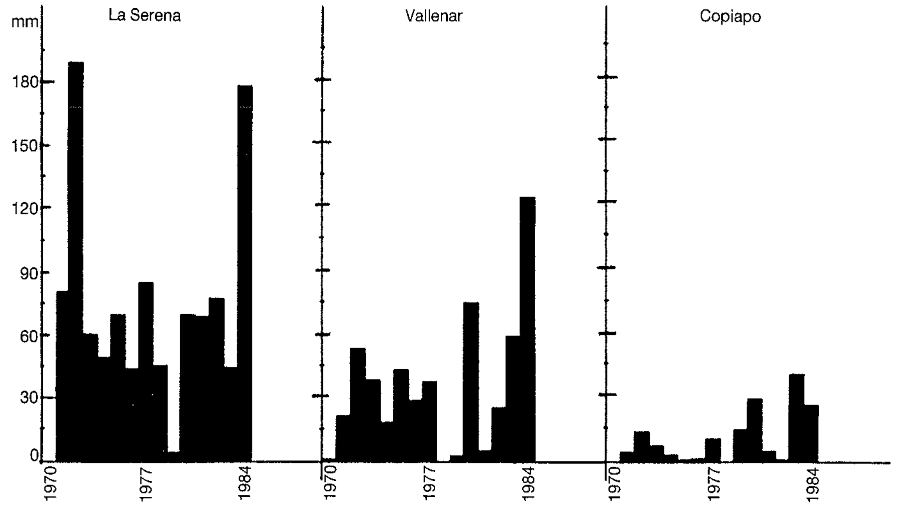

Figure 6: *The total annual rain precipitation at La Serena, Vallenar and Copiapo, between 1970 and 1984.*

Plants or plant associations with well-defined climatic requirements may be used to map the areas where the climatic conditions are within the permitted range for a given species or group. In semi-arid zones, although the plant density is small, botanical surveys may reveal microclimates with a resolution as high as a few metres.

Life cycles are very distinct from species to species. Annuals, with seeds easily dispersed by wind, are tracers of the short time climatic conditions. Perennials are indicative of mean conditions over few years to a century or more, depending on their life time and the time to reach maturity. Species, adapted to restricted climatic conditions and with little efficiency in seed dispersion, are tracers of long term conditions. This is the case with most of the Chilean cactaceae.

Plant distribution, i.e. phytogeography, allows to define the climatic conditions over very extended areas, and to associate to each vegetal group a set of climatological parameters. They are determined by interpolating meteorological data collected in the considered area, if existing, and in adjacent areas. The preselection of astronomical sites, worthy of testing, can indeed be made.

In the semi-arid zone, when the ground coverage is high enough, the location of the domes on a given site may be optimized by using the distribution of plants with distinct sensitivity to the winds, thermal or dominant.

6. The Phytogeographic Zones

Phytogeography reveals a clear zonation in latitude and altitude south of 26 °S. From Elqui Valley to the Santiago area, a Mediterranean vegetation prevails with rare trees, perennial bushes, tree cacti and a rich flora of herbs in blossom at the end of winter. Winter watering is regular as well as humidity, so no special adaptation is required by plants to survive longer than one dry summer. The lower part of Elqui Valley, including Cerro Tololo Observatory, belongs to that climatic zone. The upper Elqui Valley is drier because of rain shadow produced by the precordillera and evapotranspiration due to strong thermal valley winds.

Along the coast, the presence of cold humid Pacific air and fog allows the development of a peculiar floristic association including bromeliaceae and cactaceae.

The transition between the Mediterranean and semi-arid zone occurs north of La Serena, and is completed at Cuesta de Buenos Aires. From there to the north of Copiapo, the winter watering is no longer guaranteed and species have to survive, as seeds or bulbs, succulents or other forms, through one to several dry years. In this area, several cactaceae develop relatively enormous underground water reservoirs, like those of Opuntia archiconoides, a local endemic of Vallenar Cordillera, found at La Silla, see Figure 8.

In the alluvial plains, at intermediate altitude, where the soil is deep enough to retain humidity, a few times per decade, irregular rainy winters produce a spectacular blossoming desert. The typical vegetal association producing this phenomenon extends from Cuesta de Buenos Aires to few pockets, about 50 km north of Copiapo (see map in Figure 9). This is the zone where polar front activity produces at least 20 mm of precipitation semi-regularily. In this zone, tree cactaceae are confined to places invaded by fog during the night. In comparison, similar species are found close to the summit of Cerro Tololo.

North of 26 °S parallel, the zonation becomes East-West. A strip along the

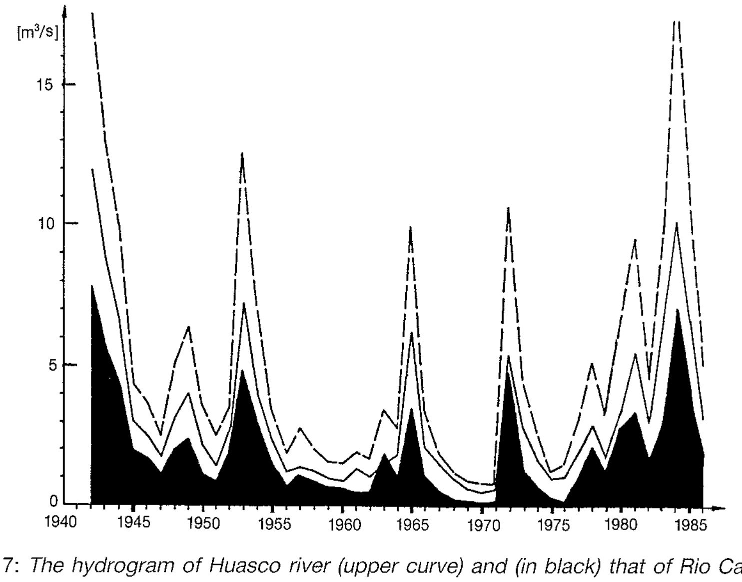

Figure 7: *The hydrogram of Huasco river (upper curve) and (in black) that of Rio Carmen as measured at San Felix, latitude 28°56 S. From Dirección General de Aguas.*

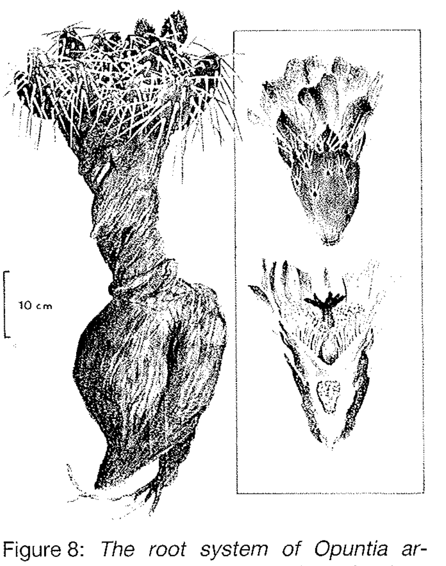

Figure 8: *The root system of Opuntia archiconoides, a La Silla plant adapted to long duration droughts. From Hoffmann (1989).*

coast, narrowing towards the equator, hosts extremely specialized vegetal associations, which in general are able to retain water from fog only. In fog pockets like Paposo, north of Taltal, extremely distinct associations are found. The high rate of endemics indicates that these local climatic conditions are indeed very ancient. Between Taltal and Antofagasta, above the inversion layer, i.e. above about 1300 m, warm desertic conditions prevail, with none to very scarce vegetation. On the western Cordillera, the vegetation is essentially inexistent below 3000 m. At Paranal, only one perennial was found in January 1990, and at Armazoni, two species adapted to extreme conditions have been collected. These are a succulent plant, Philippiamra pachyphylla, and a visquous one, Adesmia atacamensis, which is also found on other summits in the area. At Armazoni, their presence, as well as erosion features near the top, indicate that watering indeed occurs in the area with some regularity. Hoar frost or even snow may be expected at Armazoni. According to Figure 9, the absolute desert stops 80 to 110 km east from the coast, followed by a tropical semi-desert and at higher altitude by an Andean steppe. At the latitude of Paranal, the semi-desert starts at only 30 km from the coast. This is an evidence that, at that latitude, coastal summits are certainly astronomically better than interior ones.

7. Other Biological Evidences

Animals through their food resources can also be used as climatic tracers. As an example, in Figure 10, we give the distribution of reptiles belonging to Iguanidae and Colubridae families. The number of reptile species is limited, not only by the availability of their prey, as insects, and hence of vegetation, but also by temperature. The density of species is 10 to 12 species at maximum between 33 °S to 35 °S, and also shows a relative maximum in the central depression. The density remains constant at 5–6 between Coquimbo and Copiapo and falls to 1 or 0 north of 26 °S.

The only area without reptiles of these families on the western Cordillera is between 24°20 S and about 26°15 S. In the central Andes, the density is small and falls to about 0 at 24 °S, but shows a sharp increase east of Calama where the altiplanic humidity is high because of Bolivian winter.

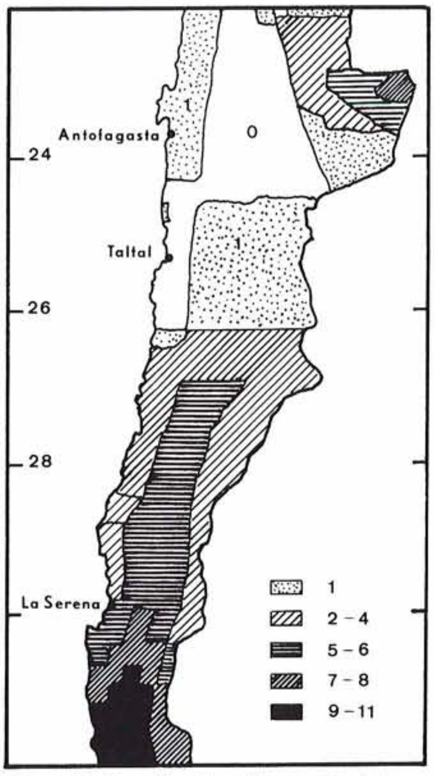

Figure 10: *Density of reptile species belonging to Iguanidae and Colubridae families, mapped according to Donoso-Barros (1966) species distribution.*

8. Phytogeographically the Optimum Latitude

When moving towards the North, the winter conditions improve continuously at least up to 27 °S. At some latitude, the gain in observing time in winter will be compensated by losses during Bolivian "winter" in summer. Bolivian winter is expected to bring moisture in the atmosphere over the whole northern Atacama desert, and for IR and millimetric astronomy, its influence should be minimized. The optimum latitude should then be that which optimizes the yearly distribution of observing time, i.e. by minimizing winter and summer losses.

In the absence of a sufficient number of Andean meteorological stations between 22 °S and 28 °S, the information can again be deduced from phytogeography. Arroyo et al. (1988), have made six transects through the Andes between 18 °S and 29 °S, and have evaluated the richness of species as a function of the altitude and latitude.

The temperature is merely independent on latitude and the richness is essentially controlled by hygrometry. At 26 °S, the richness is independent on altitude up to 4000 m. Closer to the Equator, the maximum species density is found in the altitude range 3000–3500 m, and at lower altitudes south of 26 °.

La Silla mountain with its estimated richness of 130 species, according to the author's collection, is just normal for its altitude and latitude with respect to other Andean sites.

Figure 11 shows the total richness (N_{tot}) per transect and also at an altitude of 2500 m (N_{2500}) as a function of the latitude. North of 24 °S, richness is due to summer precipitation whereas south of 26 °S to winter precipitation. By extrapolating the curves for richness versus latitude for both regimes, we can deduce that Bolivian winter contributes

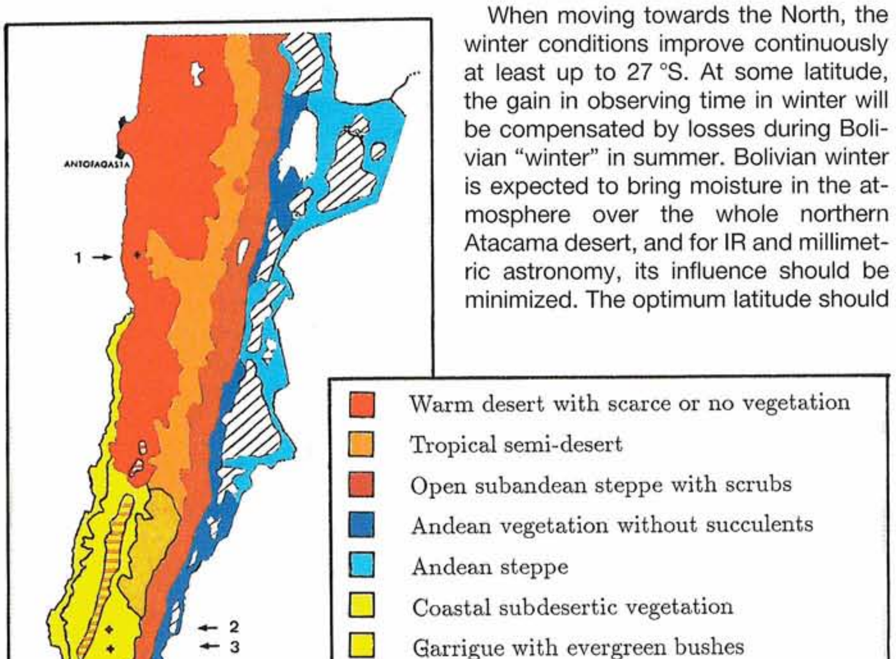

Figure 9: *Map of phytogeographic zones in central and northern Chile (adapted from Geographia de Chile III, Perez (1983). The sites of Paranal (1), Las Campanas (2), La Silla (3) and Cerro Tololo (4) are indicated by crosses.*

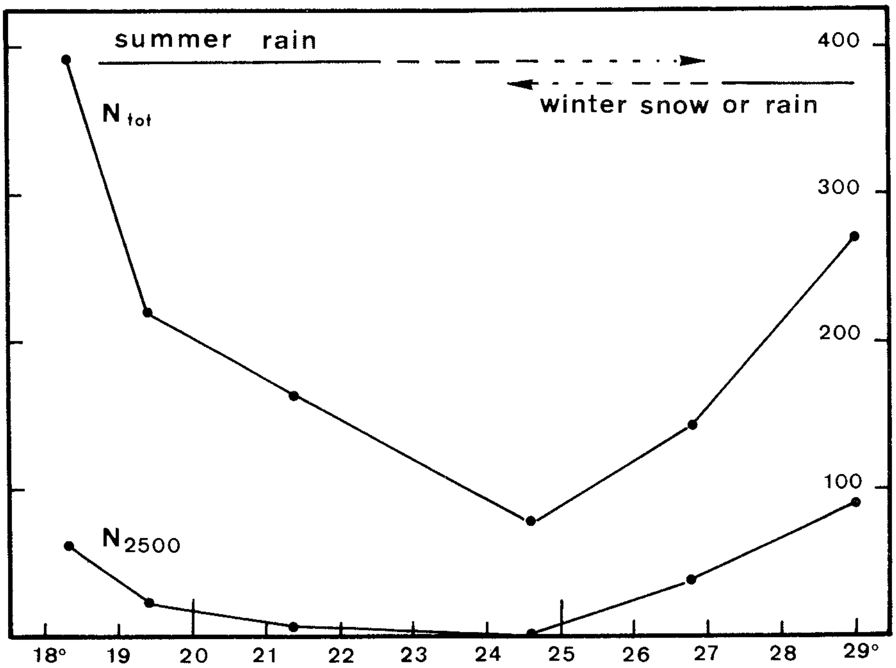

Figure 11: *The dependence of the plant diversity in the Andes, integrated along a transect N_{tot} and at altitude 2500 m (N_{2500}) as a function of latitude, adapted from Arroyo et al. (1988) with an estimate of Bolivian (summer rain) and Chilean winter extensions.*

to plant diversity down to 27 °S, whereas Chilean winter is perceptible up to 24 °S. Thus, the optimum latitude for an astronomical site is somewhere between 24°30 S and 25 °S. Paranal site at latitude 24°37 S, is indeed perfectly located.

9. The Long Term Climatic Variations

In the southern Atacama desert, as stated before, we observe intermediate time scale variations of climatic conditions with a quasi-periodicity of 7 to 12 years. There is some evidence for an intensification of aridity during the past 50 years, partly due to anthropic activity, but more so to real climatic change. At La Silla, the local endemic component of the flora seems to be stable, whereas the part composed of species growing at the northern limit of their natural geographical domain, are in regression. The ground coverage is diminishing, e.g. for the genus Proustia for which very few or no young specimens are found. On the other hand, the discovery of very old Balsamocarpon bushes, in the quebrada west of La Silla, indicates that the local conditions have been quasi stable for centuries. This bush is characteristic of the IIIrd and IVth region, and able to survive during completely dry years in dormant mode by loosing its leaves. The oldest stem shows about 700 growth rings and, depending on the fraction of years without growth, its age possibly exceeds that figure.

Palaeoclimatology indicates little change in temperature and humidity after the end of Pleistocene, 11,400 years B.P.; isotopic datation of underground water in the Antofagasta area confirms the palynological findings, with an age of 10,000 years for this fossil water.

During the moderate climatic optimum following the glacial period, i.e. between 7300 and 3600 years B.P., the temperature in the Andes was higher by 0.6 to 1.2 °C depending on the altitude. The corresponding climates on the western side of the Andes were reconstructed by Lauer (1986).

The temperature rise led to an important regression of the northern limit of the desert, from about 2 ° to 8 °S, but had no noticeable effect on the southern limit at about 26°20 S, see Figure 12. This finding supports the stability of the conditions at Paranal in the case of a moderate greenhouse effect.

The trends in the case of a global planetary cooling are better documented. The changes of snowline, of altiplanic lake shores (now salares), the fossil pollen records in peat bogs, and in particular the presence of relictual floras, belonging to Valdivian type rain forest at the Rio Limari latitude – the Fray Jorge and Talinay woods –, are all convergent indications of an important change of the southern and eastern limits of the Atacama desert.

During the last ice age, the latitudinal shift of the vegetation was about 800 km. At that time, the conditions existing now at La Silla were experienced close to Paranal, and those of Concepción at La Serena.

Multiregressive models by Caviedes (1990) predict the amount of precipitation and the change of snowline for temperature falls. With respect to the present amount of rain, 117 mm at La Serena, a cooling by 1 °, 2 °, 3 °C would produce precipitation of 480, 967 and 1450 mm, respectively. Thus, the zone at latitude 29 °–30 °S appears to be highly sensitive to climatic changes where a temperature drop of just 1 °, induces a precipitation increase by a factor of four.

10. Conclusions

In summary, the La Silla Observatory is located in a transition zone visited by polar fronts which are responsible for a serious degradation of winter observing conditions.

The weather conditions are variable and semi-regular with time-scales in the order of a decade. Although an intensification of the aridity is noticed during the last 50 years, the mean conditions appear to be stable over several centuries. This zone is highly sensitive to global climatic changes where a temperature drop of 1 °C causes an in-

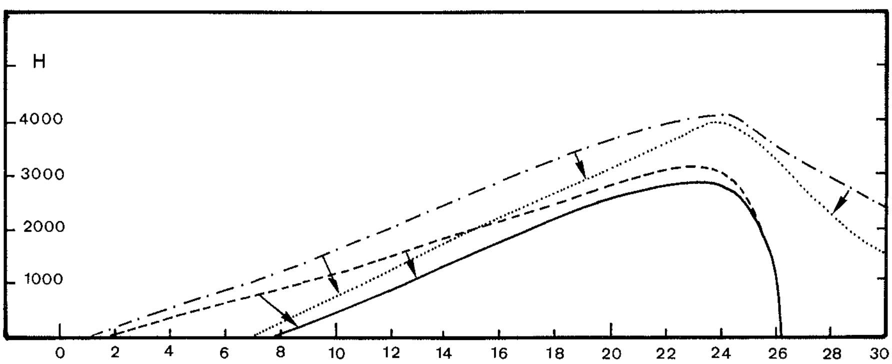

Figure 12: *The limits in latitude and altitude of the absolute desert and semi-arid area, at the present epoch (– – – –) and (– · – · –) respectively, and during the warm episode at the end of the Peistocene. The arrows indicate the effect of a global climatic warming. Adapted from Lauer (1986).*

crease of precipitation by a factor of four or more.

In northern Chile, between latitude 24°30 S and 25 °S, influences of polar fronts and easterlies are at a minimum. Cloudiness and precipitation increase from the west to the east; thus, coastal cordillera summits have to be preferred. On that mountain range, the azoic zone over 1500 m extends from 24°20 S to 26°10 S. Absolute desert is limited to a strip of 80–110 km wide, and possibly due to a purely altitudinal effect, as narrow as 30 km at the latitude of Paranal. The aridity of the western cordillera area, north of 26 °S, appears to be stable, even in case of large amplitude climate changes (warmer or colder). The occurrence of rainfall is barely related to the El Niño phenomenon.

All the climatic indicators considered here, biogeographic and meteorological, lead to the conclusion that Paranal mountain is located in the best possible area of South America for the settlement of a modern astronomical observatory.

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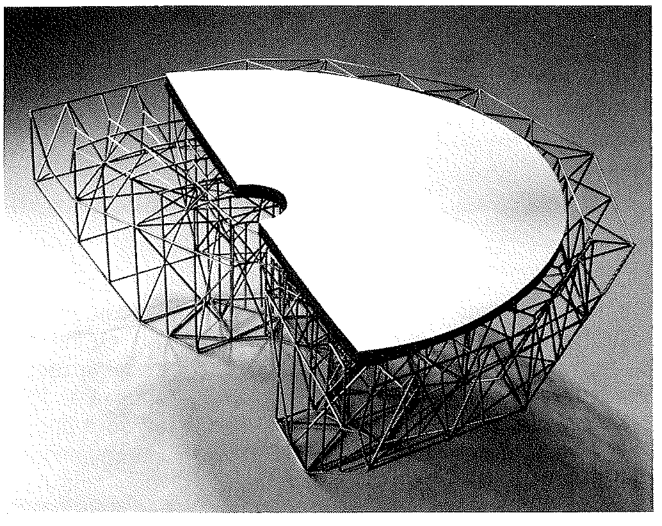
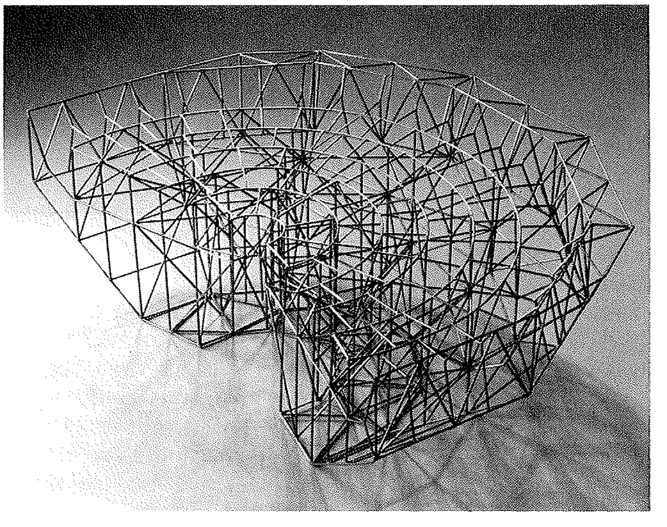
Progress on the VLT Mirror Cell Design





The NOTSA group at Risø (Denmark) is performing, under contract of ESO, the engineering of the VLT primary mirror cell.

A preliminary design has now been produced which however still needs to be optimized through computer modelling and finite element analysis. The NOTSA group thought that a preliminary "hardwire" modelling would be cost- and time-effective and decided to build several models with copper wire which can easily be soldered and rapidly modified. This approach has effectively permitted to discriminate rapidly between several designs, which would have had required much more effort through computer modelling. It also permitted to correct for a few errors which for such a complex structure are almost unavoidable, time consuming and ... sometimes may reach the manufacturing stage while still undetected.

The two photographs show one of these "hardwire" models, once with a half mirror cardboard model, once without. The actual VLT mirror cell will have a diameter of about 9 metres and it will be 3 metres high.

D. ENARD, ESO

Halley Enters Hibernation

Famous Comet Halley, now receding from the Sun after its perihelion passage in early 1986, has recently entered into a state of hibernation which will last until shortly before the next passage in 2061.

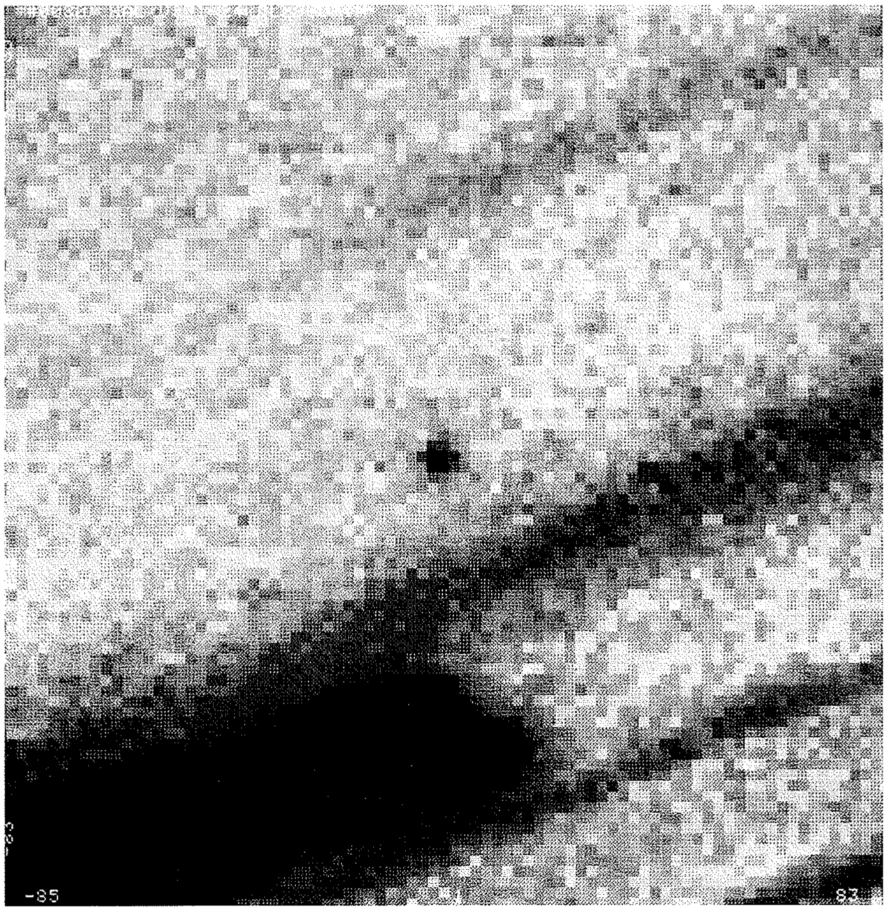
This is the main result of a series of observations in late February 1990, during which the comet was imaged with a CCD camera attached to the Danish 1.5-m telescope at La Silla. The seeing conditions were mediocre, ~1.3 arcsec. At this time Halley was 11.6 AU (1735 million km) and 12.5 AU (1870 million km) from the Earth and the Sun, respectively, that is well outside the orbit of the giant planet Saturn.

Exposures totalling 980 min (16 hrs 20 min) were obtained and the "negative" picture shown here is a composite of 23 frames, each individually cleaned. The image of Halley at the centre is pointlike; the straight lines are trails of stars and galaxies in the field, because the telescope was set to follow the comet's motion. The mean, visual brightness of Halley during the observing period was V = 24.4 mag and the brightness varied between approx. 23.7 and 25.0 mag. The field covered is 39 × 39 arcsec (84 pixels square); North is up and East is to the left.

The measured magnitude is about 0.35 mag brighter than what would be expected from Halley's nucleus alone, an avocado-shaped, 15 km long "dirty snowball", consisting of a variety of ices and dust. The brightness variations are caused by the tumbling motion of this nucleus, whereby the amount of reflected sunlight depends on the changing profile seen from the Earth.

Of particular interest is the fact that the extended coma (i.e. the dust cloud around the nucleus), which was observed with the same telescope in 1989 at heliocentric distance 10.1 AU (see the *Messenger* **56**, p. 45; June 1989), has now completely disappeared. In fact, no coma is visible at the 29 mag/sq.arcsec surface brightness level, corresponding to 1500 times less than the sky background emission.

It is therefore fairly certain that the release of dust from the nucleus must have ceased somewhere between 10.1 and 12.5 AU heliocentric distance. The former coma has now dispersed into the surrounding space and it is no longer being replenished by dust from the nucleus. In other words, Halley seems to have entered a long period of hibernation which is likely to last until about early 2061 when it again comes within about 5 AU from the Sun and will again be awakened by the sunlight.



Still, an accurate evaluation of the seemingly point-like image seen on this picture indicates that it is somewhat elongated in the direction opposite to the Sun. Together with the extra light observed, this could mean that a very low level of activity is still present and that there may still be some dust in the immediate neighbourhood of the nucleus.

This will most probably not be the last image of Halley obtained during the present passage. Modern, large reflectors are able to image objects of 27th magnitude or even fainter, so it should be possible to follow this famous comet some years more.

R. M. WEST, ESO

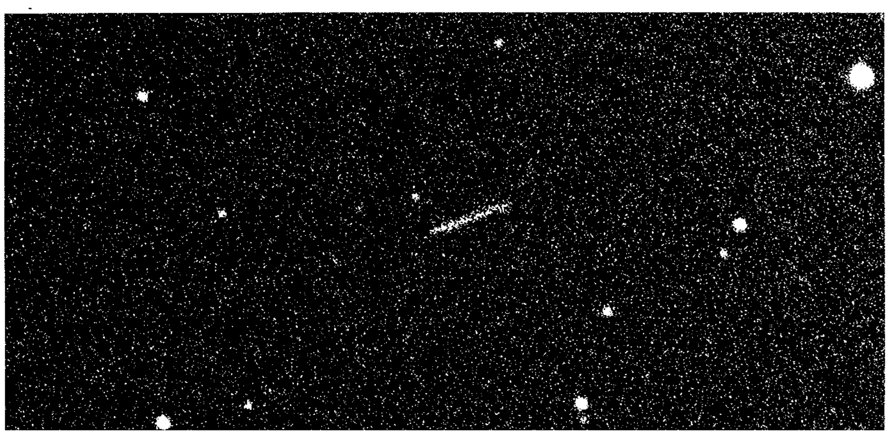
Minor Planet Named After Lo Woltjer

In the most recent issue of the Minor Planet Circulars, published by the Minor Planet Bureau of the IAU, the following naming of a minor planet is found on page 16591:

"(3377) Lodewijk = 4122 P-L

Discovered 1960 Sept. 24 by C. J. van Houten and I. van Houten-Groeneveld on Palomar Schmidt plates taken by T. Gehrels.

Named in honor of Lodewijk Woltjer, former editor of the *Astronomical Journal* and former director of the European Southern Observatory, well known for his studies on the Crab nebula. Name proposed by J. H. Oort."



We congratulate Lo Woltjer to this extremely well-deserved honour and show here a picture of his minor planet, obtained on 17 April 1988 with the ESO Schmidt telescope. Because of its motion, it is seen as a short trail on this blue 60-min exposure. On this date, "Lodewijk" was near opposition at a geocentric distance of 308 million kilometres.

The Editor

PROFILE OF A KEY PROGRAMME:

Investigation of the Galactic Distribution and Physical Properties of Carbon Stars

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After leaving the main sequence, stars of intermediate mass ($1 < M/M_{\odot} < 8$) evolve through various stages controlled by helium and hydrogen combustion. In one of these stages, called the asymptotic giant branch (AGB), hydrogen and helium burn alternately in shells around an electron degenerate carbon-oxygen core [1]. This core results from the complete combustion of helium during previous phases. Due to the high electronic thermal conductivity, its temperature is insufficient for carbon ignition. At the beginning of the evolution through the AGB, helium burns through triple-alpha reaction in a shell around the core which thus increases its mass (early AGB). This shell disappears progressively leading to the ignition of hydrogen in the surrounding shell. This second source of energy becomes progressively dominant.

As a consequence, the mass of the helium shell increases until helium is reignited violently in it (thermal pulse), then burns quietly while hydrogen in the upper shell stops burning. The star may experience 10 to 20 such cycles of $\sim 10^5$ years duration. During 10% of each cycle, the dominant source of energy is helium combustion, and, during the remaining 90%, hydrogen combustion. When helium is burning, the output luminosity of the star should be lower by 0.5–1 magnitude than when hydrogen is burning. This phase of the AGB – when helium and hydrogen are burning alternately – is referred to as the thermally pulsing AGB (TP-AGB) and often, by ellipsis, the AGB. After the AGB, the star evolves quickly (in $\sim 10^3$–10^4 years) toward the planetary nebula stage at approximately constant luminosity and then dies out as a white dwarf whose temperature and luminosity steadily decrease.

The shells in which nuclear combustion occurs are surrounded by a large convective hydrogen envelope. Following a thermal pulse, material processed by the triple-alpha reaction can be convected upward leading to an enrichment in carbon of the stellar surface. The carbon to oxygen (C/O) abundance ratio being normally inferior to 1, the surface composition is in general oxygen-rich and the stars are said to be of M-type. However, at each thermal pulse, the surface C/O ratio increases and, in some cases, can reach a value larger than 1, meaning that the surface composition becomes carbon-rich (C-type). This mechanism is thought to be responsible for most of the carbon stars (at least those on the AGB) in our Galaxy.

The hydrogen envelope is unstable and more or less regular pulsations develop in it. Stars on the AGB are classified, sometimes arbitrarily , as irregular, semi-regular or mira variables. It is thought that the regular pulsations of miras appear during the quiet phase of hydrogen burning; in general, their periods range from 100 to 500 days, but in some extreme cases may be larger. Following a thermal pulse, the star is thought to become an irregular pulsator of lower luminosity.

Also, through a mechanism which is still not well understood but which appears related to the pulsations, the stellar atmosphere is extended well above the photospheric radius ($R_{phot} \sim$ 1 A.U.). In some cases, it can reach such a large dimension ($\sim 10\ R_{phot}$) that, in its upper layers, refractory elements condense into dust. Dust formation has drastic consequences. Radiation pressure on grains accelerate them away from the central star and, in their motion, they drag the gas outwards. In these conditions, the star becomes surrounded by an expanding envelope of gas and dust. This mass loss phenomenon occurs preferentially during the Mira phases; however, some irregular and semi-regular pulsators are known to be also losing mass, whereas some miras, especially among those of short period (<350 days), do not appear to be undergoing significant mass loss.

The TP-AGB corresponds to a relatively short stage of the stellar evolution (10^6–10^7 years). However, its study is very important, because stars are reaching their maximum luminosity ($\sim 10^4\ L_{\odot}$) and experience most of their mass loss during this phase. Although we understand in broad lines the evolution of the stars through the AGB, our knowledge is often only qualitative and many relevant points stay unclear. For instance, the formation and evolution of carbon stars are still the subject of different interpretations. Also, the mass loss phenomenon is not well understood quantitatively; numerical models show that the stellar evolution through the AGB and later is strongly dependent on the mass loss history. Parameters such as helium abundance and metallicity (and in general individual element abundances) might have a strong influence on stellar evolution and, in particular, on carbon star formation; however, there is a lack of observational data in that field.

Finally, these objects during their phases of mass loss appear to be major contributors to the replenishment of the interstellar medium. The knowledge of the composition and of the total return rate of the matter that they are injecting into the interstellar medium at different galacto-centric distances is of basic importance for describing the chemical evolution of the Galaxy. This requires an accurate census of the AGB stars as a function of their location, type and mass loss rate.

In our approach of these problems, we concentrate on galactic carbon stars which are presently undergoing mass loss. Optical surveys are known to be biased against mass losing carbon stars; also, due to the interstellar absorption, they are limited to the solar neighbourhood. However, we have developed a selection method of such objects which is based on near-infrared (1 to 5 μm) and IRAS (12 and 25 μm) photometric data and which has been shown to be efficient and safe [2]. Starting from the IRAS LRS data base, we have then studied the carbon stars in the solar neighbourhood [3]. We now want to extend our study to several locations in the Galaxy, namely the disk at different galacto-centric distances and height above the galactic plane, by surveying, in an unbiased way, the mass losing AGB population in the galactic

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centre and anti-centre directions, and at different galactic latitudes.

For every sub-sample, the distributions of objects in function of their bolometric luminosities and mass loss rates will be evaluated. As the samples contain stars of different pulsational behaviours, the relationships between type of variability, luminosity and mass loss rate will be investigated. Initial masses of carbon star progenitors will be derived through their distribution perpendicularly to the galactic plane. Because metallicity depends on the galacto-centric distance, its effect on the formation and evolution of carbon stars will be sorted out. Also, the mass-return rate from carbon stars will be determined as a function of the distance to the galactic centre.

This investigation will thus cast new light on the physical properties of carbon stars in different physical and chemical environments, and on the chemical evolution of the interstellar medium throughout the Galaxy.

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PROFILE OF A KEY PROGRAMME:

High Precision Radial Velocity Determinations for the Study of the Internal Kinematical and Dynamical Structure and Evolution of Young Stellar Groups

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Purpose

Presently observable sites of star formation corroborate the viewpoint that the birth of stars occurs in groups. Such groups remain gravitationally bound for a shorter or a longer time interval and are catalogued as open star clusters or associations depending on their compactness. As far as the dynamical state of these groups is governed by the conditions in the initial phases of cloud fragmentation, star formation and nebular gas expulsion, they contain valuable information about the star birth processes and the early dynamical evolution of a star forming region (1). Evidently, the younger the groups, the more the present state reflects the initial characteristics.

An important key to the progress in such studies is the availability of information on the internal kinematics in stellar groups: the internal velocity dispersion, and its spatial and stellar mass dependence (2). That purpose imposes an accuracy of the order of a few km/s on empirically derived kinematical quantities for a considerable number of stars covering a large range in stellar mass (3). Nowadays, instrumental technology is at the point that makes such observational efforts feasible. CCD echelle spectroscopy on ground-based telescopes offers the opportunity to record good quality (S/N $>$50) spectra over the extended wavelength range required in order to acquire sufficient spectral information in early-type stars. CASPEC at the 3.6-m ESO telescope provides the stability and efficiency to obtain a reasonably large set of radial velocities (RVs) with an accuracy that is limited by stellar atmosphere physics or standard system calibration rather than by the instrument. We concentrate on the 3 subgroups in the Sco-Cen OB association and on the more distant young cluster NGC 2244 in the Rosette nebula, aiming at a detailed survey of about 500 O-F type respectively 50 O-A0 type stars. The radial velocity study is part of a continuing observing programme on nearby clusters and associations, including Walraven photometry (4, 5, 6), astrometry from HIPPARCOS, mapping of molecular gas (7), and spectroscopy for classification (6). The theoretical side of our study consists of N-body hydrodynamical simulations of stars embedded in gas (8). Reliable empirical information on the dynamical state of young stellar systems is essential as input in such numerical experiments and in theoretical models.

Interpretation of the Data

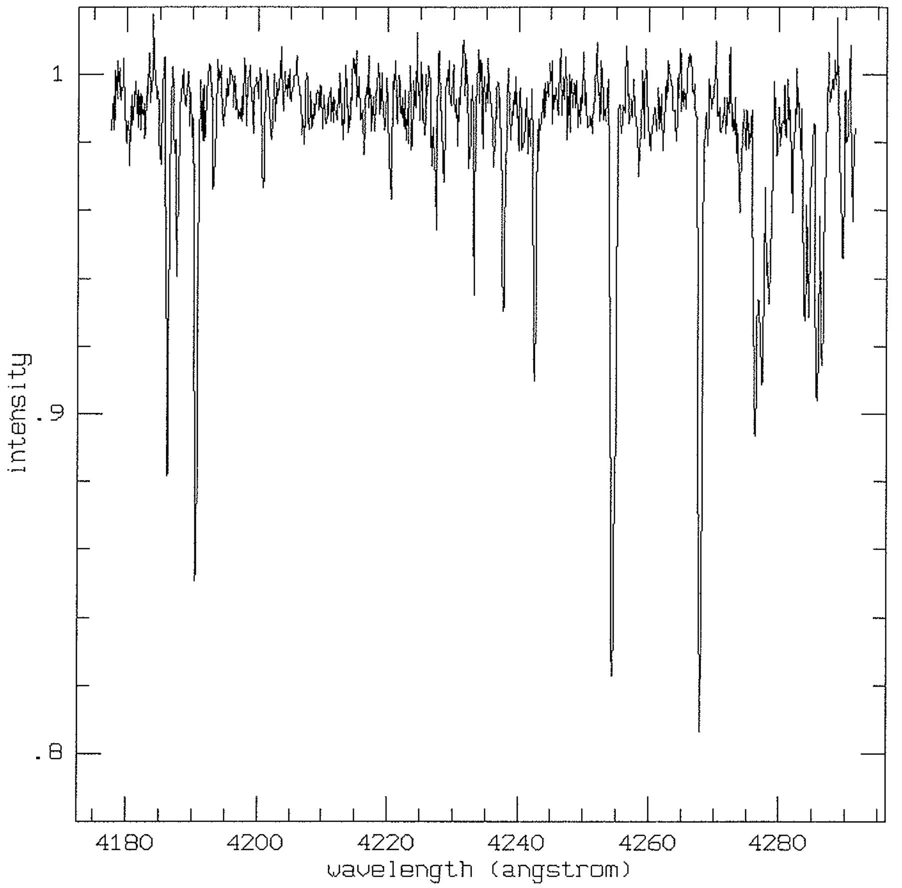
The determination of RVs in early-type stars with the required precision is, for several reasons, a challenge. The application of CORAVEL in RV work has opened new frontiers in the study of late-type stars, based on a high quality RV standard system. The use of the CORAVEL technique is unfortunately not extendable to earlier types. The establishment of a better standard system at early spectral types is still essential and our observations are expected to contribute to this task (9). RVs will be measured by the cross-correlation technique (10), although attention will have to be paid to discern systematic effects possibly originating from subsystems of spectral lines; systematic atmospheric motions in OB stars might bias the apparent RVs and could be detectable from lines formed over different atmospherical depths. As a by-product, this should almost certainly lead to additional insights into the atmospheric structure of hot stars.

It is essential, although time consuming, to disentangle effects due to binarity from effects reflecting the kinematics of the stellar group (11). Especially the lack of recognition of wider binaries with an RV amplitude of the order of 10 km/s might significantly influence the conclusions. Hence, repetition of RV observations is necessary and will in turn increase our knowledge on binarity in the selected young stellar groups. The spectra will in addition allow a study of stellar rotation in these star groups (12).

In many respects, this project forms an extension towards the earliest spectral types of the key programmes of Mayor et al. and Gerbaldi et al. (described in the *Messenger* **56**), even when the primary scientific motivation is somewhat different. In addition to the common interest in radial velocities, the stars in Sco-Cen are also observed by the Hipparcos satellite, providing space motions when combined with the RVs. Using these, we hope to reconstruct the initial minimal volumes in which the star formation occurred which gave rise to the presently expanding Sco-Cen subgroups, and to discuss the possibility of sequential star formation (13).

First Results

Strictly within the frame of the key programme, the first spectra have been obtained on 3 nights in May 1990. However, a limited amount of data has been obtained during the last three years with CASPEC and has resulted in the establishment of a stable, accurate wavelength calibration procedure (14) and an optimized echelle reduction method (15). Presently, we can concentrate on the proper radial velocity work. In NGC 2244 we detected a number of slowly rotating O and B stars (out of our current sample of 17, 5 had v·sin i <30 km/s), whose narrow lines are favourable to a very accurate determination of the RV (Fig. 1).



Part of the CASPEC spectrum of NGC 2244-201, a 10th magnitude B1 V star. The strongest lines are OII 4185, OII 4190, NII 4242, OII 4254, CII 4267, a complex of OII lines around 4277A, OII 4283, SIII 4285 and OII 4286.

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The Status of the Hubble Space Telescope

As you have certainly learnt from the news media, the focussing tests carried out during last June revealed that the Hubble Space Telescope suffers from spherical aberration. The amplitude of the aberration is about half a wavelength rms and it has a negative sign, i.e. the marginal focus lays further away from the secondary than the paraxial one. The resulting Point Spread Function is characterized by a sharp core of about 0.1 arcsec surrounded by an extended "halo": unfortunately the core encircles only about 10–20% of the energy. The forthcoming issues of the ST ScI and ST-ECF Newsletters will contain more quantitative details on the problem.

Although the spherical aberration prevents HST to reach its "level 1" specifications (about 70% encircled energy within 0.1 arcsec) and has serious consequences on its imaging capabilities, the actual impact on the scientific output has to be evaluated a bit more carefully than what has been unfortunately done by the generic press. In particular, any comparison with the capabilities of ground-based telescopes has to consider the uniqueness of the UV imaging from space and the fact that, since the HST Point Spread Function departs considerably from a gaussian-like profile, spatial resolutions cannot be compared just by using the FWHM as a parameter. Moreover, the two HST spectrographs are less affected than the cameras and most of the scientific programs should still be feasible, albeit with an increase in the exposure times.

Currently, a Scientific Assessment Team has been formed at the ST Science Institute with the task of preparing an observing programme (to be carried out in August-September) which will allow a better evaluation of the actual performance of the scientific instruments. The relevant data will be made available to interested scientists shortly after the observation. Concurrently the Guarantied Time Observers and General Observers' proposals are being reviewed for feasibility and modification. More about this exercise will be published in the ST Newsletters, in the electronic Bulletin Board and communicated directly to the HST Principal Investigators.

On the front of correcting the problem, NASA intends to speed up the construction of the second generation instruments, in particular of the WF/PC II, which will include appropriate modifications in the optical design to compensate for the spherical aberration of the telescope. The situation of the ESA Faint Object Camera in the light of the HST performance will be reviewed in the coming weeks.

Considerable effort is also being invested in evaluating the applicability of different image restoration methods. ECF staff, in collaboration with ESO colleagues, is experimenting with different algorithms on simulated images which make use of the actual, aberrated, HST psf. The results will be presented to a specific workshop on the subject which has been organized by the ST Science Institute on August 21–22. Meanwhile the ECF continues to maintain contact with the European PIs who are involved in Cycle 1 observations offering assistance in the review and possible modification of their programmes.

P. BENVENUTI, ST-ECF

"Matching Error" (Spherical Aberration) in the Hubble Space Telescope (HST): Some Technical Comments

R. N. WILSON, ESO

Much consternation has been caused in the astronomical community because of the revelations since the last week of June that the Hubble Space Telescope (HST) has a systematic error giving an image with about 70 % of the geometrical light energy within about 1.5 arcsec diameter instead of less than the 0.1 arcsec predicted from its specification of "diffraction limited performance" for visible light (wavelength 500 nm). The error has been identified as mainly spherical aberration due to "matching error". The above quality figure has been quoted in a number of reports, but may include other errors (including residual focus error) of unknown amount. From more specific information on the amount of spherical aberration, I have calculated below that the spherical aberration error *alone* would give an image at best focus with 100 % of the geometrical light energy within about 1.5 arcsec diameter.

Before considering further the origins of this error, let us look at the meaning of the term "spherical aberration". Elementary text books on optics usually explain it as a "longitudinal aberration" as shown in Figure 1. Rays coming from the central part of the optical system (near its axis) focus at the point O on the axis, whereas those from the outer circumference focus at A. The sign of the aberration as shown above with A to the left of O is what a simple convex lens would generate, whereas in the HST it is probably the opposite. The distance AO is called the longitudinal spherical aberration and is about 40 mm in the HST. If the focus for the detector is chosen to be at O (the so-called paraxial or Gaussian focus), then the total transverse spread of the light has the diameter BC. It can be shown that, for the basic (so-called "third order") spherical aberration, the optimum focus reducing the diameter of the light patch to a minimum is at D, one quarter of the distance from A to O. This minimum diameter is called the "disk of least confusion" EF which is obviously one quarter of BC. Taking AO as about 40 mm in the HST, an exit beam of f/24, the diameter BC containing 100 % of the energy at the Gaussian focus is 6.0 arcsec; at the best focus it is 1.5 arcsec. These figures, expressing angular aberration, can easily be converted into the so-called "wavefront aberration" which gives the maximum phase error of the image forming light. This is 4.34 μm for the above figures and an aperture of 2.4 m for the HST. This wavefront aberration is the best physical measure of the error and is, in fact, exactly twice the maximum error on the mirror surface involved, referred to the Gaussian focus, which is therefore 2.17 μm. Frequently, the rms (root mean square) error on the surface has been quoted which is about one sixth of the above, or 0.36 μm, or somewhat more than half a wavelength of laser light of 0.632 μm. The above figures reveal how essential it is to define exactly what definition is being used, otherwise serious confusion results.

Let us now return to the probable origin of this spherical aberration error in the HST.

In the technical domain of the produc-

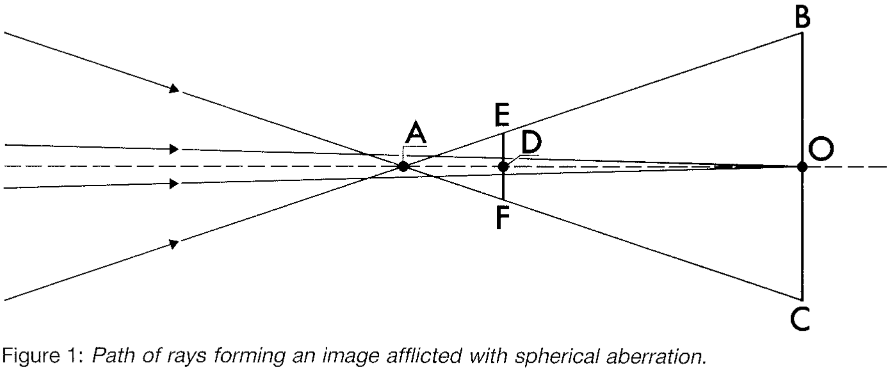

Figure 1: *Path of rays forming an image afflicted with spherical aberration.*

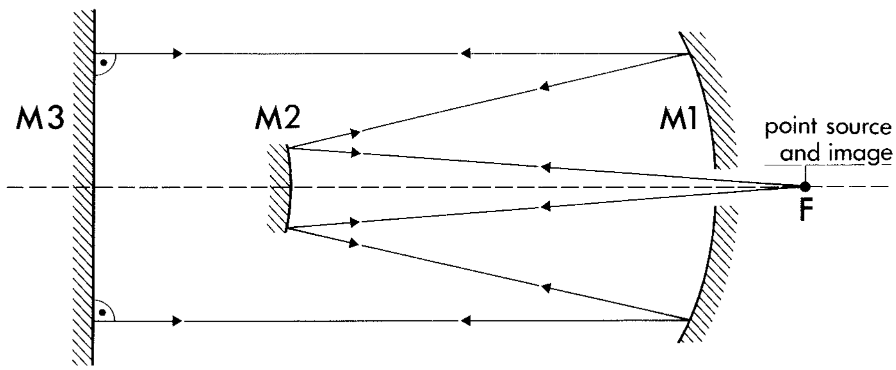

Figure 2: *Autocollimation test of a Cassegrain telescope in functional geometry against a plane mirror. A point source at the nominal focus F sends a light beam backwards through the telescope which is reflected back in the same path by the plane mirror M3. The image formed at F contains the errors of M 1 and M2 doubled by the double pass. Any errors of M3 are also imprinted on the image. In practice, a plane mirror M3 of adequate quality is prohibitively expensive and difficult to produce for diameters above 1 m. The errors in the image at F are measured by an image analyser, usually an interferometer or a Shack-Hartmann device.*

tion of large precision optics, the danger of such "matching error" is well known. A complete functional test of a combined Cassegrain system (see Fig. 2) cannot be performed for apertures above about 1 m since a plane mirror of the excellent quality required does not exist for larger apertures – even a 1-m diameter flat is a rare and very expensive element. However, there are other possibilities for testing for "matching error" in a functional way, as shown below.

In practice, the primary mirrors of modern large telescopes are tested in autocollimation at their centres of curvature, the errors being determined by interferometric or Hartmann type analysis of the image. Since modern, short primaries are strongly aspheric (slightly hyperbolic for Ritchey-Chrétien type telescopes) the autocollimation image is strongly aberrated. This aberration is normally compensated by a so-called "compensation" or "null" system, so that the errors can be referred to a corrected image. This key technology was first proposed by the English amateur Horace Dall in 1947 [1] and is the basis of most modern mirror testing. The "null system" must be correct to very high precision, in its design, manufacture *and in its positioning in the test set-up* – otherwise a systematic error arises which is spherical aberration in its classic form.

Cassegrain secondaries are more difficult to test because they are convex and cannot deliver a real image without an ancillary system. Testing of convex secondaries is a whole technological area in its own right [2]. However, the test methods will all have tolerances (more or less severe, depending on the method) which will lead to a similar systematic spherical aberration error if they are not rigorously respected. But there is one test of secondaries which effectively ensures that such "matching error" cannot occur. This is the so-called "Pentaprism Test". In fact, the Pentaprism Test is only a test of the spherical aberration, i.e. a test to ensure that the basic form of the two mirrors will, in combination, give an image free from spherical aberration at the nominal Cassegrain focus. For other errors over the surface such as astigmatism or high spatial frequency errors, some other test of the whole surface is required and various possibilities exist [2].

The Pentaprism Test (see Fig. 3) was probably first invented by Wetthauer and Brodhun in 1920 [3] and has been systematically used by a number of manufacturers, for example REOSC in Paris [4], who have applied it routinely with great success for 25 years or more, or Korhonen in the successful manufacture of the optics of the recently completed 2.5-m Nordic Optical Telescope. It was also used already in 1939 in the United States by Hendrix and Christie [5] in connection with Schmidt systems, and described by Hochgraf [6] in 1969. It seems surprising that this test, which is simple and cheap to set up (with the system axis either horizontal or vertical), was not applied to the HST, since it would certainly have revealed the error. However, its use is by no means general in the manufacture of ground-based telescopes which explains why "matching

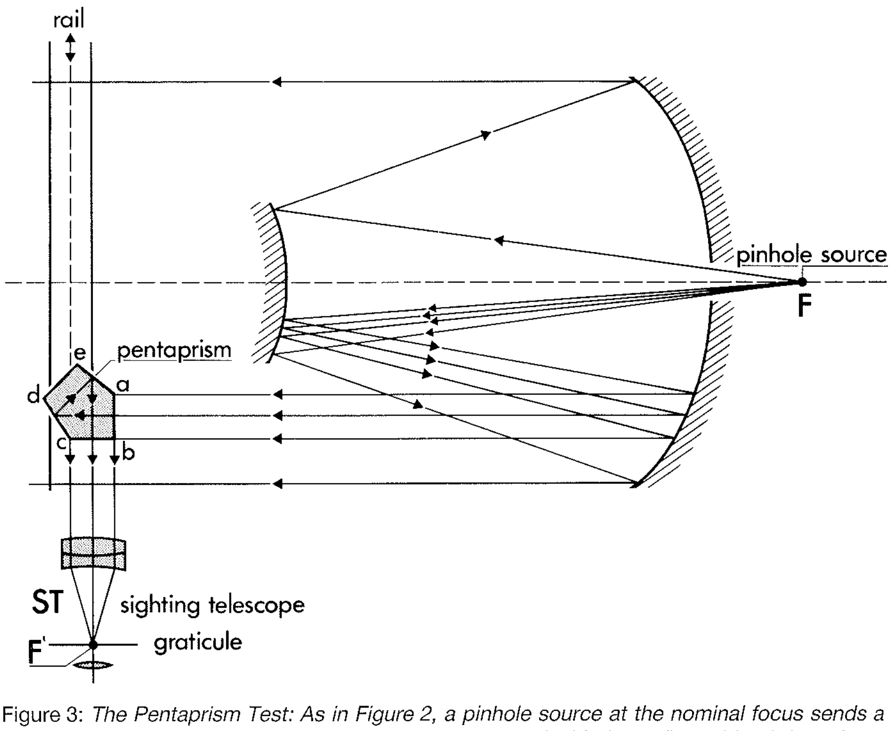

Figure 3: *The Pentaprism Test: As in Figure 2, a pinhole source at the nominal focus sends a beam of light backwards through the telescope. Instead of being reflected back by a large plane mirror, a small part of the parallel beam enters the face ab of a pentaprism which can be moved along a rail across the diameter of the telescope. After reflections at faces cd and ea of the pentaprism, the selected beam emerges via face cd deflected about 90 °. A fixed sighting telescope ST, firmly mounted, measures the direction of the beam by observing the image F' of F on a graticule. The basis of the test is that, in the section shown in the diagram,* the deflection of a pentaprism is unaltered by small rotations of the pentaprism about an axis perpendicular to the plane of the paper. *Such small rotations of the pentaprism are unavoidable in moving it across the diameter, but have no effect on the angles measured in the plane of measurement. Thus one can measure directly the differences of angle of the small beams as the pentaprism is moved over the telescope diameter. This measures directly the angular spherical aberration, from which integration gives the wavefront aberration. Other errors, such as defocus and coma, can be eliminated as they have a different dependence on distance from the axis.*

error", often very large, has been a common technical error. One telescope where this happened was the Canada-France-Hawaii-Telescope (CFHT), for which the spherical aberration was afterwards successfully corrected by bending the secondary (a case of dc-fixed-active correction at the secondary).

The NTT also had a matching error, provoked by a systematic error in positioning of the compensation systems used in testing the primary. Although this error was small (1.8 mm in a test distance of about 15.4 m) the spherical aberration error introduced had a coefficient (i.e. peak-to-valley wavefront aberration) of about 3000 nm. This corresponds to an image diameter, for this effect alone, containing 100% of the geometrical light energy, of 0.71 arcsec at optimum focus. Although this was outside the so-called "passive" specification, *we were able to correct it completely by the first (fixed) level of the active optics system of the NTT,* as has been reported in our recent paper "Active optics IV" [7].

It is interesting to consider the decisions taken with respect to a possible matching error at the time of the contractual discussions for the optics of the NTT. At that time, the author proposed to the manufacturer, Carl Zeiss, that a pentaprism test be done to ensure that matching error would be negligible. However, the active optics concept allows relaxed tolerances precisely for such errors as spherical aberration (this is one of its two principal aims) and a relaxation up to a coefficient of the order of 2000 nm was proposed. Furthermore, the test procedures for primary and secondary comprised not only tests at the normal visible wavelength (632 nm) but also a test with an independent IR system working at a wavelength of 10 μm. Although the resolution of the IR system was about 16 times lower than that of the visible one, it was considered by Carl Zeiss that an error exceeding the tolerance would be detected by the comparison between the two systems. (In fact, the matching error made *was* detected in this way, but was believed to be still just within the measuring noise – all other errors showed excellent agreement between the two test systems). Because of the tight time schedule, ESO and Carl Zeiss agreed to drop the pentaprism test in view of the above cross-check security of the tests and the considerable dynamic range of correction of the active optics system. This decision was subsequently validated by our ability to achieve complete correction actively of the matching error as well as all other actively controllable errors in the system, giving the spectacular image quality results of the NTT [7]. The essential feature of the figuring work by Carl Zeiss was the excellent quality regarding the more rapidly varying (higher frequency) defects on the surfaces such as zones or local hills and hollows, for which they were well inside the very hard specification. Thus the excellent work of Carl Zeiss and the NTT active optics system were both essential and complementary to each other for the success of the final optical system.

The HST, by contrast, has a very stiff, lightweighted, egg-crate type of primary. From its nature, the dynamic range available with the 24 actuators operating on the primary must be far too small to permit correction of a matching error significantly larger than that of the NTT in terms of wavefront aberration. Probably only a retouch of astigmatism would be possible with them. So the HST is effectively a passive telescope so far as bending (correcting) the primary is concerned. For this situation, the pentaprism test would have been the best guarantee against matching error. It is reliable, simple and cheap.

Statements have been made that the current performance of the HST is as good as the best ground-based telescopes. This is certainly not true. Apart from the NTT which – because of its active optics, very "smooth" mirrors and building concept – routinely produces total images at the excellent La Silla site with a d_{70} (i.e. diameter containing 70% of the geometrical light energy) of less than 0.5 arcsec, there are a number of excellent "passive" telescopes in operation (including the William Herschel Telescope) capable under favourable seeing conditions of producing total images with a d_{70} well under 1 arcsec. In contrast, the HST has a d_{70} from given data of about 1 arcsec from the spherical aberration alone.

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HST Images: What Can Image Processing Do?

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In these first days after the actual image quality of the Hubble Space Telescope has become known, two lines of effort to achieve improvements are being mentioned most often: optical correctors in the second generation instruments and numerical image processing – i.e., deconvolution. The first measure will undoubtedly be more effective but its realization will take at least 2½ years. Deconvolution, on the other hand, can be applied already to data achievable with the present instrumental configuration.

Previous Work

Originally, image restoration algorithms were thought to be desirable for HST data because most of the imaging modes would undersample the anticipated point spread function (PSF). We therefore developed and implemented one such technique (Lucy and Baade, 1989), which combines deconvolution with a simultaneous resampling to a smaller pixel size. In that particular implementation, an iterative deconvolution method (Lucy, 1974) was used, but our technique of simultaneous resampling can in principle be mated with other image restoration algorithms, e.g., the maximum entropy method. Indeed, such tests as have been carried out (Heasley, 1984) indicate that the maximum entropy method will yield results

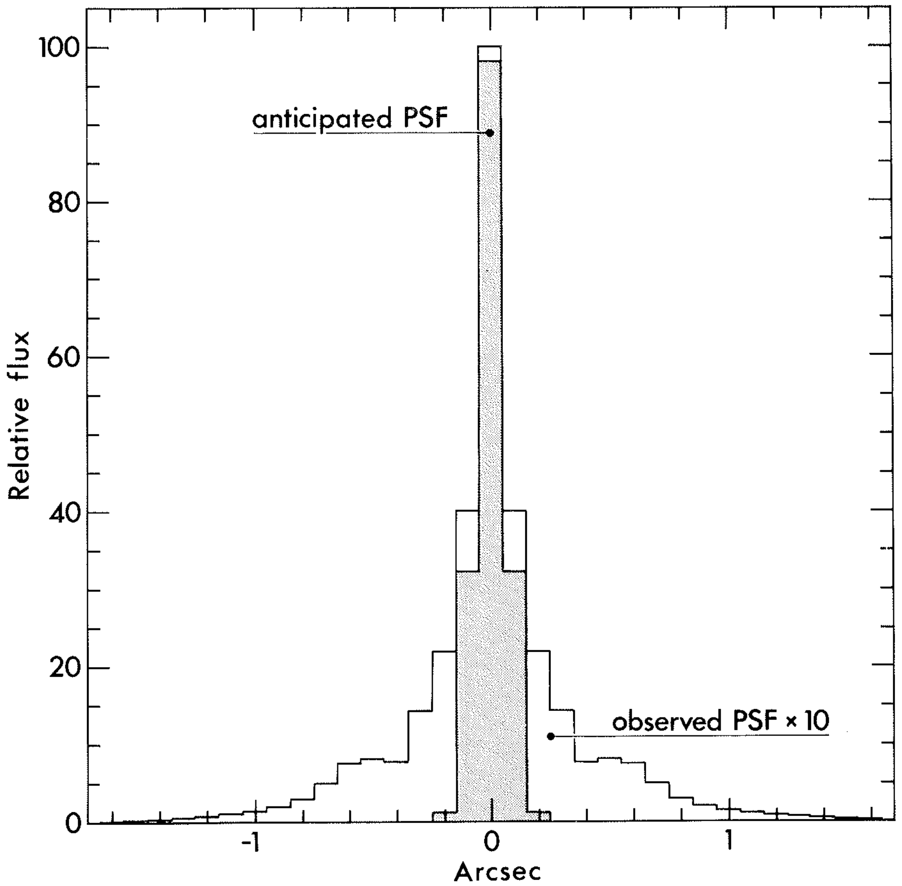

Figure 1: *Central cuts through the adopted and the originally specified (shaded) point spread functions of HST sampled with 0.1 arcsec pixels. Both PSF's are normalized to the same total flux but the adopted PSF is plotted on a 10 times expanded flux scale.*

closely comparable to those presented herein.

Readers of the *Messenger* have already seen examples of the performance of the deconvolution method in No. **56,** p. 3 and p. 35, where it was applied to the first NTT images and to 3.6-m telescope observations of the nebulosities around SN 1987A, respectively.

Numerical Experiments

In a note dated June 29 and posted on the electronic bulletin board of the Space Telescope-European Coordination Facility, H.E. Bond and H.S. Stockman (Space Telescope Science Institute, Baltimore) provided the fractional encircled energy at radii 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 1.0, and 1.5 arcsec as measured with the Planetary Camera on board HST during June 10–24. Under the assumption of circular symmetry, we have used this information to construct the PSF plotted in Figure 1. This adopted PSF has a full width at half maximum (FWHM) of 0.2 arcsec (or two pixels). However, the comparison (Fig. 1) with the original specifications for the PSF shows how dramatic the loss in contrast actually is (or, conversely, how big the gain over conventional ground-based observations could have been). Note that the non-monotonic decline of the adopted, schematic PSF is in agreement with actual HST stellar images, which consist of a core and a ring-like outer halo. Since, in the absence of a real focus position, the definition of "the" PSF is in fact somewhat blurred, our approximation should be good enough to test the viability of deconvolution techniques for HST images. This is the purpose of our present exercise.

Our simulations assume a pixel size of 0.1 arcsec and therefore correspond to the case of the Wide Field Camera. Figure 2 illustrates the effects of deconvolution on a single noise-free point source with perfectly compensated (i.e., black) background. As can be seen, by going from 10 to 20 iterations – as would be appropriate for very high S/N data – the gain achieved is still worth the effort. The comparison with the two PSF's of Figure 1 shows that although the shortfall with respect to the original specifications is still large, the improvement over the raw data is even larger. In these deconvolutions, the resampling option was turned off.

As can partly be seen in Figure 1, the PSF has a very narrow core which, in some observations, has been found to be as narrow as 0.07 arcsec FWHM but to contain only about 15% of the total flux. This shows that, in spite of the broad wings, there is still genuine high-frequency information in HST images and that this is only sparsely sampled. In order, therefore, to test the ability of our technique to recover some of this high-frequency information, we have simulated observations of a double-star in the following way: Star A, of total flux 3000 units, is located at fractional coordinates (0.7, 0.4) pixels. Star B is 2.5 times (i.e., 1 mag) brighter and is shifted with respect to Star A by (−4.1, −1.3) pixels, which corresponds to a separation of 0.43 arcsec or just over 2 times the FWHM of the PSF. Neither stellar profile includes noise, but a background with an average flux of 50 units per pixel and Poissonian noise has been added. The raw image as well as the results of 10 and 20 iterations of the deconvolution algorithm with simultaneous resampling by a factor of 3 in both dimensions are shown in Figure 3.

From other experiments with our method, we have found that, with a Gaussian PSF, a necessary condition for it to be able to separate two point sources is that along the line connecting the centres of the two sources a local minimum occurs. (For example, two stars of equal brightness usually need to be separated by more than one FWHM.) This makes sense because without further information it is otherwise impossible to distinguish between two point sources and a truly elongated, single object. Our double star just satisfies this condition. Generally, the ability to separate two closely spaced point sources depends on their relative distance and their brightness ratio. Because of the narrow core of the adopted PSF, the corresponding two-parameter space for the nominal performance of HST appears relatively little affected with respect to separation, whereas the constraint on the maximum allowable brightness ratio at a given scale is strongly compromised. In other words, the ability of HST to resolve fine structures is not too severely affected so long as their contrast difference is small.

In some sense, our input assumptions represent a worst-case situation: The relative noise in the background is high, the separation is small, and the sampling is the coarsest of all HST imaging modes. We therefore infer that cameras on board HST with imaging modes that sample the reported 0.07 arcsec core of the telescope's PSF better than in our crude simulation of the Wide Field Cam-

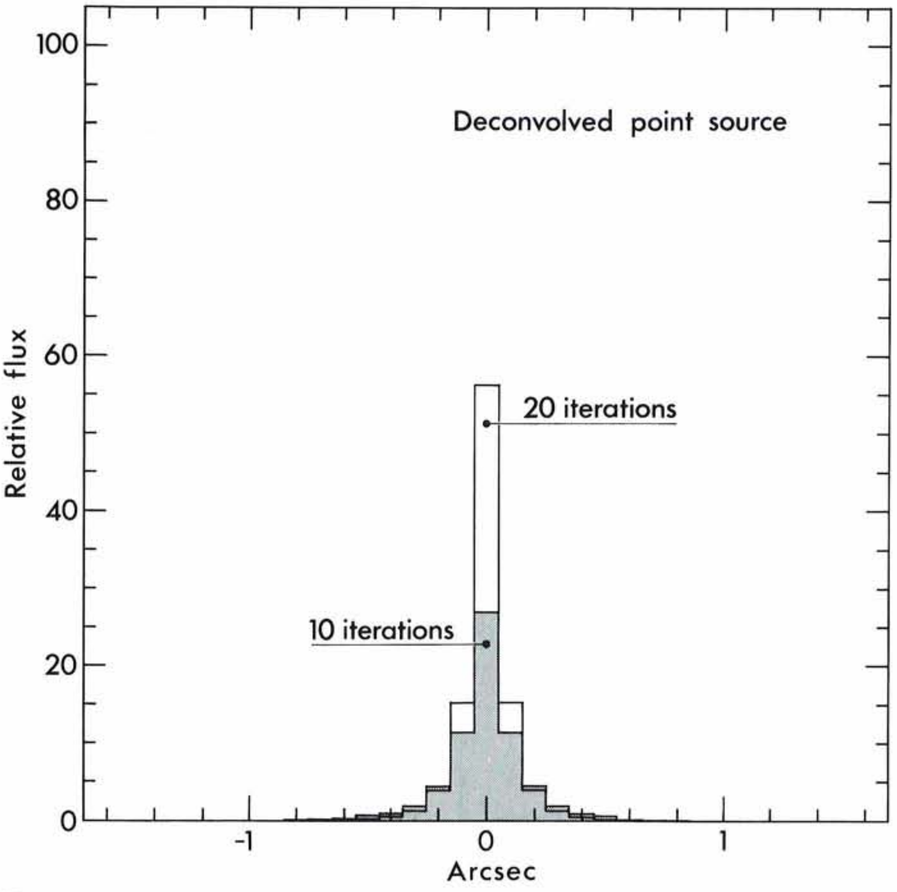

Figure 2: *The adopted PSF after 10 (shaded) and 20 deconvolution iterations, respectively. Flux scales and total fluxes are the same as in Figure 1 for the specified PSF.*

era will yield data from which image structure can be restored at spatial frequencies that are presently still inaccessible to routine direct imaging from ground-based observatories.

Even on an array processor and after vectorization of the code, the amount of computer time required for the deconvolution of a full 1600 × 1600 pixel WFPC image will still be very considerable, especially with the resampling option. However, given the other expenses of the HST project – or even only the costs of replacing some of HST's instruments – this point is of relatively minor importance. Nevertheless, if the assumption of point sources is justified or other additional information is available about the nature of a given structure, PSF fitting and similar, source-model techniques are much more effective than an assumption-free deconvolution. However, even then, a previously applied, mild deconvolution could still be advantageous, as it provides a PSF-neutral smoothing, especially if the simultaneous resampling option is chosen. It may also help to recover part of the loss in limiting magnitude incurred because of the image spread.

Existing Options

We conclude this brief report by pointing out that the tools we have been using here have, since the 1989 November release of ESO's MIDAS image processing system, been made generally available (command REBIN/DECONVOLVE, context PHOTOM) so that anyone interested can repeat our experiments but tailor them more specifically for the needs of a particular observing programme. Indeed, such experiments could determine whether the scientific goals of an approved imaging proposal can still be at least partly achieved. Note that the MIDAS implementation can accept any numerical representation of the PSF and does not require axial symmetry. Thus, already available is the option of carrying out deconvolutions using the highly structured, two-dimensional observed PSF, which shows numerous spikes and rings.

With respect to the resampling option, it should perhaps be stressed that this is implemented (Lucy and Baade, 1989) without any degradation of the observational data. In contrast, this is not true for the experiments reported by Evans et al. (1989) since their shifting and adding procedure for introducing sub-pixels represents a convolution applied to the observed data.

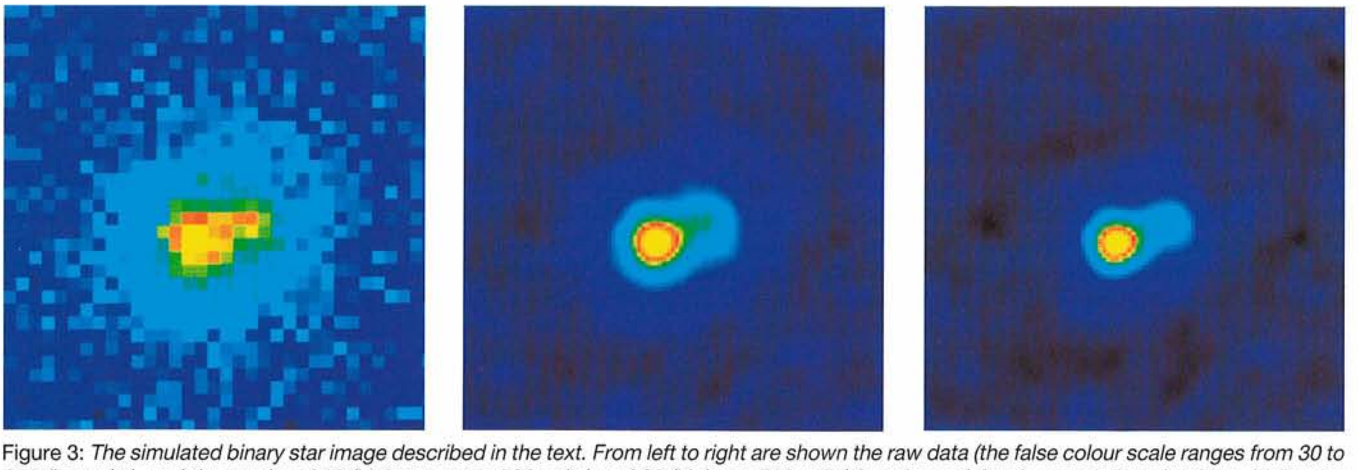

Figure 3: *The simulated binary star image described in the text. From left to right are shown the raw data (the false colour scale ranges from 30 to 220 flux units), and the results of 10 (high cut set to 530 units) and 20 (high cut 760 units) iterations of the deconvolution algorithm. In the raw data, the coarse 0.1 × 0.1 arcsec pixels are clearly seen. The deconvolved images are smoother partly because of the simultaneous resampling to a pixel size of 1/30 arcsec and partly because of the deconvolution algorithm's reluctance to introduce structure on a finer scale than the PSF allows.*

Potential Options

If required, the programme could be extended to take account of the variation of the PSF with position in the focal plane.

At present, the code assumes a spatially invariant PSF but, in contrast to, e.g., Fourier transform techniques, this assumption is not fundamentally demanded by the iterative deconvolution algorithm.

A further possibility is to develop a code that simultaneously deconvolves several images of the same field, each of which is displaced by a fraction of a pixel.

This possibility, which has been investigated theoretically by Adorf (1989), introduces an element of image reconstruction by tomography and might well be useful for certain objects with structure on the scale of the narrow core of the observed PSF.

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ESO'S EARLY HISTORY, 1953–1975

VIII. The 3.6-m Telescope Project; From Concept to the Late 1960's*

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"Le programme initial de l'Organisation comporte la construction, l'installation et le fonctionnement d'un observatoire dans l'hémisphère austral, comprenant: a) un télescope d'environ 3 mètres d'ouverture; – – –"
From the ESO Convention, Art. II.2.

Introduction

This article reviews work towards the realization of the 3.6-m telescope from the early beginnings of ESO up to the moment, at the end of 1969, when Council drastically changed course. These early years saw an Instrumentation Committee, a Directorate and an engineering bureau devoted to the creation of an instrument of dimensions and costs, an order of magnitude larger than anything achieved so far in optical astronomy in Europe. Unfortunately, lack of experience proved to be a serious drawback, and this unavoidably puts its stamp on the present, somewhat cheerless, account. The new approach adopted by Council late 1969, will be described in the next article.

Basic Concepts

A telescope project like the one for the ESO 3.6-m telescope, starts by specifying the dimension of the main mirror as this determines the light gathering power of the instrument, and by choosing the desired focal ratios for the different modes in which the instrument is to be used; the Prime focus, the Cassegrain focus and the Coudé focus. These focal ratios determine the dimensions of the telescope tube. The design of all other components of the project follows from these. It has been mentioned before (article IV) that the example ESO had in mind in the very beginning was the 3-m telescope of Lick Observatory, however the ESO design soon deviated from this.

Naturally, the designs of the various components of the project are interrelated, but once a certain stage has been reached, the further development and construction of the various parts tends to proceed largely independently. For our project this was particularly so for, on the one hand, the housing of the telescope, i.e. building and dome, and on the other hand the ensemble of tube, optics and mounting. Within the latter again a subdivision can be made: the combination tube/optics, and the mounting plus drive. The account on the progress in the project can be subdivided accordingly. Up to the early 1970's, the progress of the project as a whole was determined almost entirely by the (lack of progress in the) design of the mechanical parts of telescope tube and mounting. Contrary to what seemed to have been a tradition in earlier generations of large-telescope building, progress for the ESO 3.6-m telescope was not determined by the completion of the optics.

Early Conferences and Texts

The early years of ESO's project coincided with a general, international broadening of interest in large-telescope building and the publication of significant documentation. In the year 1960 appeared the compendium "Telescopes", Volume I of the series Stars and Stellar Systems edited by Gerard P. Kuiper and Barbara Middlehurst. It contained chapters by leading experts, among which descriptions of the two recently completed largest instruments: of the 200-inch Hale Telescope by Ira S. Bowen, and of the Lick 120-inch by W.W. Baustian; and furthermore chapters on Design of Reflecting Telescopes by Aden B. Meinel; and on Schmidt Camera's, again by Bowen. This Volume became a basic reference text for the next decades.

Another important event was IAU Symposium No. 27, "The Construction of Large Telescopes" held from 5 to 12 April 1965 at Tucson, Arizona, and at Pasadena and Mt. Hamilton (Lick Observatory) in California. The proceedings, edited by David L. Crawford and published in 1966, contained much basic information and instructive discussion reports. Among the participants from ESO countries were Baranne, Bahner, Courtès, Elsässer, Fehrenbach, Heckmann, Ramberg and the engineer who worked for ESO, W. Strewinski. In the present context mentioning should be made also of K. Bahner's Chapter "Teleskope" in Handbuch der Physik, Vol. 29, 1967, and Bahner's article "Large and Very Large Telescopes; Projects and Considerations" in ESO Bulletin No. 5 of December 1968, which includes a summary of large telescope projects under design or construction in December 1967.

Finally, as a quite useful – and readable! – review of the main elements in large-telescope construction and the status of the principal projects, let me mention B.V. Barlow's monograph "The Astronomical Telescope" of 1975 [1].

* Previous articles in this series appeared in the *Messenger* Nos. 54 to 60.

The Choice and Ordering of the Optics

The increase of the originally suggested diameter of the big mirror from 3 to 3.5 m (eventually 3.6 m) was one of the outcomes of the visit of Fehrenbach and Heckmann to observatories in the United States in 1961 (see article IV). Experience with the recently completed Lick 3-m telescope had shown that the observers-cage at the prime focus was inconveniently narrow when used by a bulky observer. As, however, an increased diameter of the cage would block an unacceptably large part of the surface of the 3-m primary mirror for the infalling light, Heckmann and Fehrenbach suggested an increase of its diameter to 3.5 m [2]. The ESO Committee in its meeting of November 1961 took note of this, but thought it wise not yet to change the text of the Convention which was still in the process of being approved by the governments. For the time being, the formulation "un télescope d'environ 3 mètres d'ouverture" would leave the door sufficiently open for changing the size once signing and ratification would have passed. However, in the planning of the telescope, a mirror diameter of 3.5 m soon became the canonical figure, and this grew to 3.6 m after it had turned out later – in 1967 – that the blank of 3.72 m diameter, as delivered by the manufacturer, Corning, allowed a useful diameter of at least 3.6 metre. In retrospect, it seems to have been ESO's good fortune that one of Lick Observatory's most ardent observers of the 1950's, apart from being highly respected scientifically, also was one of more-than-average circumference . . .

The order to Corning in its final form was placed on January 25, 1965. The blank, made of fused Silica, was accepted at Corning's (at Bradford, USA) on February 23, 1967 in the presence of Fehrenbach, Heckmann, J. Texereau (of the Laboratoire d'Optique of Paris Observatory) and J. Espiard of the firm of REOSC in Ballainvilliers, France, where the mirror was to be processed for its final shape. The contract with REOSC was signed in June 1967 and the blank arrived there later that year. After it had turned out in the course of 1968 that the blank showed certain superficial defects which required providing it with a new toplayer at Corning's, it was back again at REOSC in September 1969 for final processing. This was completed two years later; in February 1972 formal acceptance by ESO took place. By that time two studies of the properties of the mirror had been published. One, in 1967, by J. Texereau in collaboration with J. Espiard: "Examen du Disque en Silice Fondue de 372 cm pour European Southern Observatory", and one, in 1971, by G. Lemaître of Marseilles Observatory: "Sur la Flexion du Grand Miroir de 3,60 m de European Southern Observatory". These studies appeared in *ESO Bulletin* Nos. 2 and 8, respectively.

From the very beginning, the design for the telescope aimed at using it in the three modes: Prime, Cassegrain, and Coudé focus. Exact values of the three focal ratios – F/3, F/8, F/30 – were chosen by the Instrumentation Committee (IC) after consultation with various observers in the United States among whom especially I. S. Bowen, the Director of Mt. Wilson and Palomar Observatories, should be mentioned. At the first Council meeting after the ratification of the Convention, in February 1964, Fehrenbach as Chairman of the IC summarized the situation as follows.

"1 – Le télescope doit comporter un foyer Cassegrain ouvert à F/8 qui entraîne une ouverture du miroir principal comprise entre 2,7 et 3, le foyer Coudé ouvert à F/30.

2 – Un effort particulier doit être fait pour augmenter les champs de bonne définition. – – –

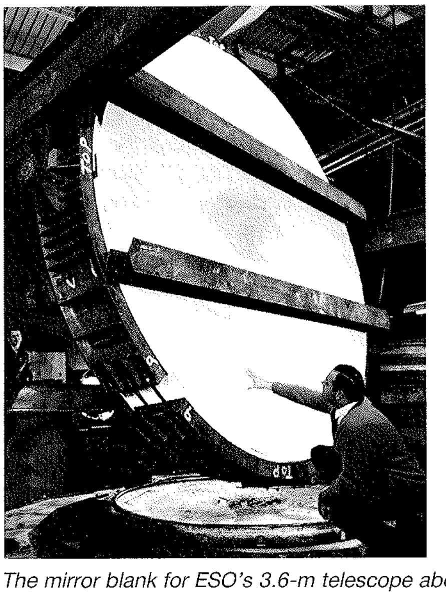
5 – – – Une combinaison du type Ritchey Chrétien ouvert à F/3 doit permettre d'obtenir:

– au foyer Cassegrain, ouvert à F/8, un champ plan de 30′ de diamètre (Solution de M. Köhler).

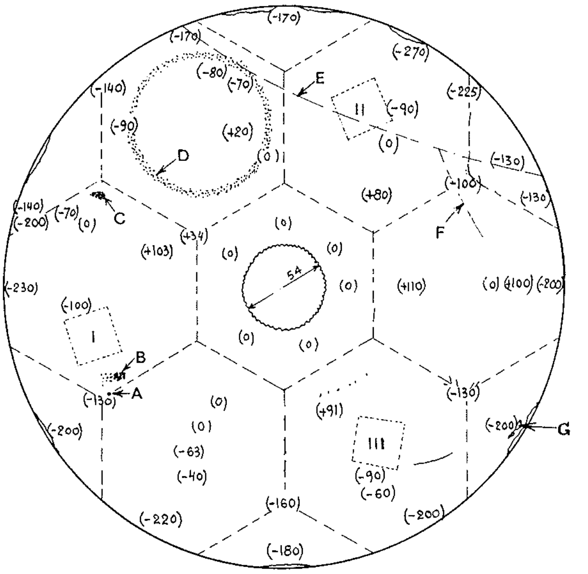
– au foyer direct, un champ de 1° avec lentilles minces et de diamètre relativement petit, dont une de surface asphérique. (Solution de M. Baranne.)

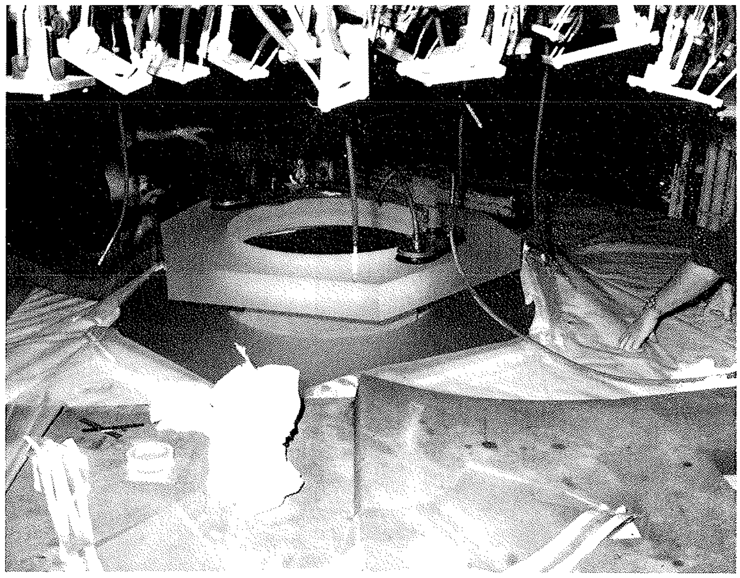
– un champ suffisant au foyer Coudé."

A. Baranne of Marseilles Observatory and H. Köhler of Zeiss-Oberkochen, mentioned here, both experts in astronomical optics, had been engaged in the design since the early stage of the project; their studies contributed essentially to the final properties of the telescope. Early results of their work were communicated in *ESO Bulletin* No. 2 of August 1967: "Le télescope de 3.50 m de diamètre" by Baranne and "The Optical System for the 3.50 m Telescope" by Köhler [3]. Compared to the earlier generations of large optical telescopes, the ESO 3.6-m optics was designed to en-



The mirror blank for ESO's 3.6-m telescope about to be delivered by Corning Glass Works. The right-hand photograph shows ESO's Director, Otto Heckmann, in discussion with a (yet unidentified) person of Corning's Management. The (undated) photographs were presented to ESO by Corning's.
From the EHPA.





The mirror blank for ESO's Large Telescope, made of fused silica, was delivered by Corning's in February 1967. The blank with total diameter of 3.72 m, of which about 3.6 m became the optically useful part, had been manufactured by fusing seven hexagonal pieces, plus the six triangular pieces to complete the circular form, as sketched in the drawing at the left. This formed part of a study of the disk by J. Texereau and J. Espiard, published in ESO Bulletin *No. 2 of August 1967 (page 39). The photograph at right, presented to ESO by Corning, shows the positioning of the central hexagonal piece in the fusing procedure in December 1968 when a superficial flaw was eliminated from the mirror.*
From a set of photographs by Corning's in the EHPA.

able observers to obtain photographs with sharp definition of the stellar images in considerably larger fields. Essential in these solutions is, that just before reaching the photographic plate, which is placed in the focal plane of the Prime or Cassegrain focus, the light traverses a combination of lenses. By a suitable choice of their optical properties, in combination with a properly chosen figure of the mirrors – a choice made possible through the new computer techniques of the 1960's – optimal optical performance could be achieved. The principle of such a combination of reflecting and refracting elements was known as a Ritchey-Chrétien system after the names of the American and French opticiens who developed it in Paris earlier this century. The combination chosen for the ESO 3.6-m is sometimes referred to as a Modified Ritchey-Chrétien or a Quasi Ritchey-Chrétien system.

For the extra reflecting components employed in the Cassegrain mode (one mirror) and in the Coudé mode (four mirrors), all of them sometimes referred to as "secondary optics", the blanks were ordered in 1966 from the firm of Heraeus-Schott in the German Federal Republic and delivered in the years 1968 and 1969. These also were made of Silica. Their figuring was included in the contract with REOSC and finished by them in the years 1970–1972.

By the time of the formal acceptance of the optical ensemble of primary and secondary mirrors, in 1972, the Telescope Project had become the responsibility of the TP Division about which more will be written in the next article, but in the course of the preceding years the work on the figuring and testing at REOSC had been accompanied by a small group of experts on behalf of ESO, of whom I should mention especially A. Baranne and G.J. Monnet of Marseilles, D.J. Malaise of Liège, A. Behr of Göttingen and K. Bahner of Heidelberg-Königstuhl.

The Mirror Cells

Between the optical system and the telescope tube there is an important interface: the mirror cells. In them, the mirrors are carried permanently and in such a way that deformation of their shape (which would result in deterioration of the stellar image) is avoided as much as possible. This is no small requirement if one realizes that during the motion of the telescope tube while it "follows" the star, the mirrors assume continuously changing tilts and orientations. The problem was particularly pressing for the large primary mirror. This has, as mentioned, a diameter of 372 cm, and an average thickness of about 50 cm and a total weight of 10,970 kg. (For detailed specifications see the article by Lemaître quoted before.) The mirror derives its rigidity from this thickness, but this is not quite sufficient.

On the other hand, there is a limit to the thickness because an increase of weight leads to rapidly increasing demand on the sturdiness of tube and mounting and, hence, to rapidly increasing cost of the telescope. Compensation for the residual tendency to flexure of the mirror therefore was achieved by a support system placed under the mirror which acts through the force of gravity. It consists, for the ESO telescope, of a series of 30 concentrically placed and independently acting supports at the bottom side of the mirror, whereas at its sides the mirror is supported by three pads and a system of air cushions. Each of these 30 bottom supports is adjustable in itself but once the telescope is in operation, the supports cannot be adjusted from outside.

The design and manufacturing of the mirror cells was ordered from the firm of REOSC that also was to do the figuring of the mirrors. The reason is, that what is finally tested is the performance of the combination of mirror and cell as a unit. These combined units were delivered by REOSC in 1972.

At the moment this article is written, it is just in this domain of telescope design that a revolutionary improvement has been introduced: the "active optics" described in the *Messenger* of June 1989 and implemented in the New Technology Telescope. Modern techniques, including continuous computer control, have made it possible to abandon entirely the idea of rigidity of a mirror as achieved by its thickness. The solution towards the problem of obtaining optimal performance is found by taking advantage of a thin (and light!) mirror's flexibility and steadily controlling its

In (August?) 1968 the blank for the 3.6-m mirror arrived at the firm of REOSC in Ballainvilliers near Paris, for grinding and polishing towards its final shape. On the above photographs:
- *upper left: arrival of the mirror blank in its crate at REOSC,*
- *upper right: the crate deposited horizontally,*
- *lower left: wooden packing material and the iron ring holding the mirror being removed,*
- *lower right: first hand- and foot acquaintance with the mirror by (in the foreground) Charles Fehrenbach (left) and André Couder (right).*

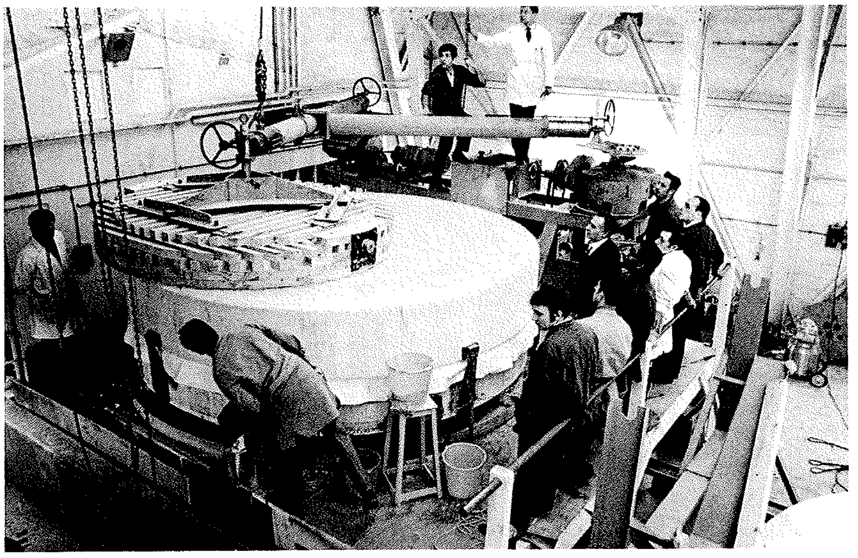
From a set of photographs in the EHPA.

shape by a system of numerous and independent, but actively, from the outside adjusted supports. Twenty-five years ago, when Heckmann and his associates searched for the best support system for the ESO 3.6-m, this was undreamt of . . .

Tube and Mounting; Strewinski's Pre-Design

Fehrenbach's summary of the recommendations of the IC by the time of the first Council meeting, in February 1964, also contained the following statement: "L'étude de la mécanique de l'instrument devrait être fait par un bureau d'études indépendant, acceptant un marché d'étude." It confirmed the early intention of the ESO Committee to create a design bureau. In May of that year it had become clear that of the two engineers whose collaboration in the project was hoped for, the work for the large telescope would mostly involve Strewinski. According to Heckmann's report at the June 1965 Council meeting, a draft contract with the engineering bureau of Strewinski had been drawn up (but it is not clear whether it was ever signed). Ideas about the nature of the design were shaped within the IC, but they were influenced strongly by suggestions of Strewinski.

Strewinski's design deviated in several important respects from that of large telescopes then in operation. First, note that the whole concept was still based on the classical model of a telescope moving around a polar axis (which is directed towards the celestial pole) and the declination axis, perpendicular to this. Of these two motions, only the first (and uniform) one is required during the telescope's following a star during observation. The radically different azimuthal design now employed for large optical telescopes was in use at that



Shaping and testing the mirror at REOSC. Left: grinding the mirror (the large "white" disk) by means of the (smaller) rotating disk touching the upper surface of the disk. Among the spectators, the Director of REOSC, M. Bayle (in dark jacket in front of the group at right). Right photograph: the optical laboratory of REOSC at which the shape of the mirror was tested. In order to do this with the mirror in horizontal position, REOSC built the high "optical tower" at right in the picture.
From a set of photographs provided by REOSC in the EHPA.

time only for large radio telescopes, and it was planned for (and later realized in) the 6-m USSR optical telescope in the early 1960's.

One of Strewinski's innovations concerned the storage of the optical elements which are alternately used for the different modes of operation. Whereas, for instance, at the 200-inch Palomar telescope those optical elements, which are not in use during operation in a particular mode, remain stored within the telescope tube, Strewinski proposed for the ESO telescope separate top ends of the tube carrying the different secondary mirrors, so that those not in use could be parked outside the tube in quickly interchangeable manner. An advantage of this solution was a reduction of the weight of the tube, and hence, simplification of the design and reduced costs of the mounting.

Another aspect of Strewinski's design was the combination of horse-shoe and fork mounting. In the classical mounting, realized, for instance, in the Lick 120-inch and also in the ESO 1-m and many other telescopes, the extremes of the declination axis rest in the extremes of the two prongs of a fork which forms an extension of the polar axis. For large telescope tubes, the top end of the fork which carries all the weight of the tube including the optical elements, is rather distant from the upper bearing of the polar axis, particularly so if the fork is made long in order to leave room for bulky equipment at the Cassegrain focus. This implies high demands on the system of bearings of the polar axis, and in the case of the ESO telescope especially so because at La Silla the axis makes an angle of 29 degrees only with respect to the horizon. An impression of the weight we are dealing with may be obtained from the minutes of the 28th meeting of the IC, of May 1969, when the tube including the optics was estimated to weigh about 60 tons.

A different concept had been adopted for the Kitt Peak 150-inch telescope. Here, the bearings carrying the extremes of the declination axis rest in a very sturdy horse-shoe which in itself forms the upper bearing of the polar axis. Even without detailed knowledge of the forces acting on the bearing, one senses that for a heavy telescopes tube such a design is more suitable than a fork mounting. A solution like this was considered by Strewinski also for the ESO telescope. However, he rejected it in order to avoid the large diameter which would have been required for the horse-shoe, about 12 m. As Ramberg explained in his presentation of Strewinski's design at the April 1965 IAU Symposium, Strewinski feared "that it will be a fairly complicated matter, after having manufactured such a disk in Europe, to transport it to Chile and then take it up to the top of La Silla – – –" [4], and Ramberg mentioned this also at the December 1965 meeting of the IC.

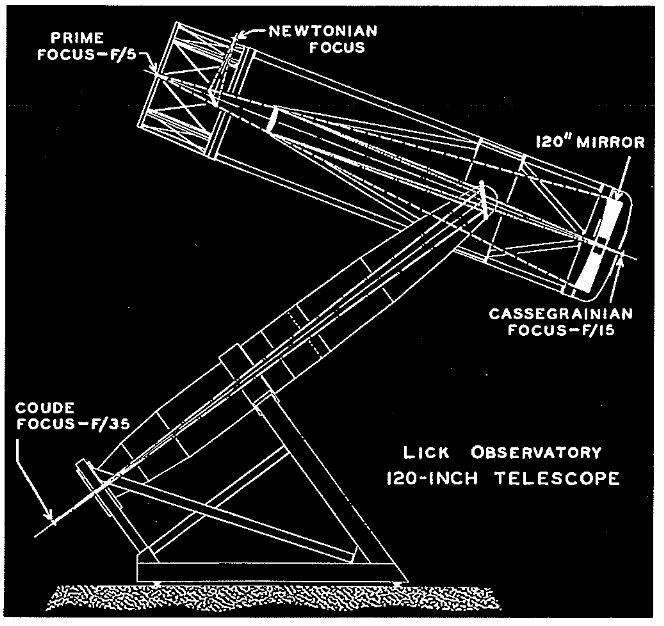
The Combined Horse-Shoe and Fork Mounting

This led Strewinski to his compromise solution: the combined horse-shoe and fork mounting. It is demonstrated in the accompanying drawing, taken from the presentation in the 1965 Symposium Report. Here, the declination axis is supported by two relatively short and very strong fork prongs mounted on the horse-shoe disk. By this construction the diameter of the horse-shoe could be diminished to less than 8 metres. For the upper (horse-shoe) bearing Strewinski chose an oil bearing, the sliding surface of which is supported on two fixed pedestals, and in Strewinski's design the centre of gravity of the movable parts of the telescope is vertically above the midpoint of the line joining these two oil pads. Oil is constantly pumped at high pressure into the two sliding surfaces, so that during the operation the telescope floates on two thin films of oil. The sliding surfaces of this upper bearing were given a spherical shape, a concept Strewinski had earlier introduced for the Schmidt telescope of Hamburg Observatory.

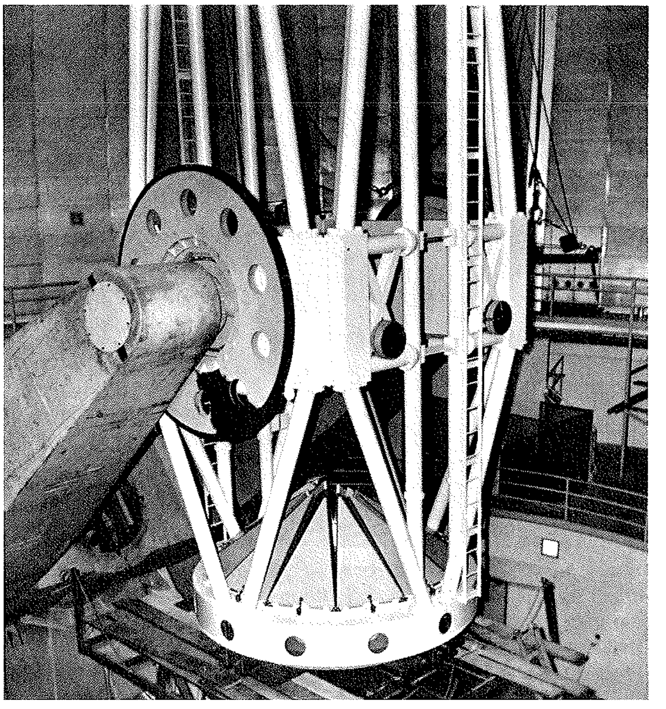
Once these principal design characteristics had been agreed upon – and we do recognize them in the 3.6-m telescope as it has ultimately been realized – many details had to be worked out in close consultation between the bureau of Strewinski, the Directorate and the IC and its subcommittees. They met frequently in the year 1966 and thereafter. This led to the so-called pre-design studies and drawings in which specific solutions were formulated for the various technical problems encountered. Next should follow the exact designs required for the construction when the project would be in the hands of the manufacturer.

Stagnation – and Growing Impatience

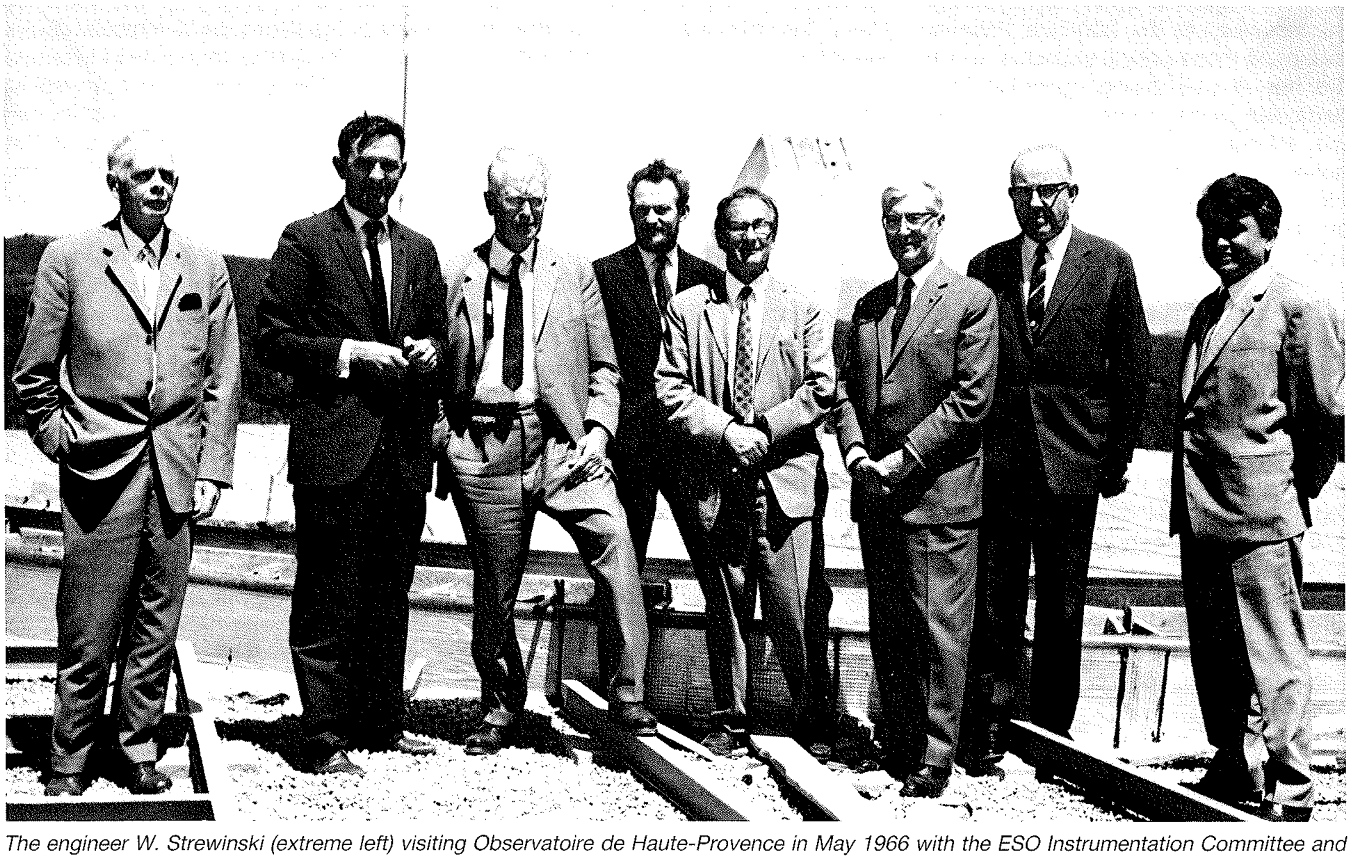
These pre-design studies and drawings were, however, produced at unexpectedly low rate by Strewinski's



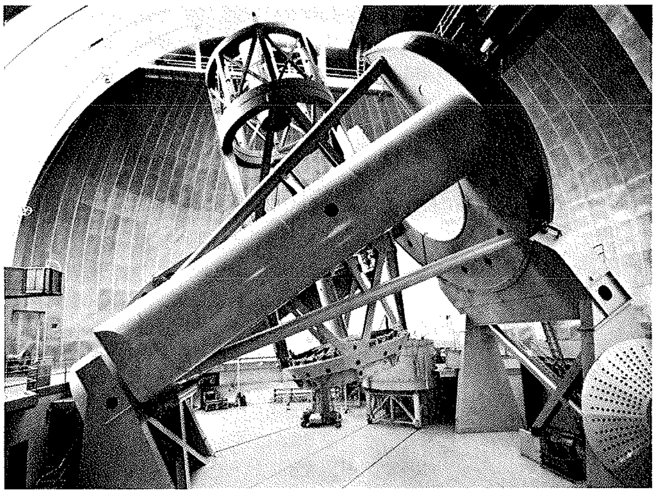
A sketch of the design of the 3-m telescope of Lick Observatory. In 1953, Walter Baade suggested that the principal telescope for the European Southern Observatory should be a copy of this telescope, which became operational soon afterwards. The sketch shows the telescope tube with its primary mirror of 3 metres and secondary mirrors for operation in the Cassegrain and Coudé modes. For motion in declination, the telescope tube rotates around an axis which is mounted at the top end of two long fork prongs; the fork forming the extension of the polar axis.
From: Sky and Telescope, *March 1955, p. 176.*



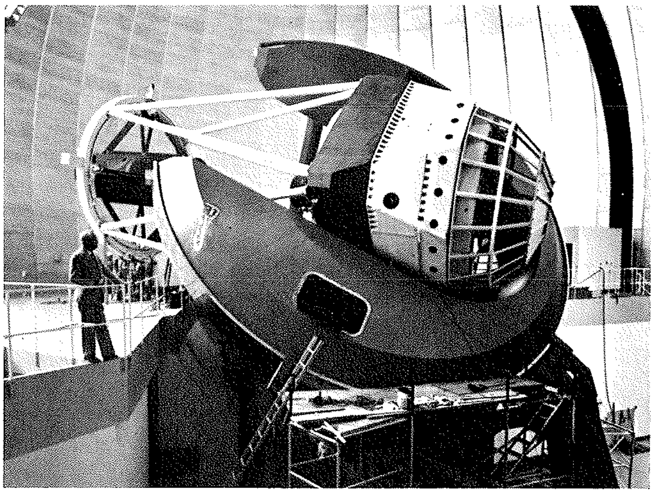
The Lick 3-m telescope when its mounting was virtually complete, in November 1954. The lower part of the telescope tube is shown, hanging on the declination axis at the top end of its long fork, the arms of which are about 7 metres long. The weight of the tube including the optics is about 40 tons (whereas the estimated weight for the ESO 3.6-m tube and optics was about 60 tons).
From: Sky and Telescope, *May 1955, p. 272.*



The engineer W. Strewinski (extreme left) visiting Observatoire de Haute-Provence in May 1966 with the ESO Instrumentation Committee and other specialists. From left to right next to Strewinski: Ch. Fehrenbach, O. Heckmann, a collaborator of Fehrenbach, A. Behr, A. Couder, M. Migeotte, and A. Baranne. Main features of the mechanical design of ESO's 3.6-m telescope and Schmidt telescope are due to Strewinski who had been engaged by ESO since soon after its creation. Early in the 1970's the ESO TP Division at Geneva took over for the realization of the 3.6-m telescope, as will be described in article IX; for the completion of the Schmidt telescope see article X. The photograph was taken on the roof of the Spectrographic Telescope Building-in-construction at Haute-Provence Observatory.
Photograph in envelope marked "Spectrographic Telescope" in the EHPA.



The 5-m Hale telescope of Palomar Mountain, shown here, had been in regular operation for four years when first talks about the creation of ESO took place in 1953. Its realization had taken many years due to interruption by World War II. The declination axis is positioned about half way between the south and north bearings of the polar axis so that the weight of telescope tube and polar axis is devided over the two bearings. The horse-shoe shape of the north bearing allows the telescope to observe objects near the north pole.



The 4-m Mayall telescope of Kitt Peak Observatory, which came into regular operation in 1974 after its creation had been initiated in the early 1960's by AURA. As in the case of the 5-m Hale telescope, the north bearing of the polar axis has the shape of a horse-shoe, but now the declination axis lies in the plane of the horse-shoe. This solution was considered for the ESO telescope, too, by Strewinski, but he preferred the solution described below in order to avoid the large diameter of the horse-shoe.
From Sky and Telescope, *January 1973, p. 14.*

bureau. The Directorate, especially Heckmann, in first instance kept full confidence in Strewinski to handle the task, but doubts began to grow among the IC and Council when a year after the Large Telescope symposium little progress was evident. In his report at the Council Meeting of April 1966 in Santiago (following the dedication of the road on La Silla), Fehrenbach felt compelled to state:

"Il faut considérer que l'étude du grand télescope est arrivée au stade où il est nécessaire de penser à sa réalisation dans un délai raisonnable. Un certain nombre de membres de la C.I. m'ont indiqué, en privé, leur inquiétude concernant la méthode proposée.

D'après des informations, nos collègues américains prévoient un bureau d'études de 50 ingénieurs et techniciens, travaillant pendant plusieurs années pour l'étude complète de leur télescope de 3,75 m à Kitt Peak. Il est certain que l'organisation prévue par nous, c'est à dire un bureau d'étude réduit, par ailleurs chargé de l'étude du télescope de Schmidt, ne permet pas une réalisation dans un délai acceptable. Je me demande s'il ne vaudrait pas mieux passer la commande de la mécanique à une firme privée, le bureau d'étude de M. Strewinski restant organe de liaison entre cette firme et la C.I."

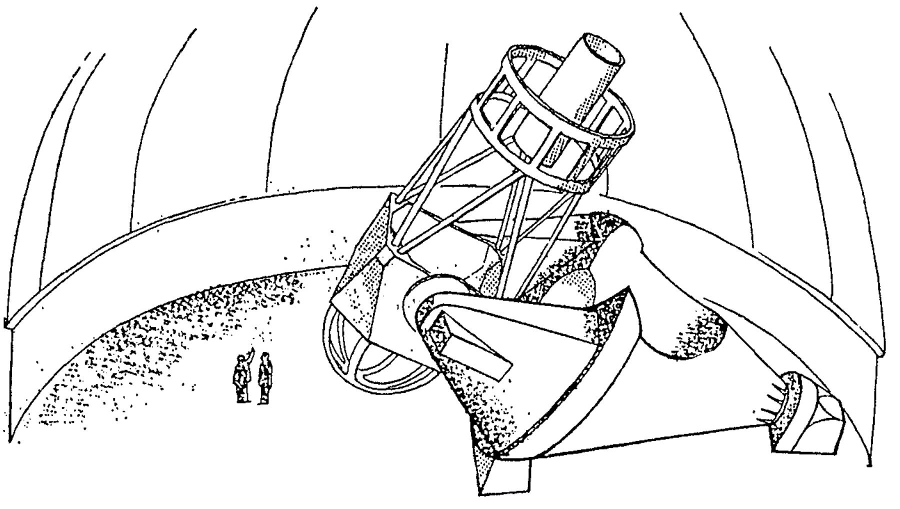
Concern about the lack of progress in the pre-design continued to be expressed at meetings of Council and IC. A year later, at the June 1967 meeting of Council, it was agreed that *"although the quality of Strewinski's work is excellent, the capacity of his bureau is evidently too small – – –. A solution would be to give the main part of the definitive design to a large firm which then could work under the supervision of Strewinski."* However, suggestions to give part of the pre-design to an outside firm met strong opposition from the part of Heckmann, who emphasized *"that the pre-design forms a unit; – – – It would be a considerable loss of time to give the task – – – to another firm, because no firm exists holding something like Strewinski's specific knowledge on the subject."*

Again a year later, in the July 1968 meeting of Council, Fehrenbach on behalf of the IC reported that Strewinski was supposed to deliver the complete pre-design, drawings and descriptions, before June 1, 1968 but that this had been delayed due to the necessity for Strewinski to enter deeply into parts of the definitive design . . . In fact, the first part consisting of 34 drawings, mainly related to the telescope tube, was delivered only in November 1968 and extensively discussed by the IC in January 1969, whereas the second part, also 34 drawings, for the telescope mounting, was delivered in May 1969 and discussed by the IC in May and June 1969. As these three meetings were the last ones of the IC before the policy of Council was radically changed, and the creation of the Telescope Project Division of ESO was on the horizon – the IC would meet again only a year later, in June 1970 –, let me briefly describe the proceedings of those IC meetings in 1969.

The IC Meetings in 1969

The meeting in January 1969 was almost entirely devoted to the design of the telescope tube. Items discussed were: technical solutions for the secondary mirror exchange when the observer changes his mode of observing; the stability of the position of the primary mirror during exchange of top parts of the tube, when the mirror is in vertical position; the interchange of equipment used at the prime focus; the design of the mirror supports; specifications and design of the Cassegrain cage; and the design of the drive system. Items taken up in May 1969 were: the (very important!) question of the flexure of the fork prongs in different positions of the tube; the design of the south (upper) bearing and the safeguard against earthquakes; the choice of the (mechanical?) drive system; the control of "mirror 5" of the Coudé system.

During the second part of this meeting, a small ad-hoc group consisting of Strömgren (as Chairman), Fehrenbach, Heckmann, Ramberg and Strewinski convened separately. It subsequently reported to have found Strewinski's pre-design sufficiently advanced that preliminary steps might be taken towards the implementation of the project, and it suggested names of firms to approach for first contacts. Strewinski would be supposed to continue the detailed design work but should rather not be involved in shop-drawings unless he would increase his staff by 10 to 15 engineers and draftsmen. A time



The design for the ESO 3.6-m telescope as presented by Strewinski at IAU Symposium No. 27 on "The Construction of Large Telescopes" in April 1965. In order to reduce both the length of the fork arms as required for the Lick 3-m telescope design, and the large diameter of the horse-shoe as realized in the case of the Kitt Peak 4-m telescope, Strewinski proposed the combined fork and horse-shoe solution shown here, Another feature of his solution was a spherical shape for the horse-shoe bearing, and positioning the centre of gravity of telescope plus polar axis vertically above the line joining the two oil pads which carry this bearing.
From The Construction of Large Telescopes, *IAU Symp. No. 27, Ed. D.L. Crawford, 1966, p. 118.*

schedule was proposed for the ordering of parts: for the period October 1969 to April 1970 these should include the main parts of the mounting, and subsequently, until October 1970, the main parts of the telescope tube. In a third period, until April 1971, the ordering of the telescope drive and mirror support systems were foreseen. Presupposition would be that Strewinski would settle for this time-schedule contract. Strewinski himself recommended collaboration with a local firm.

However, doubts were expressed – particularly from the part of S. Laustsen (about whose role in the project we will see more below) – whether the time schedule was realistic: *"An efficient group of astronomers and engineers is necessary for the planning and coordination of the whole 3.6-m project and for the design studies and development work bearing on control and automation"* [5].

In the June meeting, four weeks later, aspects of the design of the Cassegrain cage and the Coudé mirror system were reviewed, after which Heckmann globally summarized still pending matters: mounting of the Coudé mirror; Cassegrain cage; facilities for optical adjustments; mirror support systems; prime focus correctors and plate holders; drive system; encoders; computer control interface. However, no decision was taken with regard to a recommendation to Council for entering contacts with construction firms as had been suggested at the May meeting. A next meeting of the IC was scheduled for October 1, 1969, but not held.

As described in my previous article, around this time – the middle of 1969 –, dissatisfaction about the lack of progress was one of the reasons for creating the Working Group of Alline, Funke and Scheidemann. A worried Council considered alternative ways to realize the telescope, and the role of Strewinski's bureau was more and more confined to the completion of the Schmidt telescope. We shall come back to the Schmidt in article X, and before entering the description of the new approach in the 3.6-m telescope project, review what had been done on the design of the telescope building and dome and in the field of automation.

The Building

Once the main properties of the telescope had been fixed, steps were taken toward the design of building and dome. At its November 1966 meeting, Council, at Heckmann's request, agreed that this project should be handled separately from the building projects of the first stage of which we described the dedication in article VI. In order to allow close consultation, a civil engineering firm in Hamburg was chosen, Lenz Architekten & Ingenieure. Their architect Mr. Mix gave a first report at the IC meeting of December 19, 1967. From the minutes of this meeting [6] main features of the design can be inferred, but unfortunately no drawings have so far been located in the ESO files. A basic feature of such a telescope building is its consisting of two parts on separate foundations: part A for the support of the telescope and its auxiliary equipment such as spectrographs, and part B supporting first of all the heavy rotating dome, but also serving for electronic laboratories, dark rooms, storage space, laboratories, aluminizing facilities, air conditioning, elevators, etc. Reason for this separation of structures is that no vibrations caused by the activities in part B should be transmitted to the telescope and its auxiliaries of part A (for instance those caused by the rotation of the dome).

An important feature of structure A for the 3.6-m Telescope was a large floor below the observing deck for the erection of the Coudé spectrographs; these, together with the size of the dome, became the determining factor for the horizontal extension of the building. A length of 24 metres for the Coudé light path figured in early planning, but was reduced to 18 m at most by November 1966. The diameter of the dome was estimated to be 28 metres [7]. Throughout the designing by Lenz, the result of the special requirements for the Coudé floor was a building of rectangular shape which risked to have a deteriorating effect on the image quality in the telescope.

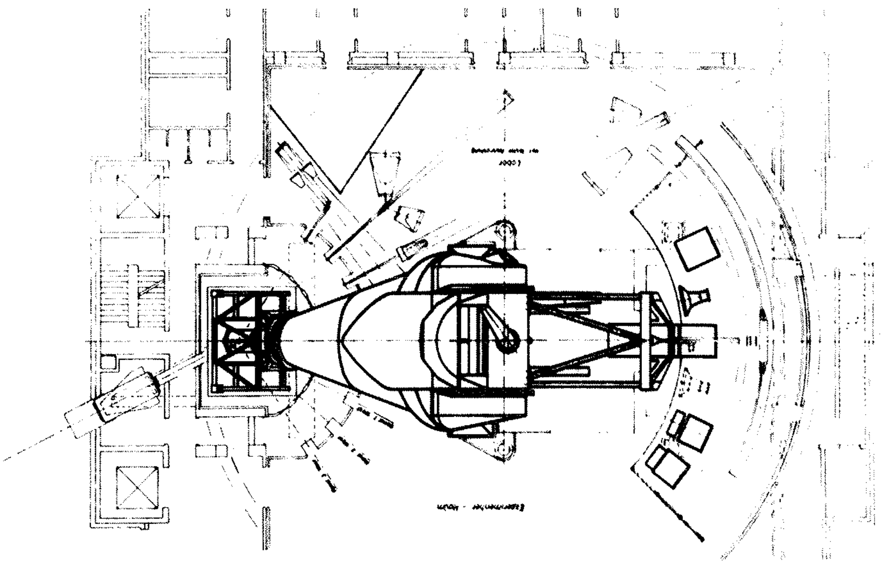
Another basic measure was, of course, the height of the telescope above ground level. This was defined as the height of the crossing point of declination axis and polar axis, and fixed at 24 metres. The decision to put the telescope that high goes back to the results of measures of image quality at different heights above ground level by the method of Siedentopf described in article II, for which data had been obtained by André Muller over a long period by means of high masts, one of which was erected at the highest summit of La Silla. Note that it was this element, the required image quality, that determined the height of the building, not the need of space for housing the various facilities.

Of the many other aspects of the design, let me mention only the important problem of providing proper heat insulation in order to avoid heating up of the inside of the dome during day time.

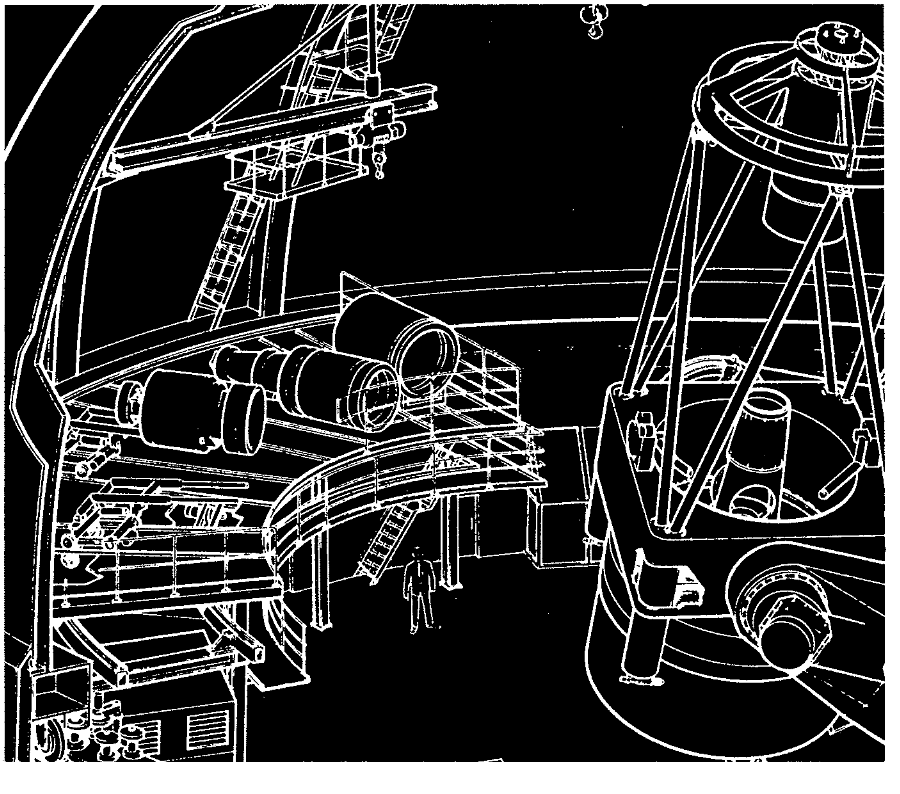
In the July 1968 meeting of Council, Ramberg could report that the firm of Lenz expected to finish the pre-design by the end of that month, and in the December meeting first steps for a building contract were discussed. However, the delay in the design of the telescope kept Council and Directorate from taking this further step towards realization. Coordination of construction activities on La Silla with those for the building of the 4-m telescope on Cerro Tololo was discussed with AURA in Santiago in March 1969 [8].

The Dome

Simultaneously with the planning of the building, preparations were made for the design of the dome. Favourable experience had been gained with the firm Seibert-Sécometal at Saarbrücken, that had provided the domes for the first construction phase. This early work had been supervised by their engineer W. Bauersachs, who has described it in *ESO Bulletin* No. 4 of July 1968 (and who years later joined the staff of ESO). Hence, this firm was now also charged with the design and construction of the dome for the 3.6-m telescope. This was finished by the end of 1968, and so this project, too, was ready for tendering in 1969.



The drawing reproduced here is part of a set of drawings made by the bureau of the engineer Dr. W. Strewinski and marked "Gesamtanordnung" and "Stand 18–10–1968". This set of drawings was reproduced in Document Cou-59, written by ESO's Technical Director J. Ramberg for the Council meeting of December 1969 and entitled "The Present State of the 3.6 m Telescope Project". This section of the drawings shows the arrangement proposed by Strewinski for the storage of the different top-ends of the telescope tube which carry the secondary mirrors for use in different modes of operation.
The proposal led to the more detailed design by the TP Division shown in the sketch below. We also note, albeit vaguely, in this drawing the square contour of the telescope building extending beyond the projection of the dome, a design that followed from the large space that was deemed necessary for the long optical paths in the Coudé spectrographic equipment. The design of the final, cylindrical, telescope building on La Silla represents a radical change, introduced in the early 1970's.



Automation in Telescope Control

Among the many valuable experiences of Fehrenbach and Heckmann during their visit to observatories in the United States in 1962 was the confrontation with new, electronic computer techniques for the control of telescope functions. This rapidly developing field was also energetically pursued in the ESO member states and led to a document "Some Suggestions for Automation of the 3.6-m Telescope" issued by the ESO Directorate in February 1968 under supervision of the Technical Director Jöran Ramberg [9]. The authors included two young astronomers, F. Dossin of Liège who had joined the office of the Director in February 1966, and S. Laustsen of Copenhagen Observatory who acted as consultant to the Directorate.

Main functions of the automation as listed in the document and elaborated in detail were: A) Automatic Control: setting of the instrument, telescope driving, dome and shutter operation, setting and driving of siderostate, and "local driving", and B) Semi-automatic operations (push-button control). The new concepts were discussed in a series of meetings: in February 1968 in Paris, in September 1968 in Karlsruhe at the firm of Siemens (in view of a collaborative project with this firm) [10], and at the IC meetings of November 1968, and May and June 1969.

Meanwhile, Svend Laustsen had become a staff member of ESO per September 1968, in order to assist the Directorate in matters of automation of telescope operation and for the development of a programme for auxiliary instrumentation for the 3.6-m telescope. Gradually, an in-house working group was formed headed by Laustsen, which by the end of 1969 also included the astronomical technician B. Malm and the electronics engineer M. Blichfeldt, both also from Denmark. It continued to grow in 1970 and would become the nucleus of the 3.6-m Telescope Division, the creation of which we shall describe in the next article.

Whereas in the early phase of ESO, the three telescopes, 1-m, 1.5-m, and the Schmidt, as we saw in article IV, could be identified with the specific interests of institutes in the Netherlands, France and the German Federal Republic, respectively, it now had become Denmark's turn by providing this nucleus.

References and Notes

Abbreviations used:

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

FHA = Files Head of Administration at ESO Headquarters.

EHPA = ESO Historical Photographs Archives.

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

[1] Wykeham Publications Ltd., London–Winchester 1975.
[2] Heckmann Sterne, p. 323.
[3] For reports on work by Baranne, Köhler, and Paul of the years 1962 and 1963, see EHA-I.C.1.9.m.
[4] See page 118 of the Symposium Report.
[5] FHA, Minutes 28th meeting of the IC, p. 9/10.
[6] FHA, Doc. IC-26 = BG-16.
[7] FHA, Doc. IC-18 = BG-15.
[8] FHA, Minutes of the 12th Cou Meeting, p. 13.
[9] FHA, Doc. IC-24.
[10] For reports of these meetings, see FHA Docs. IC-27 and IC-29.

Observations of Visual Double Stars at La Silla

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Introduction

Of the many types of observing programmes made at La Silla with the most sophisticated equipment provided by modern techniques, one in particular distinguishes itself because it utilizes for the observations only the human eye, the oldest and most traditional of detectors used in astronomy. This research is the micrometric observation of visual double stars.

The concept of a visual double star is a relative one: by a visual double star we mean the whole of two or more stars, angularly close, which can be distinguished from each other through the eyepiece of the telescope. It is then evident that, when increasing the diameter of the telescope, ever more narrow double stars should become visible as distinct objects. However, there exists a lower limit, introduced by the earth's atmosphere, which is of the order of 0″.1. This limit to visual observations can sometimes be overcome by observers of great experience, on sites of particularly good seeing (Couteau, 1987).

The astronomy of visual double stars is by now over two centuries old. In 1778, W. Herschel, following one of Galileo's ideas, began systematic observations of visual double stars with the purpose of determining stellar parallaxes. He did not manage, comprehensibly, to determine any parallax, because the quantities to be measured were too small for the coarse micrometers of that period, but in 1803, with a publication that has made history (Herschel, 1803), he proved that physical binary stars were a reality and that the law of universal gravitation was valid also outside the solar system.

More than 600 astronomers after Herschel have measured visual double stars with various techniques, leaving a patrimony of about 1,000,000 individual measurements, summarized for practical purposes in over 410,000 annual averages.

This enormous task of observation has led to the discovery of over 70,000 double visual stars in the entire sky, of which about 900 have today a known orbit.

The history of the visual double star astronomy is a fascinating chapter in the history of Astronomy; for those who would like to examine it more closely, there are many articles and books that deal with it in detail (Baize, 1930 – Heintz, 1978 – Couteau, 1988).

The Method

The first "modern" measurements, by quality and accuracy, date back to 1828, and were made by F. G. W. Struve who used a refractor with a diameter of 24 cm at Dorpat in Esthonia. It was built by J. Fraunhofer and was at the time the greatest and the first conceptually modern instrument in the world. Struve discovered and measured 3134 double stars on the basis of a specific research programme.

We also owe to Struve the method of measurement of separations with the filar micrometer, known as the double distance method, commonly utilized even nowadays. The filar micrometer (utilized for over 80 % of visual measurements) is a very simple instrument: it is made up of a reticle of spider threads, placed in the focal plane of the telescope, two of which are fixed and perpendicular to each other. The third is mobile (by means of a micrometric screw) and is parallel to one of the fixed lines. The entire device can rotate around the optical axis of the telescope (Fig. 1).

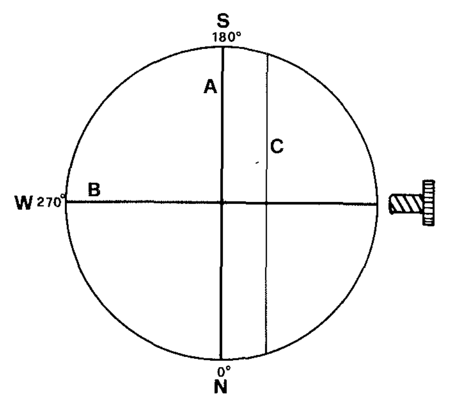

Figure 1: *Scheme of a filar micrometer: A and B are fixed wires, while C is the mobile wire whose movement is commanded by the rotation of the micrometric screw.*

The measurement of a visual double star consists in the determination of three fundamental parameters:

(a) the date of observation expressed in years and decimal fraction;

(b) the position angle ϑ, or the angle between the line that connects the two stars and the north direction, taking as the origin the "main" star (usually the brightest) (Fig. 2);

(c) the separation ϱ between the two stars, expressed in arcsec (Fig. 3). For this it is necessary to know the scale of the instrument in arcsec/mm.

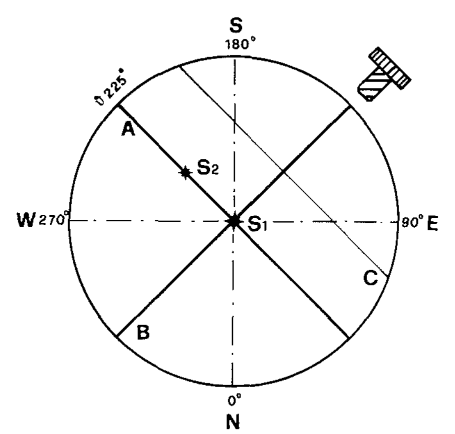

Figure 2: *The measure of the position angle ϑ is made by rotating the micrometer around the optical axis of the instrument so that the fixed wire A bisects the two stars S 1 and S 2. The most luminous star S 1 is, by custom, considered the principal star and is chosen as the origin of the coordinates.*

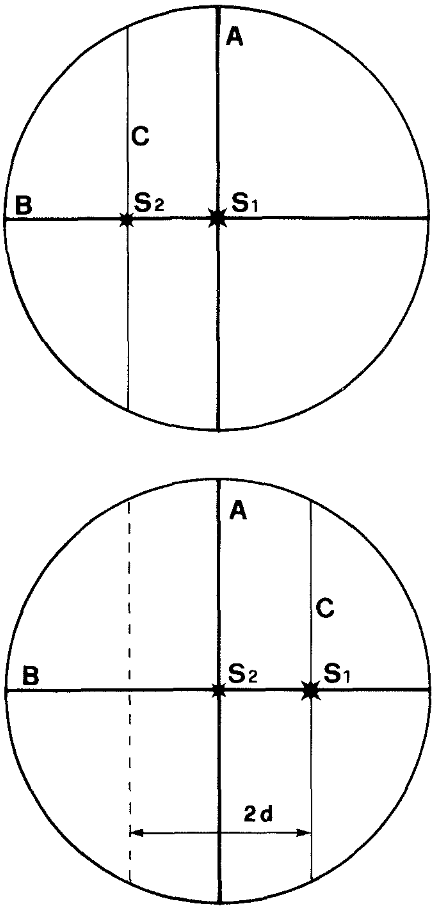

Figure 3: *The double distance method. To measure the separation, the micrometer is rotated in such a way that the fixed wire A and the mobile wire C are perpendicular to the line S1–S2. By means of the fine motion of the instrument the fixed wire A is superimposed exactly on the star S1 and by moving the micrometric screw the mobile wire C is brought to bisect the star S2 and a first reading of the micrometric screw is done. The operation is then repeated, bringing the fixed wire over the star S2 and the mobile one over S1. The difference between the two readings (2d), expressed in fractions of a millimetre, multiplied by the scale of the instrument expressed in arcsec/mm, gives us the double of the distance (ϱ) between the two stars in arcsec.*

An estimate of the difference in magnitude between the two stars is often added to these main quantities. Some brief comments on the measurement (the difficulty, the aspect of the couple, the state of the seeing, etc.) may be useful later, for a possible weighting. An essential condition however is that the seeing must be good.

"To measure well, you must see well": this principle, always valid, by Otto Struve, son of F.G.W. Struve and like his father a great observer of double stars, should never be forgotten by observers of visual double stars.

The Precision

The best instrument for this kind of high resolution observations is the traditional refractor, which was very common throughout the last century. Its long focus allows high magnification factors, which are essential in order to clearly examine the diffraction image provided by the lens. Experience teaches that an magnification which is 3–4 times the resolving magnification (the minimum magnification needed to see the diffraction image at the limit of visual acuity) is sufficient for this purpose. Also reflectors are currently used for such observations, but their use is more delicate because of the obstruction by the secondary mirror, of the less stable focus and of the higher sensibility to the air turbulence.

The precision which a good double star observer can reach is considerable; if the observing conditions are optimal, he can measure the separation of a large double star or estimate the one of a very narrow double (below the resolving power of the instrument used) with an uncertainty of only a few hundredth of an arcsec. For the position angle, the matter is different, because the uncertainty depends on the separation: from a few tenths of a degree for a well separated double star, to few degrees in case of a double star whose separation is just a bit more than half the resolving power of the objective used. In these conditions he will not see two distinct images anymore; the double star will appear like a slightly oval image (Fig. 4).

The final purpose of the observation of visual double stars is the calculation of the orbital elements which, once known by means of the third law of Kepler, make it possible (if the parallax is known) to determine the sum of the masses of the system.

The visual double stars, in conclusion, are indispensable for the determination of stellar masses, this fundamental parameter of astrophysics, which other types of binary known are not able to provide, except in particular cases. Few astronomers are aware of how modest the number of the accurately measured masses really is. The astronomical community usually uses the mass-luminosity relationship, but this empirical law is obtained experimentally starting from a few dozens of masses known.

The Patience

The observation of visual double stars necessarily implies long periods of time, because the huge majority of them has periods of hundreds, thousands and even tens of thousands of years. To obtain the orbital elements of a binary star, even only relatively reliable, it is necessary to observe at least half of its orbit. Hence the necessity for systematic and continuous observations and for a new generation to take the place of each generation of observers that passes. The astronomy of double stars is the branch of astronomy in which the ties between past, present and future are the closest. Today we are able to calculate an orbit only because earlier generations of astronomers have observed this star, and similarly our observations will be indispensable for the astronomers of the future. The unrelenting flow of time, instead of condemning these measurements to oblivion, makes them precious and indispensable.

It could be objected that astronomers don't have the patience to wait all this time to obtain more information about stellar masses, and that a sensible choice of the systems to be observed could shorten the waiting time. The problem has been dealt with and it has been proved (Couteau, 1978), on the basis of a hypothesis about the work which is very close to reality, that the rapidity with which information on masses can be obtained, grows as $D^{1.5}$, where D = diameter of the instrument. The large apertures allow the observation of narrower doubles, which have a higher probability of being short-period binaries and therefore give us information on their masses in few decades.

New techniques of observation, like the speckle interferometry, were implemented during the last twenty years, but are still little used. The potential of this technique, which was introduced by A. Labeyrie (Labeyrie, 1970) is great, especially for the very narrow double stars ($\varrho < 0''.2$), where the efficiency and the precision of the visual observation are lower. However, it is rather complicated and, for the time being, quite expensive in men and material, which is the opposite of the visual observation

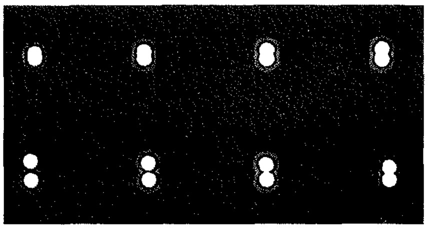

Figure 4: *The aspect of a double visual star for different values of the distance between the components. The distance is expressed in function of the radius of the first dark ring of the diffraction image ($r = 1.22\,\lambda/D$).*
0.5 0.75 1.0 1.25
2.25 2.0 1.75 1.5
(taken from "Lunettes et Télescopes").

whose cost and complexity are very low. A comparison between the speckle measurements and the visual ones shows that they match very well, especially in the position angle (which is the most important parameter for the calculation of the orbital elements). However, as far as the separation is concerned, one sometimes gets the impression that the speckle measurements are systematically shorter than the visual ones, which on the whole, nevertheless, appear to have a higher dispersion. The observers of double stars are becoming progressively rarer: their number can already be counted on our fingertips. This speciality, which requires years of tough apprenticeship, suffers from the disaffection of the young who, dazzled by astrophysics, prefer theoretical researches or shorter, experimental ones requiring less observing engagement, which are able to offer secure funds and fast careers, because it is "fashionable". The indifference and, sometimes, the incomprehension of the astronomical community also contributes to making the work of the few who still devote themselves with passion to this type of research more difficult.

Observations at La Silla

The southern hemisphere, which in the first half of this century was in a leading position, owing to the energetic activity of some great observers like Innes, Finsen, Van den Bos, Rossiter, etc., has been suffering for many years of complete neglect, because no astronomer is permanently observing any double star there, and the survey of the southern sky relies on the observing activity of only three astronomers, two North-Americans, Heintz and Worley, and the writer, the only European.

Only a few months ago the working group C.H.A.R.A. from Atlanta (U.S.A.), headed by H. McAlister, began to observe the double stars of the southern sky, using the 4-m telescope of Cerro Tololo and speckle interferometry.

At La Silla, the systematic observation of visual double stars of the southern sky began in 1986. The choice of the instrument fell on the GPO astrograph for very simple reasons: First, the GPO is a refractor with a diameter of 38 cm, whose limit of observation is close to 0″.18. Its diameter, which is not very large, guarantees a good result, because it is hardly affected by the air turbulence; therefore, there is a high probability of having a good number of utilizable nights during each observing mission. It represents an excellent compromise between resolution power and yield. It is a simple instrument, robust

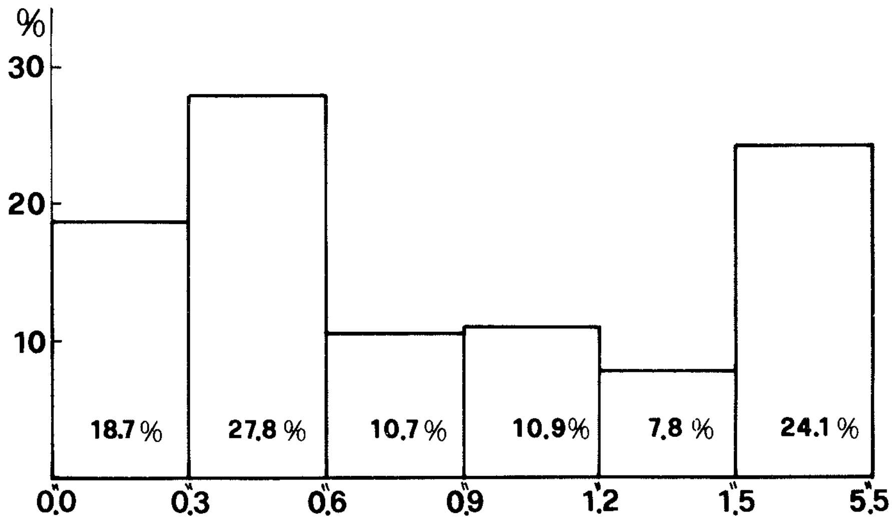

Figure 5: *Percentage of the measurements made at La Silla for each class of separation.*

and extremely reliable. This means no time wasted because of instrumental breakdowns. Second, the GPO is relatively little requested by the European astronomical community; it is therefore possible to obtain a reasonable number of nights in each observing period, thus optimizing the relative number of measurements/cost of the mission.

Small changes have been necessary to adapt the GPO astrograph to the visual observation of double stars. The correcting lens for astigmatism near the focal plane has been removed, because the observations are made on the optical axis. The original focal length, which is only 4 metres, has been increased to 9.5 metres, with a barlow lens; the examination of the image is made with a magnification of 760 times (4 times the resolving magnification). It was necessary to correct the chromatism of the objective, which has the minimum of the secondary spectrum close to 4300 Å, instead of the traditional 5600 Å, with a yellow filter GG 495 (initially a filter OG 530 had been used). In this way the troublesome blue halo around the bright stars which makes difficult the observation of fainter companions has been considerably reduced. The mounting, because of the position of the finder, prevents observation south of $\delta = -70°$, and the observation of objects near zenith is rather uncomfortable, because of the insufficient distance between the eyepiece and the floor of the dome. The ninth magnitude is the limit at which stars can be observed with reliability. But in spite of these restrictions, thousands of doubles of every separation are accessible for observation. The diffraction image provided by the lens is of good quality: it presents itself round and without defects. The observing programme foresees the observation of all the double stars, orbital and not, which satisfy the following conditions: (1) $\delta < 0°$, (2) $m < 9$, (3) $0''.18 < \rho < 5''.5$.

Each measurement of the position angle is an average of 8 or more set-

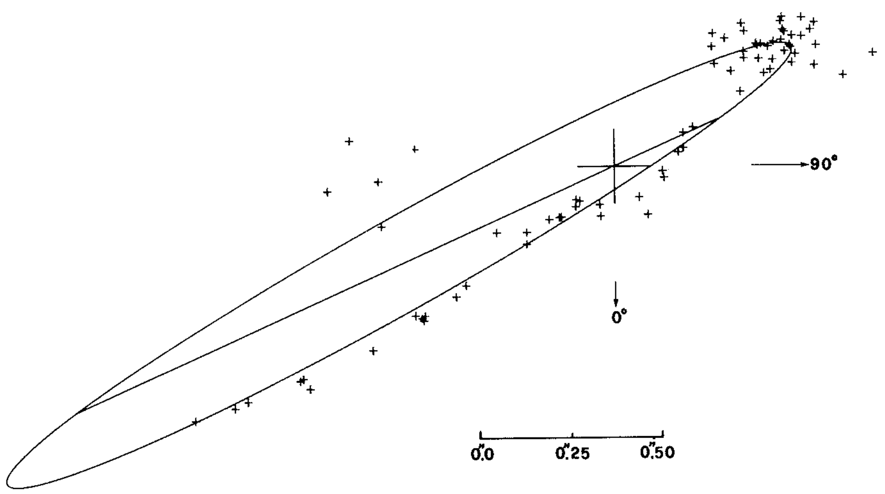

Figure 6: *Orbit of the binary star BU 738 (P = 305 years) obtained, utilizing also the measurements made at La Silla in the last few years.*

tings, while each measurement of separation is an average of 4 measures of the double distance.

It is possible now, after nearly four years and seven observing missions at La Silla, to make the first conclusions on the work done.

Regarding the air tranquillity, La Silla is largely superior to the average of European sites of which I have direct observing experience. 51% of the nights have been completely utilizable or in part (26% "good quality" nights and 25% "sufficient quality" nights), while during the remaining 49% of nights, bad seeing or covered sky have prevented the observations. A comparison with the seeing measurements made at Cerro Vizcachas has allowed to establish that, when the value measured there is better than 0."7, generally, the images at the GPO can be considered good; in these conditions the diffraction image presents itself as stable and the "turbulence" is less than 0."14 (for the definition of "turbulence", see Danjon and Couder, 1935, or Texereau, 1958).

Up till now, a total of 1840 measurements of 432 systems, down to separations of 0."18, have been made at La Silla. Figure 5 shows the histogram of the percentages of the measurements made by class of separation.

From these first results, it is my firm belief that La Silla is a very valid site for the observation of visual double stars. The contribution that a good observer (who could rely full time, for this kind of observations, on the GPO astrograph, or on an instrument of superior class) could give to the astronomy of visual double stars and to the knowledge of stellar masses, would be fundamental.

A Final Plea

It is exactly because of the validity of the arguments exposed above that the voices heard in recent times "on the arid mountain" regarding the future of the small instruments are a cause of worry. They contribute to make even more uncertain the future of this branch of astronomy with great traditions, still scientifically valid, and which has lost none of its reasons of existence.

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Long-term Photometry of Herbig Ae/Be Stars in the Strömgren System

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Introduction

Our working group on the study of Herbigt Ae/Be stars has joined Sterkens group of Long-term Photometry of Variables from the beginning on. The photoelectric photometry is based on Strömgren's system and is done with the small ESO telescopes at La Silla. Since the magnitude limit for accurate measurements is about 9, in this long-term photometry we have monitored only the brighter 27 members of the Herbig Ae/Be stellar group. When after some time a star turned out to be non-variable we have discontinued observations of it. The study of Herbig Ae/Be stars, which usually are varying irregularly, is done for giving a better explanation of the complex problems connected with the variability of these ob-

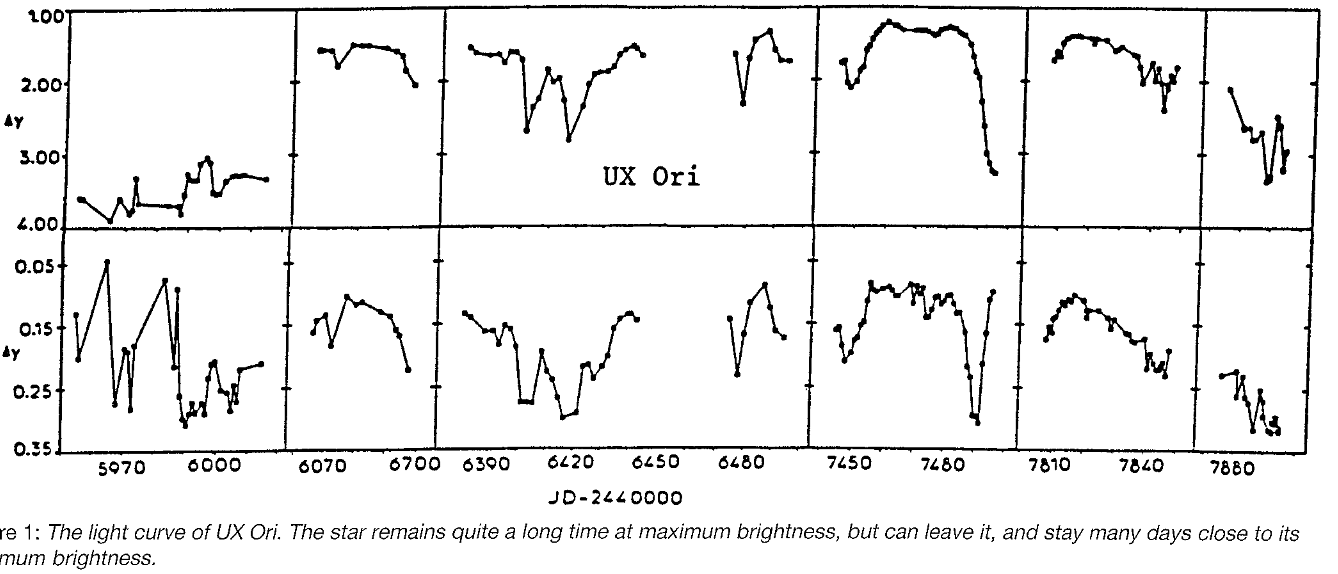

Figure 1: *The light curve of UX Ori. The star remains quite a long time at maximum brightness, but can leave it, and stay many days close to its minimum brightness.*

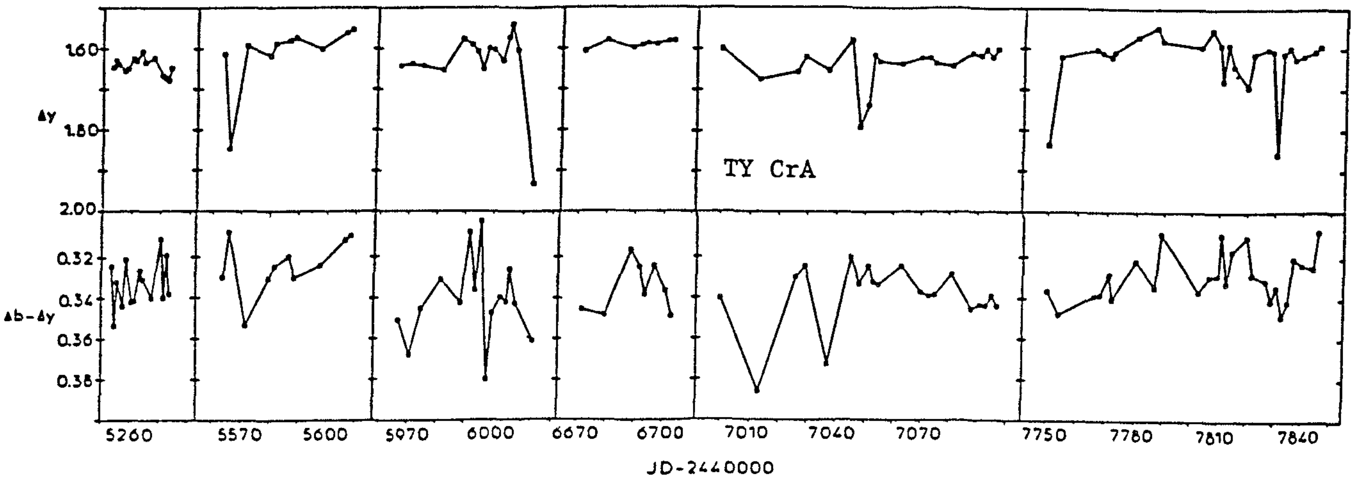

Figure 2: *The light curve of TY CrA. There are fewer observations compared to those of UX Ori, but from the figure it is clear that the star remains close to its brightness level all the time, with sudden changes to lower brightness.*

jects. We have in mind the study of three problems, explained further below, which can only be done with long-term photometry on the same photometric system.

Type of Variability, and its Correlation with Spectral Type and Spectroscopic Variations

The first purpose of the long-term photometry of Herbig Ae/Be stars is the determination of the shape of the light curve and the range in brightness. Light curves of UX Ori and TY CrA are shown in Figures 1 and 2 as examples. It is then important to know whether the type of variability and/or the brightness amplitude has some relation with the spectral type and luminosity of the star. In other words, do they depend on the location of the star in the Hertzsprung-Russell diagram, which is determined by the evolutionary state of the object?

Many observations were also made simultaneously with spectroscopic observations. For the study of the variable emission lines in the visual and/or in the UV, the knowledge of the brightness level of the star at the time when the spectroscopic observations were made, is necessary. Recent results of such studies have been reported by Tjin A Djie et al. (1989), for the visual spectral region, and by Blondel et al. (1989), for the ultraviolet.

Correlation Between Light and Colour Variability

A specific problem shown by several Herbig Ae/Be stars is that the light variability is correlated with the changes in colour in a special way. In the beginning, the colour of such a star becomes redder when the star dims, but after reaching a certain "turning point", it gets bluer when becoming fainter again. A typical example of a star exhibiting such a behaviour quite strongly is UX Ori, as shown in Figure 3.

There are several mechanisms proposed to explain this behaviour (Zajtseva, 1986, Pugach, 1981, Grinin, 1988), but no one adequately explains the observed phenomena. A revised mechanism for Grinin's (1988) explanation of the long-term photometric behaviour of UX Ori is reported in a recent paper by Bibo and Thé (1990).

Periodicity in the Light Variations

Although apparently irregular, it seems that in the light variations of Herbig Ae/Be stars, there are quasi-periodicities. These are perhaps caused by periodic variations in the characteristics of the stellar atmospheres. Such a quasi-period (of about 49 days) was found in the light variations of the star HR 5999 (A7 IIIe) by Baade and Stahl (1989). By using a stronger code on the data used by Baade and on those obtained by the long-term photometry (spanning in total a time interval of about 7 years), we have found in addition a quasi-period of about 110 days. An explanation for this behaviour is still lacking.

This study is made in collaboration with M.R. Pérez and J.R. Webb.

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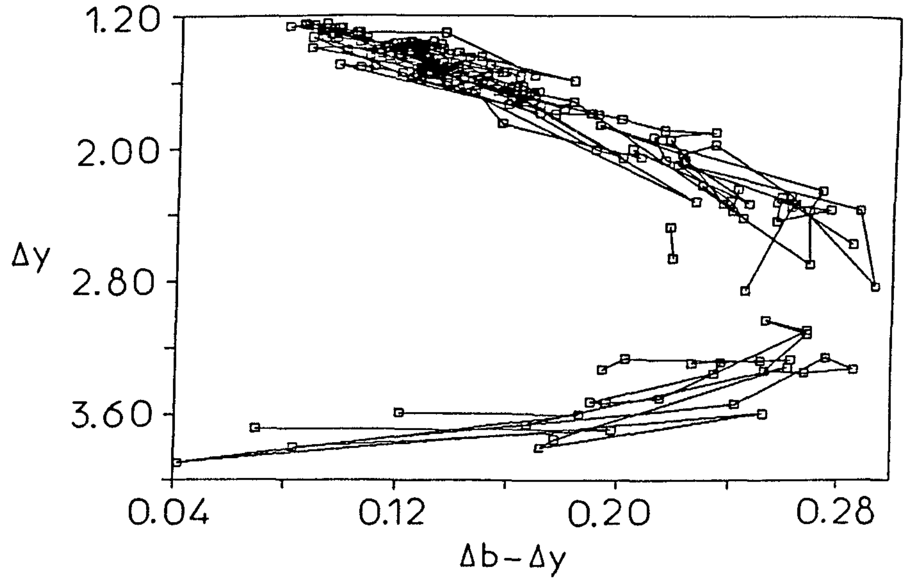

Figure 3: *The magnitude-colour relation of UX Ori. The star becomes redder when it dims, but after a certain turning point it gets bluer when decreasing in brightness further.*

The 1990 Outburst of VY Aqr

M. DELLA VALLE and T. AUGUSTEIJN, ESO

Introduction

The sixth outburst of VY Aqr in the last eight years was recorded by several amateur observers on June 30.75 U.T. 1990 (IAUC 5046). Thanks to the extensive monitoring, the observed maximum m_V = 10.4, should be very close to the true one. The spectroscopic and photometric observations began at La Silla some nights later, with the ESO 1.5-m and the Dutch 90-cm. The visual light-curve, represented in Figure 2, has been derived by plotting the magnitudes published in the IAU Circulars (5046, 5053) and the Walraven photometry obtained at the Dutch telescope. Figure 2 shows reproduced on the same scale the light curves observed during the other five recent outbursts (see Table 1).

Originally, VY Aqr was believed to be a fast nova (Payne-Gaposchkin, 1957). This was due to the large amplitude of the outburst recorded in 1907 ($\sim$ 10 m_{pg}), and to the fact that the second eruption in order of discovery was detected only in 1962 (Strohmeier, 1962). On the other hand, the lightcurve of this star does not fit in many respects that of a *classical nova.* In particular it does not satisfy the well established relationship between the magnitude at maximum and the rate of decline (Capaccioli et al., 1989) or between the amplitude of the outburst and the rate of decline (Warner, 1987). On the contrary, the amplitudes and the recurrence times of its outbursts fit very well to the *Kukarkin-Parenago* relation for Dwarf Novae (DN) : A(mag) = 1.85 $\pm$ 0.44 + 1.40 $\pm$ 0.23 $\times$ logτ_r (days) (van Paradijs, 1985). However, the most marked differences from novae come from the analysis of the spectra. Both at maximum and at minimum the spectra of VY Aqr are not at all comparable to those of a classical nova.

In principle, the occurrence of outbursts of large amplitude (7–10 mag) at intervals of years would allow us to include this star among the class of the *recurrent novae* (see Kholopov et al., 1985), but in recent years a number of

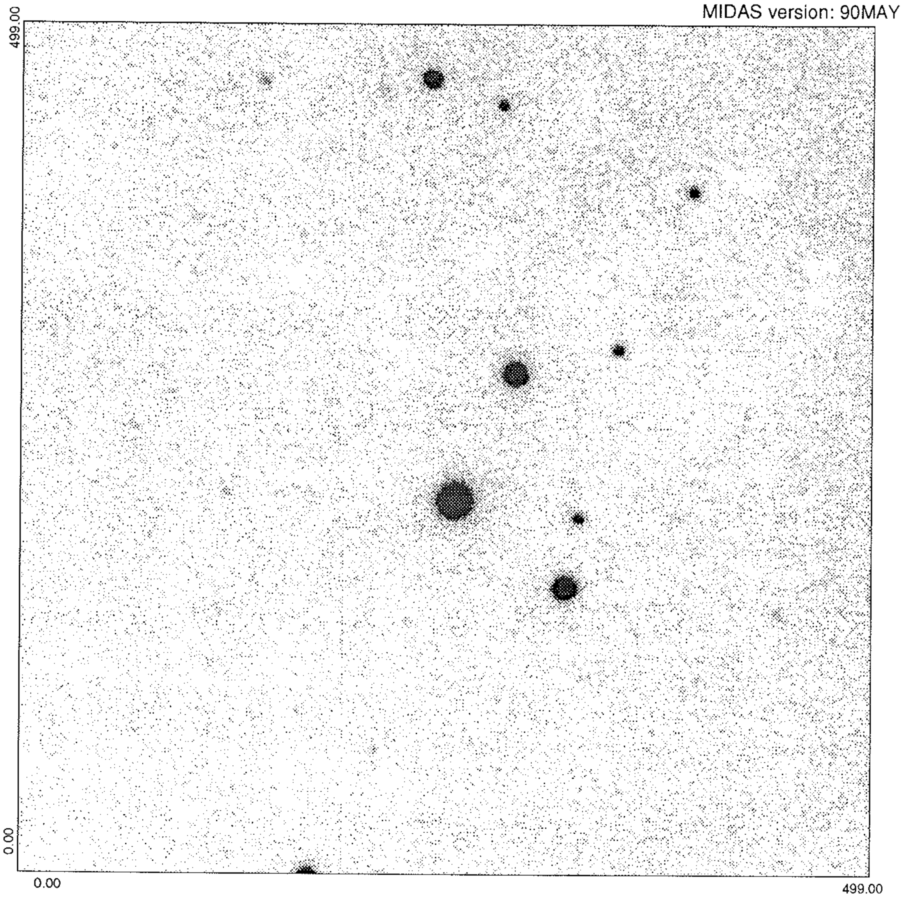

Figure 1: *VY Aqr, the bright star near the centre of the picture, during the recent outburst. The image was taken with the NTT-EMMI through an R filter on July 9 by Della Valle and Oosterloo.*

TABLE 1: *Recorded VY Aqr Outbursts*

Year	Maximum	Band
1907	8.4	pg
1929	8.0	pg
1934	9.0	pg
1942	11.0	pg
1958	10.5	pg
1962	9.7	pg
1973	9.5	pg
1983	10.3	m_V
1986	10.3	m_V
1987	10.7	m_V
1988	10.4	m_V
1989	11.1	m_V
1990	10.4	m_V

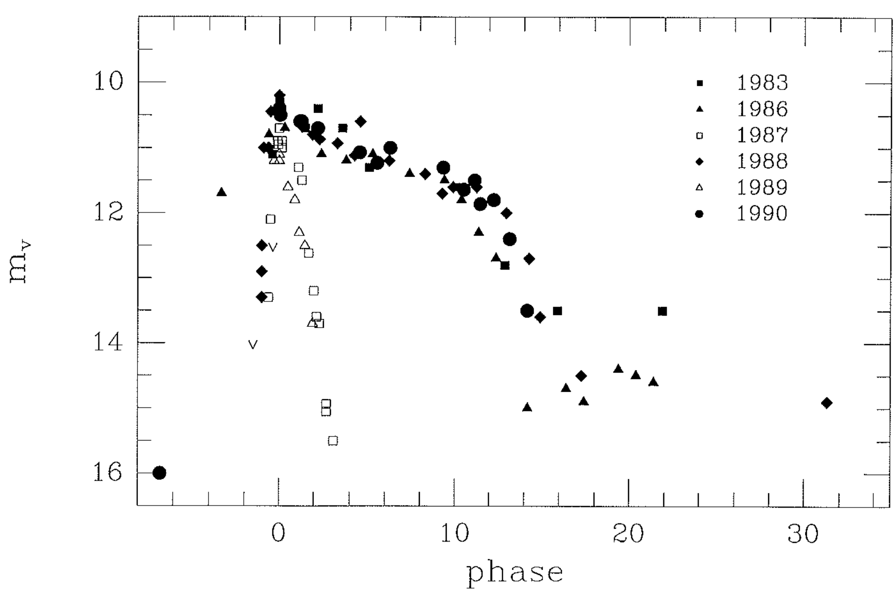

Figure 2: *Composite lightcurve of VY Aqr in the recent outbursts. The phase is expressed in days after the maximum.*

observations argue against this view. In particular: (a) the low excitation spectrum which characterized VY Aqr at minimum (Hendry, 1983), (b) the short recurrence time exhibited by the stars in the last years, and (c) the spectrum at maximum typical of a DN in outburst.

Roughly speaking, DNe form a fairly homogeneous class of variables. Their lightcurve is characterized by relative long intervals of quiescence, generally from some weeks to some months, interrupted by sudden rises in the brightness (typically 2–6 mag) which last less than one or two days. The subsequent decline takes typically a few days to a week.

Most of the DNe exhibit a spectrum at minimum of low excitation with strong Balmer lines in emission, superimposed on a faint, blue continuum. Weak emission lines of He I are also present whereas the forbidden lines, quite common in the spectra of the novae at this stage, are generally missing. As a DN increases in brightness, the continuum becomes stronger and in place of the emissions, shallow absorption lines appear, frequently filled in with emission. This type of spectrum was exactly what was observed (Augusteijn and Della Valle, 1990) during the recent outburst.

According to the current models, the absorptions probably arise from the inner, rapidly rotating portions of the disk surrounding the primary. The emission comes from the outer layers rotating in a quasi-Keplerian way.

Among the DNe, due to the large amplitude and the relatively long recurrence time, VY Aqr represents a quite peculiar case. Actually, similar photometric behaviours have been recognized only in a handful of objects, like: DX And, UZ Boo, WX Cet, RZ Leo, UV Per, WZ Sag, SW Uma, and perhaps V1195 Oph.

The Observations

Our observations were made on July 4–6, 1990, at the ESO 1.5-m telescope, equipped with the Boller and Chivens spectrograph and the CCD (GEC #14 chip). Initially, we collected 33 spectra of VY Aqr in the 405–504 nm region, with a dispersion of 59 Å mm^{-1}. The brightness of the object ($m_v \simeq 10.5$) allowed us to keep a quite high temporal resolution (168 s). In the following nights, spectra covering the whole optical range (375–680 nm) of VY Aqr and V 3885 Sgr, and in the range 375–505 nm of IX Vel and RW Sex were also taken. Finally, a new set of 21 spectra of VY Aqr in the 405–504 nm region, with a dispersion of 59 Å mm^{-1} with a temporal resolution of 300 s were obtained. From a rough reduction performed with IHAP

Figure 3: *4-minute Boller and Chivens spectrum of VY Aqr during the 1990 outburst. The spectrum is calibrated in wavelengths and corrected for flat field and sky subtraction.*

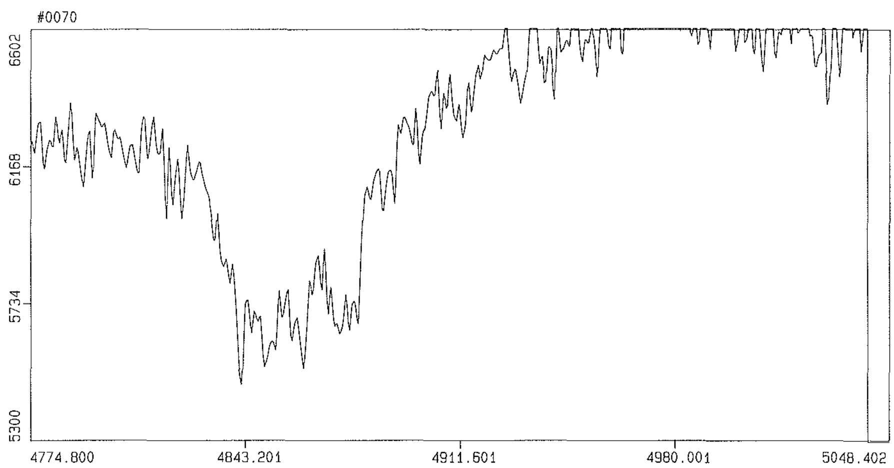

Figure 4: *The Hβ absorption with the central re-emission.*

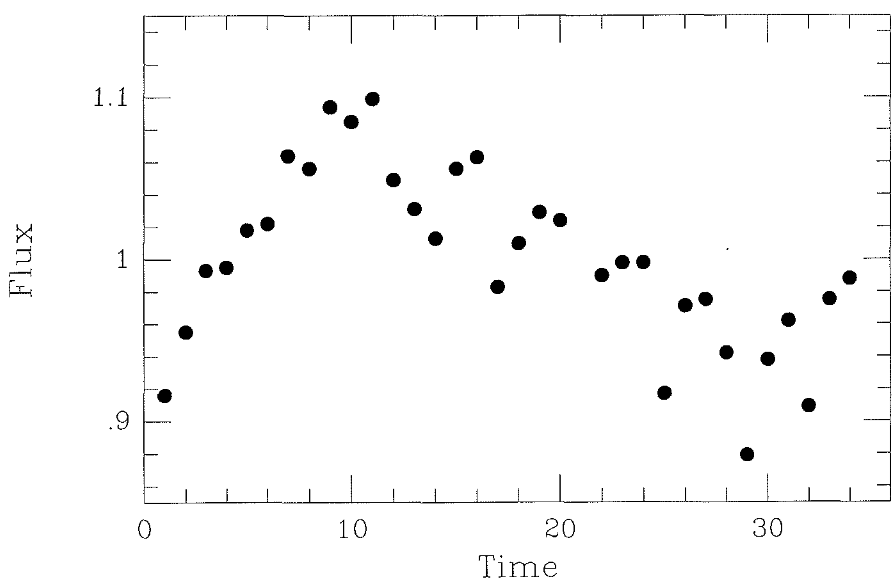

Figure 5: *Plot of the integrated flux (arbitrary unit) for 33 spectra of VY Aqr versus time. One unit in the abscissa corresponds to 168 s.*

at the telescope, we derived the spectra shown in Figures 3–6. The Walraven photometry in V has been reduced to the Johnson's V band through the colour equation: $V_J = 6.886 - 2.5\,V_W - 0.082\,(V-B(_W$ (Pel, 1985).

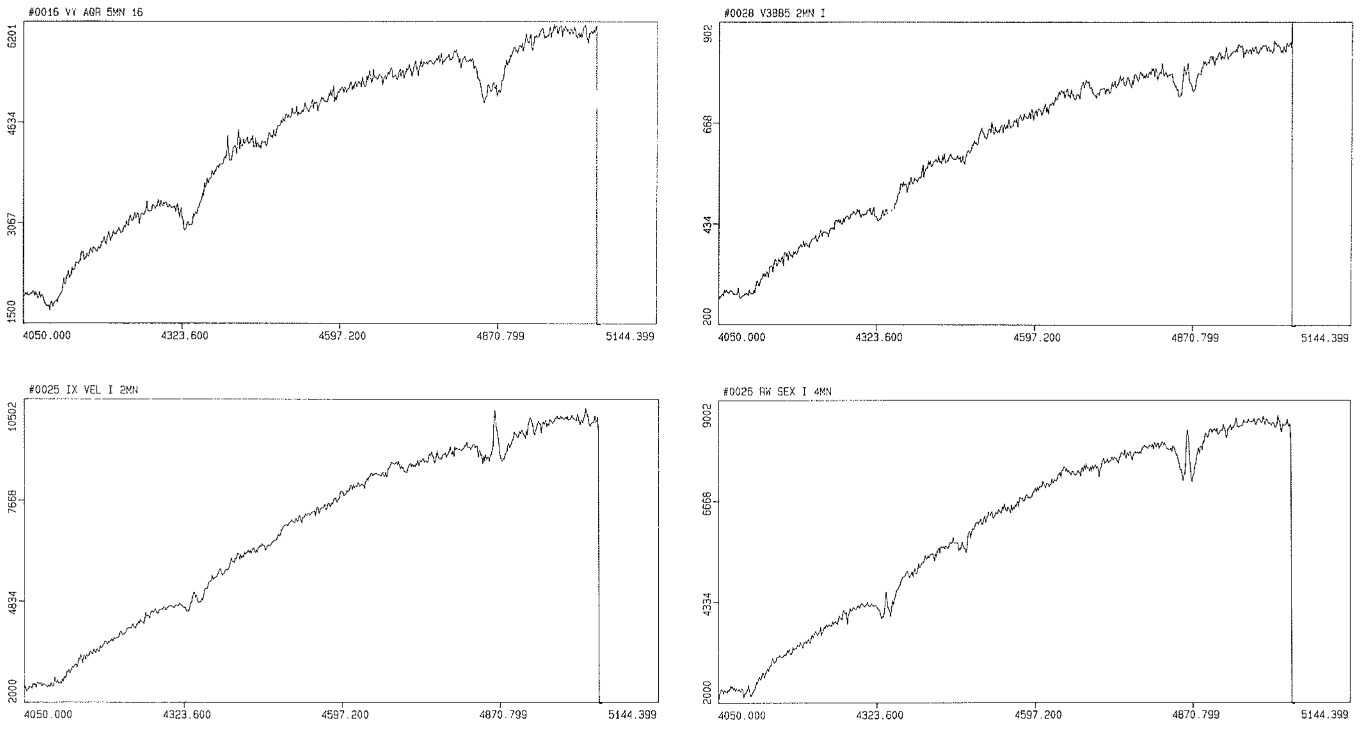

Figure 6: *The spectrum of VY Aqr at maximum, in comparison with the "normal stage" spectra of three UX UMa stars: V 3885 Sgr, IX Vel, and RW Ser.*

Results

A quick glance at Figure 2 shows clearly that VY Aqr undergoes two different types of outbursts. The 1983, 1986, 1988, and 1990 outbursts are distinguished from the ones in 1987 and 1989, by the longer duration and the greater brightness (~0.5 mag). It is worth noting that a qualitatively similar behaviour is found in the lightcurves of a sub-class of DNe; the SU Ursae Majoris stars. They exhibit, apart from the normal outbursts, the so-called *superoutbursts.* In the case of VY Aqr, differences between the two types of outbursts can also be seen from the spectroscopy. The spectrum recorded on July 5 (Figure 3), shows shallow absorption due to Balmer lines, HeI and possibly NI (599.9 and 600.8, mult. 16), superimposed on a fairly strong continuum. The H lines appear variously filled in with emission and in some cases appear double-peaked. In particular, the emission profile of Hβ is split into several components (Fig. 4). The absorption profiles for the H and He lines were measured and compared with the description of the spectrum of VY Aqr obtained during the "normal" maximum of 1987 (Leibowitz et al., 1987). In the 1990 outburst, the observed value for the FWZI of Hβ corresponds to ~5000 km s^{-1}, a 40% greater value than that observed in 1987.

According to the current knowledge, two mechanisms are believed to explain the DN explosions. In the *disk-instability* model the quiescent state is characterized by an accretion rate from the disk onto the white dwarf (WD), smaller than the mass transfer rate from the secondary to the disk. As a result of this, when the density in the disk has reached a critical value, the disk suddenly changes its low mass transfer rate onto the WD, to a high accretion rate state, originating an outburst. Later, due to a decline in the density of the disk, the DN returns to the minimum. In the *mass-transfer-instability* model, the quiescent state is characterized by the same values of accretion rate from the secondary to the disk and from the disk to the WD. In this view, the outbursts should be caused by bursts of the mass-transfer rate from the secondary to the WD. The two different types of eruptions observed in VY Aqr would perhaps suggest that the star can undergo both these mechanisms.

Figure 5 has been obtained by plotting the integrated flux (between 405 and 514.4 nm) derived for the 33 high temporal resolution spectra, versus time. The variation in the flux detected from the star, is consistent with a period of 0.059 ± 0.005 days. In agreement within the errors to the superhump period of 0.064 days reported by Warner and Livio (1987).

Finally, in Figure 6, we compare the spectrum at maximum (405–504 nm) of VY Aqr to those of three UX UMa stars, V3885 Sgr, IX Vel and RW Sex, observed during their "normal" stage. The strict similarity with the spectrum of VY Aqr points clearly to a classification of the UX UMa stars as DNe continuously in outburst, rather than Nova-like, as normally reported.

This fact is consistent with Krautter et al.'s (1981) suggestion, that the UX UMa star TT Ari was undergoing, before 1980, a standstill stage similar to the long period of activity exhibited by the Z Cam type DN.

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1.2-mm Continuum Observations of IRAS Galaxies: Implications for Gas Mass and Cold Dust Component

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Introduction

New fields of research have been opened at ESO with the SEST 15-m antenna (see *The Messenger* No. 57), and in particular we find promising the coupling between this telescope and the MPIfR bolometer because of the very high sensitivity of this instrument. This system will allow the investigation of the continuum emission at millimetric wavelengths of galactic and extragalactic objects.

We have started an observational programme, to be carried out partly with the SEST telescope, to investigate the 1.2-mm continuum emission of a complete sample of galaxies selected from the IRAS Point Source Catalogue (Smith et al., 1987).

Among the important issues which can be addressed from this project, we find of particular interest:

(a) the study of the electromagnetic spectra of galaxies at long wavelengths: late-type galaxies represent the majority of the extragalactic sources detected by the IRAS satellite. Most of their observed emission is thermal and comes from dust in H I clouds heated by the general interstellar radiation field, cold dust in molecular clouds and dust heated by hot stars embedded in compact H II regions.

However, to understand both galactic evolution and star-formation processes, which are strictly connected with the available dust and gas present in the interstellar medium, one needs to know the total amount of these components in the galaxy disks. The true dust column density cannot be properly estimated only by means of the FIR measurements, like those of the IRAS satellite, since they are not sensitive to dust colder than 20 K and the bulk of dust mass is expected to emit at submillimetre and millimetre wavelengths. Continuum flux densities in this spectral range are good tracers of the total dust, gas and molecular mass and can represent an alternative way to estimate these parameters.

(b) galaxy counts at these wavelengths: the source distribution, N(S), and its first and second moments: $I = \int S \cdot N(S)dS$ and $(\Delta I)^2 = \int S^2 \cdot N(S)dS$, provide relevant constraints on models of cosmological evolution of the studied objects. In particular, the fluctuation level generated by unresolved randomly distributed sources, given by the second moment of the N(S) distribution, can significantly constrain the small- and intermediate-scale anisotropies of the Cosmic Microwave Background (CMB) (Franceschini et al., 1989) even at ~1 mm, i.e. near the peak of the CMB.

At present, very few observations are available of the millimetre continuum emission of galaxies and they are mainly biased towards active galaxies (both AGNs and starburst galaxies), because of their enhanced nuclear emission. The only mm measurements available on spiral galaxies are those reported by Chini et al. (1986), but the claimed conspicuous presence of a cold dust component peaking around 200 μm has not been confirmed by other submillimetre observations (Stark et al., 1988; Eales et al., 1989).

The first observations have been performed at the IRAM 30-m telescope. To allow comparison between the mm fluxes with the IRAS observations and to avoid large systematic errors introduced by aperture corrections, the angular dimensions of the galaxies should not exceed the beam width. Therefore, we have chosen galaxies of the sample with optical size comparable with the IRAM 30-m beam width (HPBW = 11″).

The 1.2-mm continuum emission of 7 objects of the sample and 5 other galaxies has been studied and issues on the presence of a cold component of the interstellar medium and dust and gas masses of the disks are preliminarily addressed.

Observations

The observational mode is briefly outlined since most of the performances of the IRAM 30-m antenna are equal to those of the SEST.

The observations have been carried out with the ^{3}He bolometer of the MPIfR fed by the IRAM 30-m telescope at Pico Veleta (Spain) on March 17–18 and May 17–19, 1990.

The position of the sources was found by pointing a nearby radio quasar with strong millimetric fluxes. Pointing accuracy was most of the time better than 2″ and was checked every half hour. Beam-switching is achieved by wobbling the secondary in azimuth ON-OFF the source and nodding the telescope, resulting in a three-beam technique which, therefore, allows comparison between the source signal and that from two nearby empty sky regions. The wobbling amplitude was set to be much larger than the optical radius of the galaxy.

Each source has been observed n · 200 s times with n depending on the expected 1.2-mm intensity. To approximately evaluate the millimetric flux the IRAS 100 μm flux has been extrapolated by assuming a thermal spectrum with spectral index between 1 and 2.

Atmospheric transmission has been monitored by frequent skydips. Uranus, Mars, Neptune and Jupiter have been used as primary calibrators by assuming weighted effective temperatures at this wavelength of 93 ± 1, 200 ± 6, 96 ± 2 and 169 ± 3, respectively (Orton et al., 1986; Gear et al., 1985). The quasars 3C286, 0839 + 187, 0953 + 255, 1156 + 295, 2201 + 315 have been used as secondary calibrators mainly to detect sky variations during the observations.

The overall accuracy on the detected fluxes depends strongly on the atmospheric conditions, being between 10 and 30%.

Results

Of 12 observed sources (7 belonging to the sample and 5 are isolated objects) 9 have been detected and for the other 3 upper limits were obtained. Figure 1 shows 4 IR/mm spectra, the IR fluxes have been taken from the IRAS Point Source Catalogue (Lonsdale et al., 1989) and have been slightly modified according to the colour and K-corrections (Smith et al., 1987; Lonsdale et al., 1989).

The millimetre values have been also corrected for the overall system response and K-corrections. The former has been evaluated by computing the integral:

$$\Re(w,\alpha) = \int_{\nu_1}^{\nu_2} I_{atm}(\nu,w)\,\Upsilon(\nu)\epsilon(\nu,El)\cdot(\frac{\nu}{\nu_0})^{\alpha}d\nu$$

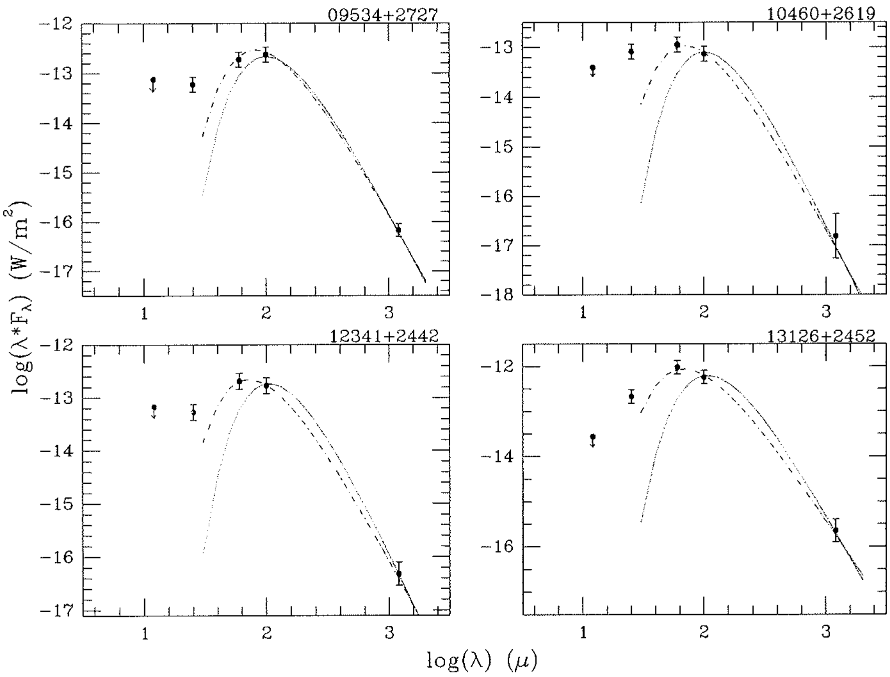

Figure 1: *IR/mm spectra of 4 of the observed galaxies. The 12, 25, 60 and 100 μm data have been taken from the IRAS P.S.C. (see text for details). Two thermal curves $\lambda^{-\alpha} B_\lambda(T_d) \sim 30 \div 40$ K ($\alpha \sim 1 \div 1.5$) (dot-dashed lines) and at $T_d \sim 20$ K ($\alpha \sim 2$) (dotted lines) are shown for comparison.*

where ν_1 and ν_2 are the lower and upper limits on the system spectral response; $I_{atm}(\nu, w)$ is the atmospheric emission, assumed to follow a cosecant law: $I = I_o e^{-\tau_o(w)\mathrm{cosec}El}$, $\tau_o(w)$ is the measured zenith optical depth for a given value of the water vapour content w, El is the elevation of the source; $\epsilon(\nu, El)$ is the antenna efficiency and $Y(\nu)$ is the optics transmission. The underlying assumption is that the spectra in the millimetric region can be approximated by $F = F_o(\frac{\nu}{\nu_o})^\alpha$, where α is the spectral index of the source.

A further correction applied to the millimetric fluxes, due to the different size between the beam width and the optical diametre, has been applied by assuming that the IR disk obeys an exponential law: $I(r) = I_o\exp(-r/r_o)$, $\tau(r) = \tau_o\exp(-r/r_o)$ (Xu and de Zotti, 1989; Bicay and Helou, 1990) and that the IR and mm emissions are spatially correlated (see for instance Andreani et al., 1990).

In Figure 1 is also reported a fit with a modified Planck spectrum $\lambda^{-\alpha} B_\lambda(T_d)$ with α ranging between ~1.0 and 1.5 and $T_d \sim 30 \div 40$ K (dot-dashed line). However, the solution is not unique because very likely the 60 μm point is affected by emission of smaller dust grain at a much larger equilibrium temperature. In fact, by excluding the 60 μm point the curve matching the data has a lower temperature, $T_d \sim 20$ K and $\alpha \sim 2$ (dotted line). Note that, in order to infer a value for the dust temperature, the spectral index must be fixed and this can be done only by adopting a dust model. In this case we used the values of $1 \div 2$ as predicted by the most accepted models (e.g. Draine and Lee, 1984).

Dust and Gas Masses

The thermal emission from dust at these wavelengths is optically thin, therefore one samples the entire line of sight and determines the total dust column density; at mm and submm wavelengths the flux density, F_λ, depends linearly on the dust mass and its temperature (Draine, 1989):

$$F_\lambda \simeq \frac{2kc\sum_i \chi_i(\lambda) < T_i > M_d}{\lambda^4 D^2} \quad (1)$$

where $\chi_i(\lambda)$ are the grain opacities due to component i; $< T_i >$ is the time-average temperature (at these wavelengths it is possible to approximate the temperature distribution of the grains with a single temperature) and M_d is the dust mass. Gas masses are then obtained by adopting the relationship between the dust optical depth τ_v and the hydrogen column density $N(H_2 + HI)$ given by the models.

We estimated the dust masses of the clouds by using two different models of interstellar dust (Draine and Lee, 1984; Mathis and Whiffen, 1989). These models provide values for the grain opacities at 1 mm using different composition and dimensions of dust grains. Draine and Lee (1984) assume that dust grains consist of a mixture of spherical silicates and graphites with size distribution: $f(a)da \propto a^{-3.5}\,da$ for a varying between 50 Å and 0.1 μm. Mathis and Whiffen (1989) model grains as fluffy aggregates of submicron-size particles composed of various astronomical minerals whose spatial structure is fractional and chemical composition inhomogeneous. Therefore, grains can attain greater dimensions (from 0.03 μm up to ~1 μm).

By using eq. (1) we find for the 7 sources of the sample the values listed in Table 1. For each source both the cold dust component (from 1.2-mm observations), the warm component (from 100 μm IRAS data) and the evaluated values for the gas masses are reported. The first row contains values deduced from the Mathis and Whiffen's model,

TABLE 1: *Estimated dust and gas masses (in $M_\odot$)*

Galaxy	Cold dust (mm)	Warm dust (IR)	M_{gas}	M(HI)
09534+2727	$*(1.9 \pm 0.3)10^6$ $\dagger(4.6 \pm 0.7)10^6$	$*(6.4 \pm 0.3)10^5$ $\dagger(8.6 \pm 1.3)10^5$	$*8.1\ 10^8$ $\dagger 4\ 10^9$	$3.7\ 10^8$
10460+2619	$*(2.3 \pm 1.0)10^7$ $\dagger(5.5 \pm 2.3)10^7$	$*(4.5 \pm 0.7)10^6$ $\dagger(6.0 \pm 0.9)10^6$	$*10^{10}$ $\dagger 1.3\ 10^{10}$	$5.7\ 10^9$
12341+2442	$*(4.4 \pm 1.0)10^7$ $\dagger(1.1 \pm 0.3)10^8$	$*(7.3 \pm 1.1)10^6$ $\dagger(9.8 \pm 1.5)10^6$	$*2\ 10^{10}$ $\dagger 3.9\ 10^{10}$	$5.4\ 10^9$
13126+2452	$*(8.3 \pm 2.1)10^7$ $\dagger(2.0 \pm 0.5)10^8$	$*(5.4 \pm 0.8)10^6$ $\dagger(7.3 \pm 1.1)10^6$	$*3.4\ 10^{10}$ $\dagger 10^{11}$	–
13387+2331	$*(8.2 \pm 3.1)10^7$ $\dagger(2.0 \pm 0.8)10^8$	$*(1.4 \pm 0.2)10^7$ $\dagger(1.9 \pm 0.3)10^7$	$*4.2\ 10^{10}$ $\dagger 10^{11}$	–
15373+2506	$*(3.7 \pm 2.1)10^7$ $\dagger(8.9 \pm 5.1)10^7$	$*(5.4 \pm 0.8)10^6$ $\dagger(7.2 \pm 1.1)10^6$	$*1.8\ 10^{10}$ $\dagger 4\ 10^{10}$	–
15566+2657	$* < 1.8\ 10^7$ $\dagger < 4.3\ 10^7$	$*(1.3 \pm 0.2)10^6$ $\dagger(1.8 \pm 0.3)10^6$	$* < 7.8\ 10^9$ $\dagger < 4.3\ 10^{10}$	$4.3\ 10^8$

* Values deduced from Mathis and Whiffen's model.
† Values deduced from Draine and Lee's model.
M(HI) are taken from the literature (see text).

and the second row those inferred from Draine and Lee's computations. When available, the M(H I) masses calculated by using H I 21 cm data are listed in the fifth column (Bicay and Giovanelli, 1987; Mirabel and Sanders, 1988; Young et al. 1989).

Discussion and Conclusion

The main advantages on the determinations of the dust mass at these wavelengths lie on a better evaluation of $< T_i >$ since at higher frequency the uncertainties in the temperature distribution function may introduce order-of-magnitude errors in $< B_\lambda(T) >$.

Note that the warm dust masses listed in Table 1 can be underestimated also because the IRAS 100 μm measurements do not fully sample the total dust in the galaxy disk.

However, the uncertainties in the grain opacities are larger at long wavelengths even if they do not depend on the details of the size distribution. Gas and dust masses are estimated, then, within a factor of 5 (see Table 1).

The comparison with M(H I) suggests that very likely there is a substantial contribution to the total gas mass due to H_2. But, to draw any firm conclusion on this point we need CO line measurements of these galaxies, which up to now have not been carried out.

Young et al. (1989) found that for a sample of IRAS spirals $M(H_2)$ ranges between 10^8 and $5 \cdot 10^{10}\, M_\odot$ and the ratio $M(H_2)/M(HI)$ is of the order of 1. If this is the case also for the observed sources of our sample, the gas mass values inferred from our measurements would agree with those determined from CO and H I data.

It should be stressed that the approach used here is not claimed to be, up to now, of greater accuracy than other determinations of gas masses (e.g. using the integrated intensity of the ^{12}CO line) but it is important either because it implies a completely independent method based on a different set of assumptions. However, these observations can substantially improve our knowledge on dust opacities at long wavelengths and constrain models of dust grains. This would turn into a better determination of dust and gas masses.

Therefore, we find this approach more promising with respect to that based on CO line intensities since the uncertainties related to this latter are largely connected to the physical conditions of the medium and then more difficult to evaluate.

Further observations will be carried out at SEST in September and they will be helpful in gaining statistical insights into these problems.

Acknowledgements

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Variability as a Way to Find Quasars: a Complete Sample

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Introduction

To study the cosmological evolution of quasars, it is first necessary to establish a complete sample. This has proved to be particularly difficult, for several reasons. Early work was based on radio surveys, and although this resulted in well defined samples with no obvious bias in redshift, it was inevitably limited to a small subset of quasars (1 or 2 %) which themselves showed a wide variety of radio properties. Most recent results are based on samples obtained by two main methods: the UV excess method (see Véron, 1983, for a review), later generalized to the multicolour method (Koo et al., 1986), and the slitless spectroscopy method (see Véron, 1983, for a review). Although both techniques can produce samples apparently containing a sizeable fraction of the quasar population, they each suffer the drawback that their detection efficiency is strongly dependent upon redshift. To some extent they may be seen as complementary procedures as the UVX method is most efficient in the low redshift regime, while slitless spectroscopy is more sensitive to high redshift objects. However, what is clearly needed is a selection technique which is essentially independent of redshift, and is capable of detecting a substantial fraction of all quasars brighter than a given flux limit.

Most, if not all, quasars are optically variable. Indeed, previous studies have shown that up to 70 % of all quasars have an amplitude of variability larger than 0.43 mag. (Trevese et al., 1989). Van den Bergh et al. (1973) first suggested using this property as a method for finding quasars, and Sanitt (1975) discussed the various types of variable star (RR Lyrae and low-luminosity M-type flare stars) which might contaminate a sample compiled by this method. There are number of advantages in using variability as a search criterion for quasars. There are essentially no instrumental redshift biases, and apart from some constraints set by the passband of the search, there are no colour- or magnitude-dependent biases. Set against this, there is the practical limitation that the timescale of variation for most quasars is several years and so a search must be undertaken over a decade or more to detect a reasonably high fraction of the quasar population.

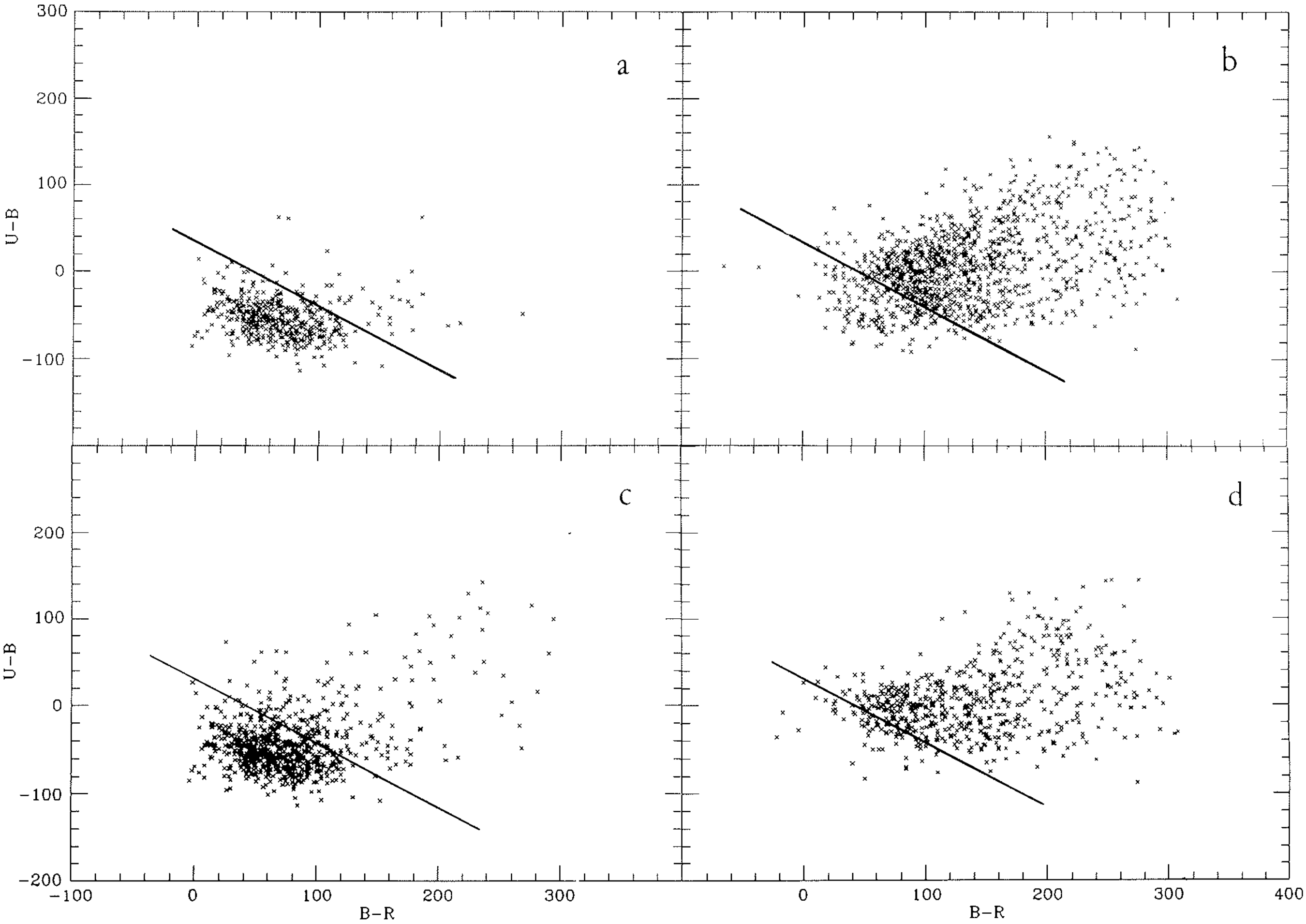

Figure 1: *U-B/B-R diagram (U-B and B-R are in units of 0.01 mag.) for: (a) all variable quasar candidates with $\Delta B \geq 0.45$ mag.; (b) all variable quasar candidates with $0.30 \leq B \leq 0.35$; (c) variable candidates with $\Delta B \geq 0.35$, the objects near a bright star and the extended objects being excluded (809); (d) the extended objects (690).*

Preliminary attempts to discover quasars on a large scale solely on the basis of variability were undertaken by Hawkins (1981, 1983, 1986) using COSMOS measures of a number of IIIa-J plates taken with the UK 1.2-m Schmidt telescope. This early work established that variability was indeed a viable way to find quasars, but dit not cover a long enough time span to detect more than a small percentage of quasars in the field.

This is because, in most cases, the standard deviation of the variability is significantly smaller in the case of a short epoch survey (2 yr) than for a long epoch (50 yr) (Angione et al., 1981), although the mean brightness remains essentially constant over 60 to 70 years (Angione, 1973).

The influence of the time dilation due to redshift on surveys of variability depends on the nature of the variability (Gaskell, 1981); however, if the r.m.s. variation increases with time to reach its maximum after two years for quasars at $z \sim 1$, as found by Bonoli et al. (1979), it is clear that the same value will be reached only after four years at $z \sim 3$.

Over the last 12 years we have been undertaking a survey based on COSMOS measures of UK Schmidt plates aimed at detecting almost all quasars in a 19 sqare degree field. Our results to date are described in the following sections.

The Survey for Variable Quasars

The survey for variable quasars has been based on the ESO/SERC field 287 at 21^h25^m, $-45°$. The first plates of this field were taken in 1975, and since then the field has been extensively photographed in UBVRI. In order to detect variables, several IIIa-J plates (33 altogether) were obtained in each of the years 1977, 1978 and 1983–88. The plates were all sky limited (approx. 60 min exposure) and reached a limiting magnitude of about $B_J = 22.5$.

The photographs were measured using the COSMOS machine at ROE and calibrated with deep CCD sequences obtained at La Silla and with the AAT (Hawkins, 1983). This measurement procedure provides some 20 parameters per image, including position, integrated magnitude and some image structure information. The measures of each plate have produced 33 B magnitudes for each image, as well as extensive additional measures in UVRI.

The actual search for quasars was constructed to detect objects which varied significantly from year to year, but which remained essentially constant within each of the eight measurement epochs. This had the effect of removing essentially all types of variables apart from quasars, as well as most non-varying objects with large photometric errors. It also tended to remove quasars with large variation over short time scales (OVV quasars), but these objects are known to be very rare. The selection algorithm divided the maximum amplitude of variation by the aggregate r.m.s. scatter within each epoch, to give a measure σ of the significance of the variability.

We have first selected all (2450) objects with a variability amplitude larger than $\Delta B = 0.30$ and brighter at minimum than $B = 21.5$; however, we have found that the contamination by non variable objects is very large (~90%) for $\Delta B < 0.35$; we therefore restricted our sample to $\Delta B \geq 0.35$ (1241 objects). Moreover, we have excluded a small area around the 300 brightest stars in the field, total-

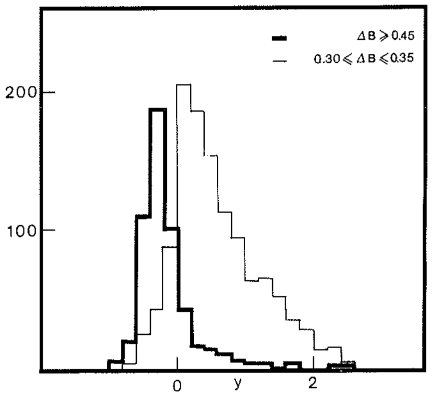

Figure 2: *Histograms of "y" for the objects with $\Delta B \geq 0.45$ mag. and for the objects with $0.30 \leq \Delta B \leq 0.35$.*

ling 3665 mm^2 or 1.28 deg^2, because measurements of weak stars near bright stars are very uncertain. Galaxies were removed from this sample using an algorithm based on maximum density versus image area, using twelve of the plates with the best seeing. The resulting sample contained 809 quasar candidates.

Reliability and Completeness

We have to ask how many of these objects are quasars and how many quasars have been missed.

In a first step, we compare the U-B/B-R diagrams for the highly variable objects ($\Delta B \geq 0.45$ mag) and for the low variability objects ($0.30 \leq \Delta B \leq 0.35$) (Fig. 1); we immediately see that, if we call y = (U-B) + 0.74 (B-R) – 0.32, almost all highly variable candidates have $y < 0$ while very few low variability objects have. Figure 2 shows the histograms of y for the two classes of objects. It clearly shows that most quasars have $y \leq 0$ and that very few low variability objects are quasars.

From the total of 809 variable candidates, 587 have $y \leq 0$. Figure 3 shows the fraction of candidates with $y \leq 0$ in various ranges of variability amplitude. For $\Delta B \geq 0.50$, this fraction is constant and equal to ~90%; it rapidly drops for lower values of ΔB, being only 42% for $0.35 \leq \Delta B < 0.40$. Among the 39 objects with $\Delta B \geq 0.50$ and $y > 0$, 18 are confirmed Seyfert 1 galaxies or quasars (and 9 have $z > 2.7$), 7 are either stars or galaxies while we have no spectra for 15 of them.

On the other hand, all 73 objects with $\Delta B \geq 0.50$ and $y \leq 0$ for which we have a spectrum are confirmed quasars except one which is a dwarf nova, therefore at least 94% of all highly variable objects are quasars.

To find out how many quasars we have missed because they have a variability amplitude smaller than 0.35, we have extracted all objects in the field with U-B ≤ -0.40, $y < 0$, and $B_{min} \leq 21.0$, irrespective of their variability.

We have found 602 such objects. 325 of them have an amplitude of variability $\Delta B \geq 0.35$. This suggests a completeness level of 54%. However, 45 objects have B-R < 0, only two of them with $\Delta B \geq 0.35$; they are most probably hot stars; this brings the statistic to 323 variable quasar candidates for a total of 557, or 58%.

Comparison of the histograms of the U-B colour index for the highly variable objects ($\Delta B > 0.50$) and the low variability objects ($\Delta B < 0.30$ and B-R > 0) suggests that only half of those are quasars; the other half could possibly be the weak blue galaxies found by Gallagher and Hamilton (1988) and Koo (1986). If this is the case, 90 of the low variability objects would not be quasars and therefore the variable quasars (323) would constitue 69% of the total.

Spectroscopy

In the course of several observing runs with the AAT and the ESO 3.6-m telescope, we have made spectroscopic observations of 176 variable objects. 140 of them turned out to be quasars, 48 having $z > 2.2$, the largest redshift being $z = 3.58$ (# 695); there is a bias against redshifts larger than this value in a survey based on IIIa-J plates because for larger redshifts, a large k correction applies due to Lyα leaving the bandpass. Three additional objects are Seyfert 1 galaxies (# 23, 211 and 746); two more (# 7 and 24) show a continuous spectrum and have a strong polarization as shown by measurements made at La Silla with a Wollaston prism; they are most probably BL Lac objects. Two objects (# 19 and 668) are dwarf novae; the others are galaxies (3), stars or objects of unknown nature due to a poor signal-to-noise spectrum. Of those objects, all have a positive y except for the two dwarf novae and two objects of unknown nature (# 10 and 24); this confirms that most objects with a negative y are quasars.

Conclusions

This paper is a first step to addressing the problem of obtaining unbiassed samples of quasars, especially with regard to redshift, for the purpose of studying the evolution of the luminosity function. We have reasons to believe that the strong redshift biases associated with other methods of finding quasars are not relevant to selection by variability. With a well sampled search period of some 11 years, we have shown that our sample, in a regime

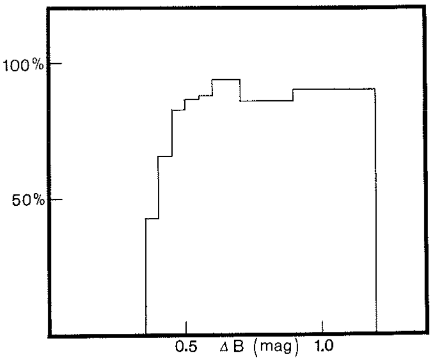

Figure 3: *Fractions of the variable quasar candidates (galaxies and objects near a bright star excluded) with $y < 0$ in various bins of variability amplitude.*

where contamination from non-variables is not significant, is about 70% complete. So far, most work has been done from searches based on blue passband plates, but we now have a baseline of 9 years for red passband plates, which should provide an excellent basis for searching for quasars in the redshift range 3.5 to 5.

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STAFF MOVEMENTS

Departures

Europe:

MAASWINKEL, Alphonsus (NL), Project Engineer in Astronomical Instrumentation
PRIEUR, Jean-Louis (F), Fellow
ZHAO, Gang (RC), Associate

Chile:

LE BERTRE, Thibaut (F), Scientist

A Search for Interstellar Be II λ 3130: CASPEC Shakes Hands With IUE and GHRS

D. BAADE and P. CRANE, ESO

The wavelength region near the atmospheric high-frequency cut-off is still a considerable challenge for high-resolution spectroscopy. The sensitivity of both IUE and GHRS on HST drops steeply at wavelengths where atmospheric absorption still is a substantial handicap for ground-based observers. The situation is even worse if signal-to-noise ratios considerably in excess of 100 are also required and which are not within easy reach of either IUE or GHRS.

Scientific Background

One of the most interesting spectral features in this domain is the strongest line of Be II at 3130.4 Å (in most of the relevant astrophysical environments, the singly ionized atom will by far be the dominant ionic species). With atomic number 4, this element is just at the limit where some non-standard big-bang model calculations predict traces of primordial abundances (e.g., Boyd, R.N., Kajino, T.: 1989, *Ap. J. (Letters)* **336**, L55). The main source of beryllium is probably the spallation by cosmic rays of heavier nuclei in the interstellar medium. Knowledge of the efficiency of the spallation process and the concomitant depletion onto dust grains is very essential for assessing the primordial abundance of lithium, the element which is the most important cosmological diagnostic. In stars, beryllium is quickly destroyed at temperatures above about 3.5×10^6 K. It can, therefore, be expected to be seen only in cool stars where, so far, crowding in the 313-mm region has permitted only upper limits to be determined (e.g., Ryan, S.G., Bessel, M.S., Sutherland, R.S., Norris, J.E.: 1990, *Astrophys. J. (Letters)* **348**, L57; Rebolo, R., Molaro, P., Abia, C., Beckman, J.E.: 1988, *Astron. Astrophys.* **193**, 193).

Also in the interstellar medium, only upper limits have so far been obtained (Boesgaard, A.M.: 1985, *P.A.S.P.* **97,** 37). They suggest that from space the best strategy would presently be to go to fainter sources with large column densities which can be detected even at relatively low S/N. By contrast, there seems to be a niche for ground-based efforts if a large light-collecting area is combined with a low-noise detector. The best upper limits on the equivalent width of interstellar beryllium lines (down to 0.23 mÅ) have, in fact, resulted from observations from the ground (Boesgaard, op. cit.).

Observations

For the detection of isolated spectral features, a spectral resolution, Δλ, roughly equal to the line width is close to optimum. This would have made the CES the instrument of choice. However, towards the UV, the high-efficiency multi-layer coatings of the optical surfaces of the CES have an extremely steep fall off in throughput which sets in at wavelengths noticeably longer than 3130 Å. Therefore, our only chance was to submit an application for observing time with CASPEC. We were allocated two nights in May 1990.

We used CASPEC with the 31.6 lines/mm echelle grating (which has twice the efficiency of the 51.6 lines/mm grating in the UV), the Long Camera (which provides a better sampling, i.e. reduces the effect of small-scale detector blemishes and facilitates the definition of order and inter-order space), and a coated (for higher UV response) GEC CCD (ESO No. 7) which has 576 × 385 pixels of 22 × 22 μm. With this configuration, we

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First Announcement of the 3rd ESO/ST-ECF

Data Analysis Workshop

ESO, Karl-Schwarzschild-Straße 2
D-8046 Garching, FRG

April 22–24, 1991

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

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

The tentative agenda is:

Analysis of Direct Imaging Data

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

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

The scientific organizing committee includes: P. Grosbøl (Chairman), L.B. Lucy, D. Baade, P. Benvenuti, S. D'Odorico, R.H. Warmels

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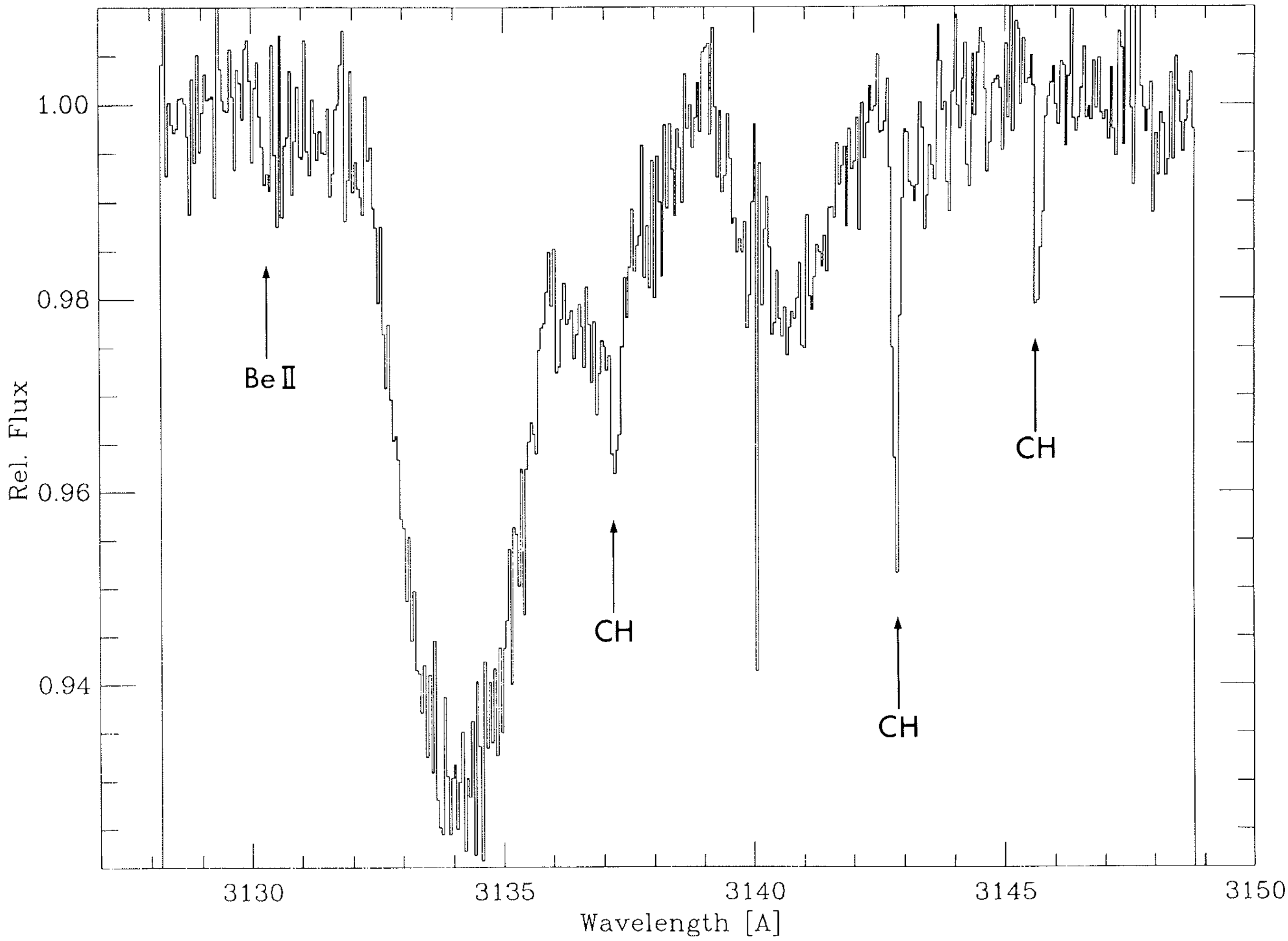


Figure 1: *Normalized spectrum (sum of four exposures for a total of 165 minutes; step size 0.05 Å) of ζ Oph in order 181 of the 31.6 lines/mm echelle grating of CASPEC. Absorption lines of interstellar CH at 3137.5, 3143.2, and 3146.0 Å are marked. The arrow points to the expected position of the BeII λ 3130 line that had been searched for. The spikes at 3140 Å are caused by a detector blemish. Broad absorption features should be of stellar origin; the strongest one is due to OII λ* 3134.8.

could observe orders Nos. 164–188, i.e. approximately the range from 3000 to 3500 Å, and there was a small overlap in wavelength between neighbouring orders.

We basically faced two technical problems. The first was (as was known in advance) that the light from the internal calibration lamps (flatfield and comparison spectrum) normally goes through a non-quartz prism which, of course, at our wavelength had to be bypassed. The installation of a quartz prism is now being considered, but has not yet finally been decided, so that observations at these short wavelengths cannot presently be offered to Visiting Astronomers. The other problem was the identification of "our" order (No. 181) which was so far beyond the range mapped in ESO's standard atlas of the thorium spectrum (S. D'Odorico, M. Ghigo, D. Ponz: 1987, *ESO Scient. Report* No. 6) that we had to approach it via two intermediate settings. (Meanwhile, we have prepared a simple extension of the atlas for the 31.6 lines/mm echelle grating towards 3000 Å which is now available also at La Silla.) With the help of Alain Gilliotte and Philippe Carton, both problems were efficiently solved.

For the flatfielding we tried an entirely new approach because at the short wavelengths fringing in the CCD should not be a problem. Therefore we turned the echelle grating to a position corresponding to about 4000 Å where the transmission of the prism is still good. We then took a flatfield exposure with the slit expanded close to its maximum physical length. This had the effect that anywhere on the CCD a large number (~20) of echelle orders were superimposed on one another so that the CCD was relatively uniformly illuminated. As far as we can tell from our preliminary analysis, this method is quite useful for the correction of detector blemishes such as column-to-column offsets which cannot be removed with standard flatfield exposures. Obviously, it should be generally valid for echelle observations, irrespective of the instrument or the wavelength range.

Although we have not tried it, it appears to us from this experiment that flatfield or trailed stellar exposures with the slit length chosen such that neighbouring orders just touch one another (and taken at the correct grating angle) could provide a useful basis for modelling the echelle blaze function.

Results

Unfortunately, we cannot report any new scientific results. Shortly after we had geared up the instrument on the first night, clouds moved in which were even worse on our second night and thus reminded us strongly of additional reasons why there are space observatories. Therefore we had to concentrate our observations mainly on the bright (m_v = 2.6 mag) O-star ζ Oph. Because of the very steep decline of the overall throughput, orders 165–177 were at least partly saturated while orders above No. 184 (3075 Å) were severely underexposed. In Figure 1, we show for order No. 181 the sum of four spectra with a total exposure time of 165 minutes (the last third of which was noticeably compromised by clouds). The signal-to-noise ratio per spectral resolution element (0.1 Å or ~3 pixels), was slightly better than 300. For the centre of this order we estimate an overall efficiency (incl. atmospheric extinction) of roughly 0.03%, down by nearly two orders of magnitude from the efficiency measured with CCD No. 8 at 4000 Å (Pasquini, L., D'Odorico, S.: 1989, CASPEC, *ESO Oper. Man.* No. 2).

In Figure 1, the interstellar CH lines at 3137.5, 3143.2, and 3146.0 Å with equivalent widths of about 3.7, 7.0, and 4.0 mÅ, respectively, are easily seen. But there is no feature in excess of 1 mÅ at 3130.4 Å. This value corresponds to the strongest feature within 0.2 Å of the expected position of BeII whereas the signal-to-noise ratio suggests a formal upper limit of 0.3 mÅ. Impressive though these numbers may be, they are only about the same as the ones inferred by York and Snow (1982, *Astrophys. J.* **255,** 524) from their observations with the *Copernicus* satellite.

In the final analysis, our experiment was only a successful and very promising feasibility study (which also included the reduction of our data with the echelle package in MIDAS). Nevertheless, we believe that it is perhaps worth reporting it to the readers of the *Messenger*, and we certainly feel encouraged to make another attempt.

We thank Fons Maaswinkel and Bernard Delabre for their expert advice on the choice of instruments and instrument modes and Alain Gilliotte and Philippe Carton for their competent and tireless efforts to get CASPEC properly set up.

EMMI, the ESO Multi-Mode Instrument, Successfully Installed at the NTT

S. D'ODORICO, ESO

The EMMI Project

In November 1985, a conceptual proposal for a spectrograph for the 3.5-m New Technology Telescope was presented at the 16th meeting of the ESO Scientific Technical Committee. The initial concept had been put forward the year before by J.L. Tanné and the author and later modified and improved by Hans Dekker; Bernard Delabre was responsible for the optical design and Heinz Kotzlowski for the mechanical layout.

The execution of the project started at

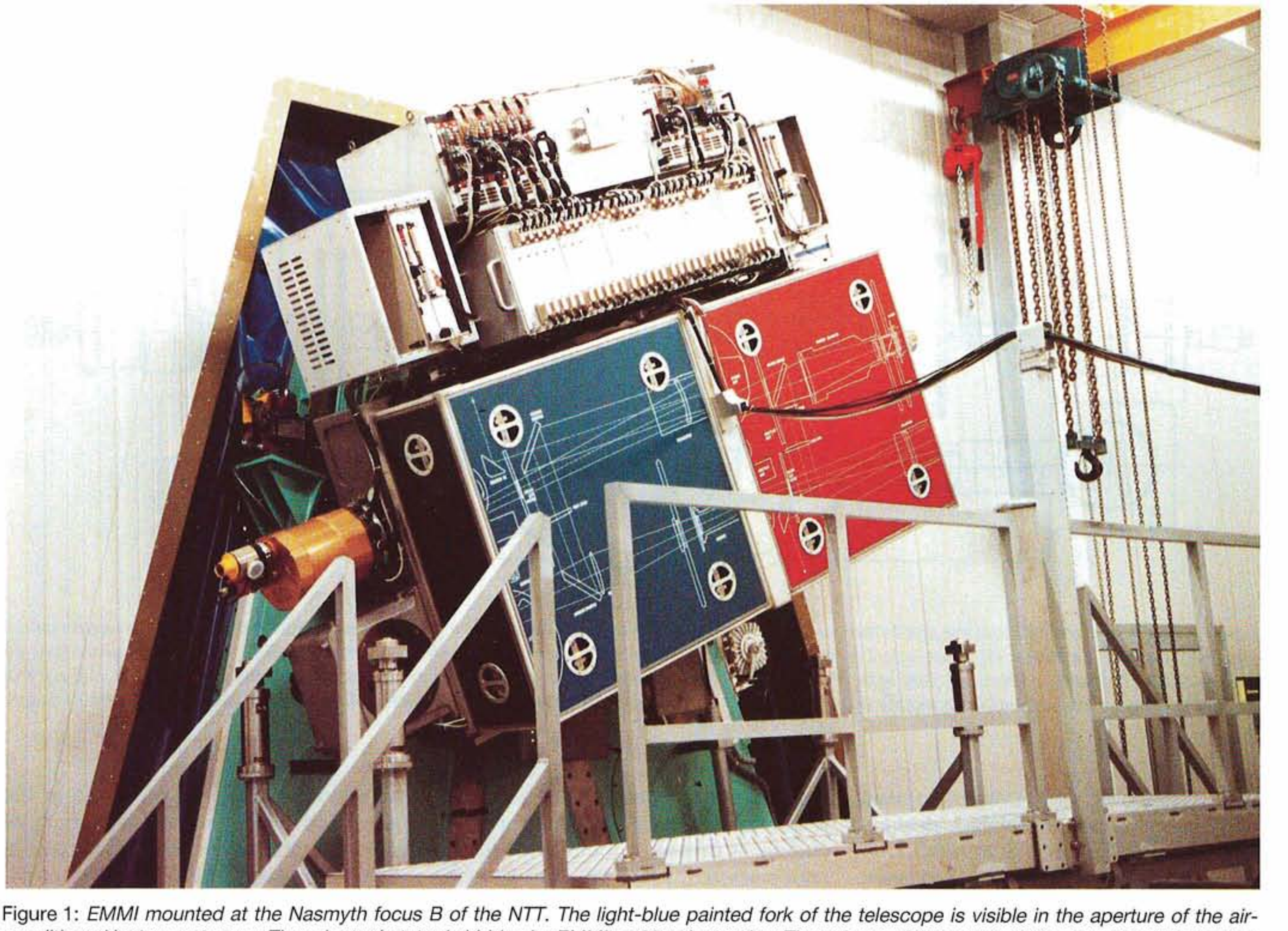


Figure 1: *EMMI mounted at the Nasmyth focus B of the NTT. The light-blue painted fork of the telescope is visible in the aperture of the air-conditioned instrument room. The adaptor/rotator is hidden by EMMI and its electronics. The colours of the panels of the cover identify the blue and red channels and show the optical path of the light in the instrument. The service platform in the forefront is also used to support the instrument when it is dismounted from the adaptor.*

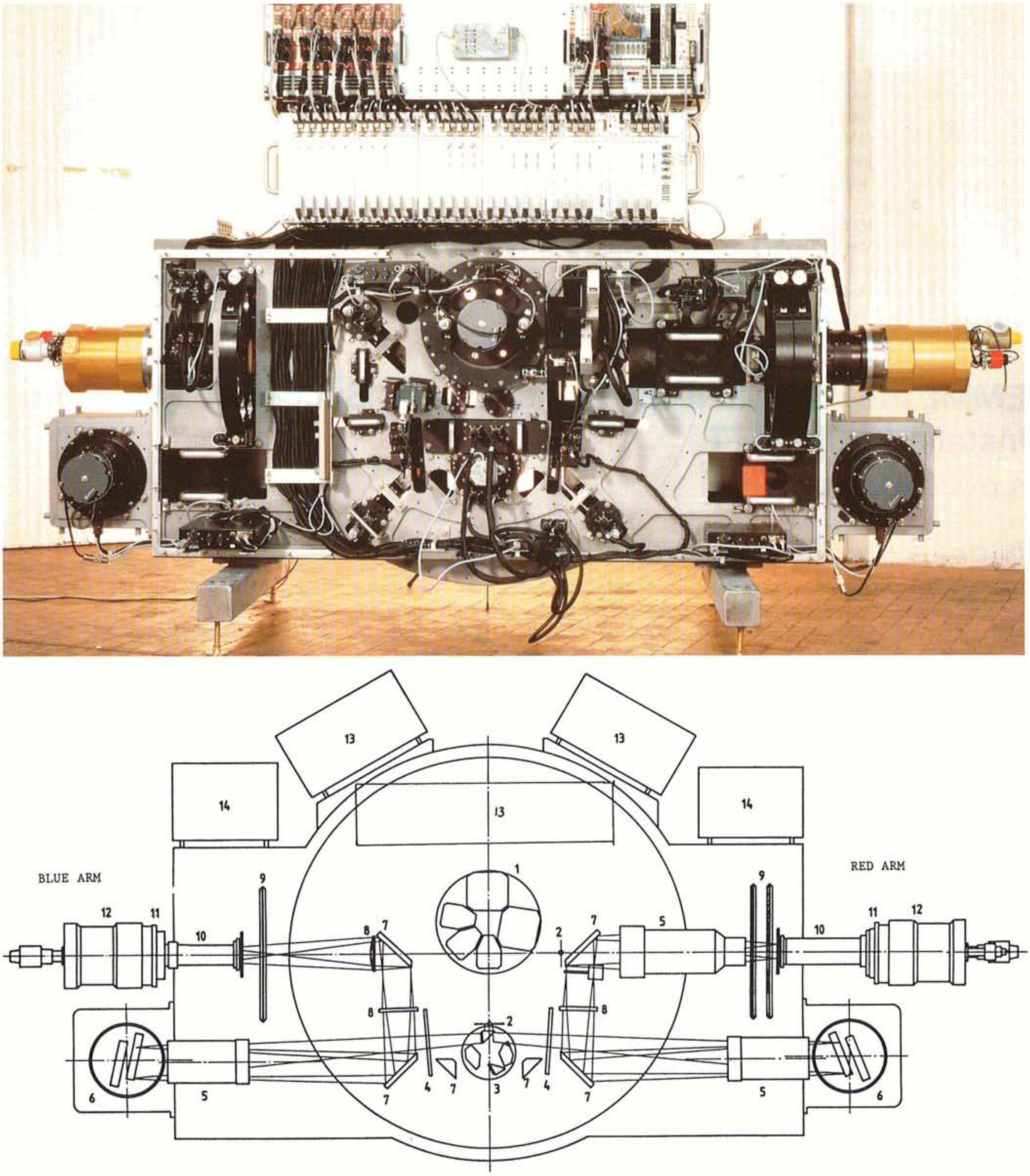


Figure 2: *EMMI is shown without the protective cover in this photograph taken at the end of the integration period in Garching. The sketch below identifies the main functions: (1) mode selection mirrors, (2) adjustable slit, (3) beam-splitter wheel, (4) below slit filter wheels, (5) collimators, (6) grating units, (7) folding mirrors, (8) field lens, (9) grism and filter wheels, (10) cameras, (11 and 12) detector heads and cryostat, (13) control electronics, mounted eventually in a slightly different way in the real thing, (14) detectors electronics, not installed at the time of the photograph.*

the beginning of 1986. Both the optical and the mechanical detailed designs were entirely conceived at ESO; the same is true for the electronic hardware (including the control cameras for the two detectors) and the software. The mechanical parts, the optical and the electronic components were procured mainly from European industries, usually with the standard ESO tendering procedure. A review of the main industrial subcontractors for EMMI is given in the insert on page 54.

About 5 years after its conception EMMI (the ESO Multi-Mode Spectrograph as it came to be named) has been installed and successfully tested at the telescope (Fig. 1). While written three weeks only after the first observations, this paper gives a brief overview of the project and wants to make prospective users aware of its capabilities. A description of the optical design and of the original performance goals can be found

Figure 3: *The "EMMI's corner" of the control room. From the left, in the lower row, a Ramtex dedicated to the user's interface displaying the layout of EMMI and the functions on line (a mouse is used to select other display options), a terminal for the exposure definition and a Ramtex displaying a long slit spectrum. In the row above two monitors for guiding and a graphic display.*

EMMI is the first optical instrument for astronomical observations which offers wide field imaging, long slit, low and medium resolution spectroscopy and echelle spectroscopy on line, with the possibility to switch from one mode to the other in a matter of seconds. Only the Hubble Space Telescope, with its 5 focal plane instruments, offers a similar broad choice of observational capabilities: the two differ so much in terms of the scientific goals that a comparison, however tantalizing, is not possible.

The complexity of the dioptric optical design of EMMI does not penalize the efficiency: in all modes this is as high or better than similar instrumentation at the other ESO telescopes (see the curves of the optical transmission of the optics in the March 1990 issue of the *Messenger*).

With its wide choice of observing modes, EMMI makes possible to select the observing programme according to the conditions of the atmosphere, in particular the seeing and the sky brightness, and to complete within a night a

in Proc. SPIE 627, p. 339 (1986). More information will be available in the Operating Manual (a first draft will be prepared by November 1990) and in dedicated technical reports, to be issued in 1991.

As stated in the minutes of the 1985 STC meeting "key factors in the definition of the instrument were the expected excellent image quality at the NTT, the need to complement and when possible to improve 3.6-m instrumentation and the desire to minimize change-overs and maintenance". The concept which was finally adopted is that of a dual beam instrument, fully dioptric and based on the white pupil principle. The main advantages of this type of design are a very high efficiency in both channels, easy conversion from the grating to the imaging and grism spectroscopy modes, and relatively cheap optics due to their small size. The instrument can be easily adapted to a new detector by building a proper camera: we took advantage of this option when the CCD originally foreseen, a 2048^2 pixel chip, was not delivered as planned. The depth of the 1.5-ton instrument is 28 cm only to keep the momentum on the adaptor small and increase the stiffness. The symmetrical supporting structure gives easy access to all the parts of the instrument even when this is mounted at the telescope. The various moving functions, most of them of new design, are built in a way to optimize reliability and minimize maintenance (Fig. 2).

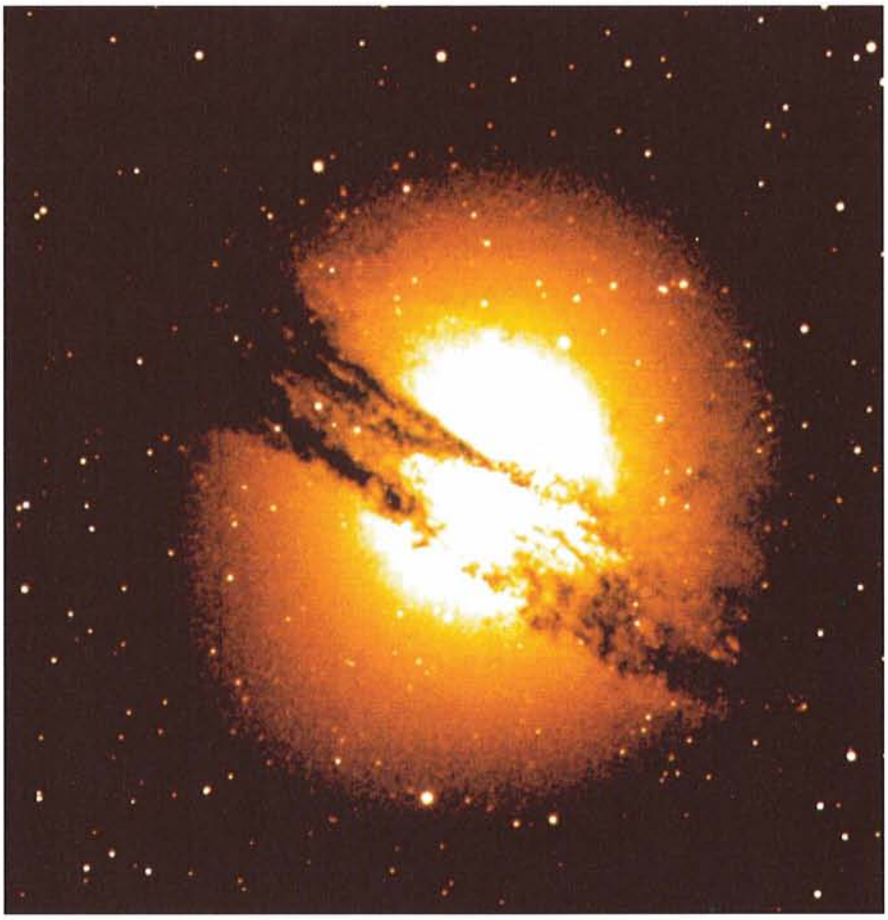


Figure 4: *A 300 s exposure of NGC 5128 in the Z colour exemplifies the size of the EMMI field with the present Th 1024 pixel detector (7.5 × 7.5 arcmin in red channel). The FWHM of the stellar images in this exposure is 0.85 arcsec. The present pixel size in the red channel (0.44 arcsec) is not well suited to exploit the intervals of best seeing at the NTT. ESO plans to introduce a CCD with a pixel size of 15 microns, corresponding to 0.35 arcsec, and it is building a CCD camera for direct imaging, to use in parallel with EMMI, with a pixel size of about 0.1 arcsec.*

MAIN INDUSTRIAL SUBCONTRACTORS	
OPTICS:	Galileo (Italy) and Fisba (Switzerland)
COATINGS:	Matra (France)
FILTERS:	Andover (USA) and Soptel (France)
GRISMS and GRATINGS:	Milton Roy (USA)
DETAIL DESIGN:	Techno (FRG)
STIFFNESS ANALYSIS:	BCV Progetti (Italy)
MECHANICAL STRUCTURE:	De Pretto-Escher Wyss (Italy)
MECHANICAL FUNCTIONS:	Enraf-Nonius (the Netherlands), Technica (Switzerland), Geissler (FRG), Kern (FRG)
COVER:	Brunet Sicap (France)
SERVICE PLATFORM:	Genius-Klinkenberg (the Netherlands)
OPTICAL ENCODERS:	Heidenhain (FRG) and Litton (USA)
MOTORS:	Portescap (Switzerland), Faulhaber (FRG), Inland (USA)
LIMIT SWITCHES:	Baumer (Switzerland)
CCD MOUNTINGS:	NTG (FRG)
CCDs:	Thomson (France)

programme which requires data of different formats.

The first months of operation of EMMI will be used to gather experience on the best way to operate it at the telescope. Some procedure of flexible scheduling will have to be introduced to exploit the periods of best seeing at the NTT for the programmes which require it at most.

Another concern is represented by the difficulty a visiting astronomer (who sees the instrument 5–6 nights a year only) may encounter in making his/her way efficiently through the various observing options. If this will prove to be the case, the introduction of some form of service observing, with its pros and cons, will have to be properly debated.

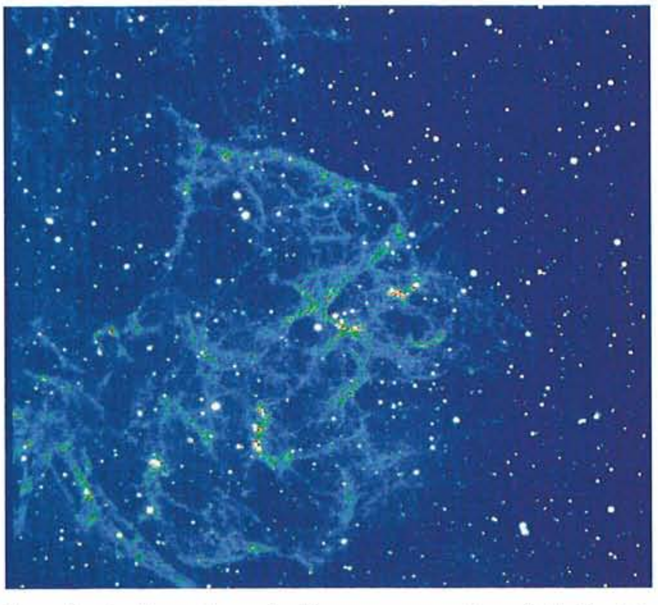
Present Capability and Future Prospects

The Application Form for Observing Time at La Silla in Period 47, distributed in August 1990 includes a description of the current operating modes of EMMI and a list of the filters, gratings and grisms which are currently available.

The modes successfully tested in July are:

- direct imaging in the red channel (spectral range 400–1100 nm, field 7.5 × 7.5 arcmin, pixel size 0.44 arcsec) with the choice of 8 filters in a single run.
- grism spectroscopy in the red channel with a 7.5 arcmin slit or slitless up to Rs (resolving power by slit width in arcsec) about 1000 and with a choice of 8 grisms.
- 6-arcmin slit grating spectroscopy in the red channel with Rs between 1300 and 5500. Two gratings can be mounted at any given time.
- echelle spectroscopy in the red channel at Rs = 7700.
- direct imaging in the blue channel (spectral range 300–500 nm, field 4.9 × 4.9 arcmin, pixel size 0.29 arcsec) with the choice of 8 filters in a single run.
- 4.5-arcmin grating spectroscopy in the blue channel with Rs between 400 and 11000. Grating housing as in the red.

Two THX Thomson CCDs (1024^2, 19 μm square pixels) are presently used as detectors in the two channels. The CCDs have been coated at ESO with special dyes to enhance the UV-blue response. The quantum efficiency curve has a peak of about 50 % at 600 nm and levels down to about 19 % in the UV-blue region. The read-out noise mea-



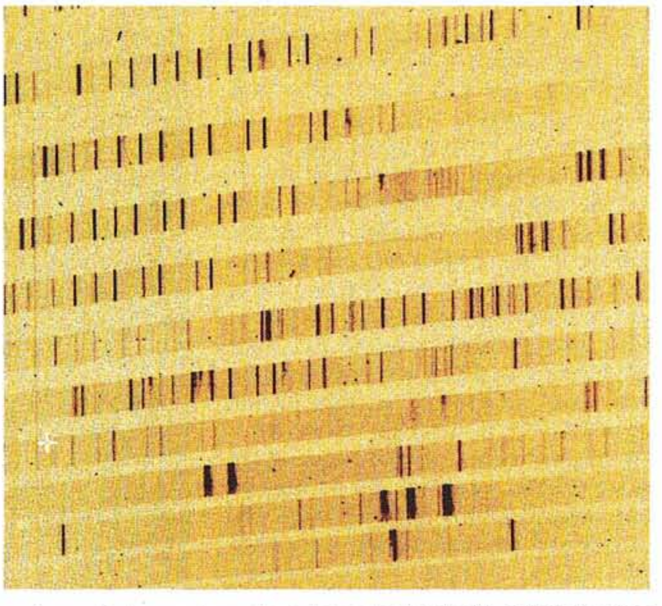


Figure 5a, b: *These two scientific exposures, a large field direct image and an echelle spectrum, have been obtained with EMMI at a time separation of a few minutes. Image (a) is a 600 s direct exposure of the supernova remnant RCW 89 taken in the red arm through an interferential filter centered on Hα. Image (b) is an echelle spectrum of a bright filament selected from the previous exposure. The spectral range covered by the 10 orders shown in the spectrum is 610–980 nm, the resolution 45 km/s, the length of the slit 20 arcsec.*
The emission lines from the remnant can be distinguished from the sky lines for their non-uniform, structured appearance, caused by density and velocity fluctuations. Visible in the three orders at the bottom are the [OI] 630 nm, [NII] 654.8, 658.4 nm, Hα and [SII] 671.7, 673.1 nm emission lines; in the two orders at the top the [SIII] 906.9, 953.2 lines.

sured at the telescope is 4–6 electrons, the dark current is less than 3 e^-/pixel/hour at 140 °K.

The global efficiency curves for all observing modes have been computed from the transmission curves of the optics, filters, grisms and grating and from the efficiencies of the CCDs, all measured in the ESO laboratories. They are available in graphic and digital forms. Most important, they have been confirmed by the observations. As data are being reduced, it appears that the combination of highly efficient optics, low read-out CCDs and sub-arcsec images at the NTT will bring the performance of the instrument above the original expectations.

Many technical aspects of EMMI deserve to be described in detail and this will be properly done in the future technical reports. There are two points worth mentioning here. There is a need in EMMI to minimize the flexures because of the large rotation rates which occur close to the zenith in an Alt-Az telescope. Even if these can be avoided by properly planning the time of the observations, the tests at the telescope have shown that the flexures in the most critical modes (the red and blue medium dispersion) are well below 10 μm, the performance goal, for rotations up to 100 (red channel) and 180 degrees (blue channel). Further optimization work is going on at some of the critical units to further improve these values.

Another source of initial concern, the grating units, have proved to be reliable and accurate "in the field". One housing mounts two gratings back to back which can be remotely selected and positioned. The positioning can be reproduced and it is stable to better than 1/10 of a pixel, an achievement which has been made possible by a control unit of new design.

The final EMMI control programme, which integrates the operation of telescope, adaptor, instrument and of the two detectors, was being tested in July and was not used during most of the observations. The hardware set-up display is however already in place. The "EMMI" corner in the control room of the NTT is shown in Figure 3.

EMMI will undergo another commissioning period in October before being offered to the first regular users. At that time, besides installing the user interface of the software, we will test three operation modes which are foreseen to become fully operative in period 47 (starting April 91). These are the dichroic beam-splitter for spectroscopy in the two channels at the same time, echelle spectroscopy with a 31.6 grooves/mm echelle giving a resolving power of 28,000 in the red channel and multiobject spectroscopy using "punched" slits in an aperture plate.

It is important to note that the pixel size in the red channel of EMMI (0.44 arcsec/pixel with the Thomson CCD) is larger than originally foreseen and does not permit to exploit the optical quality of the telescope when the atmospheric seeing is very good. We had originally planned and built a slower camera to be

THE EMMI PROJECT TEAM

P. Biereichel:	CCD Software
B. Buzzoni:	Testing of the optical components
S. Deiries:	CCD and dewars integration and testing, CCD coating
B. Delabre:	Optical design
H. Dekker:	Optical concept, procurement of the optical elements, testing of the instrument off and on the telescope (Project Coordinator)
S. D'Odorico:	Astronomical specifications and project supervision (Project Responsible)
G. Hess:	CAD design and drafting. Preparation of the Call for Tenders for mechanical parts. Documentation
G. Huster:	Design of the CCD mounting head
H. Kotzlowski:	Mechanical concept and design of the overall instrument and its functions. Supervision of realization. (Coordinator of mechanics)
J. L. Lizon:	Integration, testing and optimization of the instrument functions and of the overall instrument in the Garching laboratory and at the observatory.
A. Longinotti:	CCD VME software, EMMI software
W. Nees:	Design, procurement and testing of the control electronics
T. Oosterloo:	Commissioning at the telescope and analysis of the results
G. Raffi:	Overall EMMI software
R. Reiss:	CCD control system and detector optimization
J. Roche:	Ramtex user interface

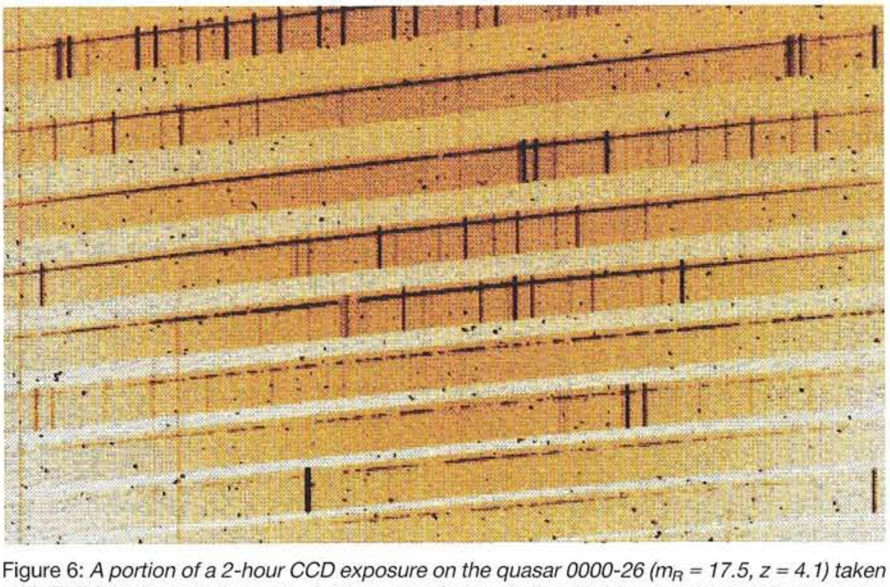


Figure 6: *A portion of a 2-hour CCD exposure on the quasar 0000-26 (m_R = 17.5, z = 4.1) taken with EMMI in the echelle mode. A 60 grooves/mm echelle with blaze angle 28.7 degrees was used with a 360 grooves/mm grism as cross disperser. The resolving power with the 1-arcsec slit used for this observation is 39 km/s. The spectral range covered in one frame is 420–800 nm, this figure shows the range 520–750 nm only. The length of the slit as shown by the height of the sky lines is 20 arcsec. In this observing configuration the global efficiency of the observation (product of the transmission of the atmosphere, telescope, instrument optics and detector) has a peak value of 7%. This high value combined with the small slit losses (courtesy of the average good seeing at the NTT) and the low read-out noise of the CCD (4 e^-/pixel) permits to reach good S/N in the spectra of objects as faint as mag. 18–19 in a few hours integration. In this example, the Lyman α emission of the quasar is visible in the central orders, a portion of the Lyman α forest in the lower ones. The S/N in the extracted orders varies in the range 20–30.*

used with a 2048^2 CCD from Tektronix, which has not yet materialized on the market. A faster camera was then built to match smaller CCDs without too severe losses of the spectroscopic capabilities, but paying a price in terms of sampling frequency of the images in the detector plane. Two actions are underway to improve the situation by the beginning of 1991: ESO will install a CCD of smaller pixel size (0.35 arcsec/pixel) on the red channel and is building a CCD camera to be permanently mounted at the other nasmyth focus (pixel size about 0.1 arcsec) to exploit the windows of exceptional seeing (hopefully down to about 0.3 arcsec FWHM).

Examples of Astronomical Observations

The commissioning period in June–July was centred on the full moon and plagued by the first heavy rain of the year. It was however still possible to collect a number of astronomical observations. Many of them were obtained with a specific goal in mind (e.g. stability tests during long integration, measurements of the absolute efficiencies in the various observing modes, testing of the photometric accuracy and of the image quality, testing of polarization effects by mirror 3, etc.). The analysis of the data will further verify these aspects of the performance of the instrument at the telescope and will serve as input to the operating manual. We also obtained astronomical observations for illustrative or scientific purposes and four examples are shown in Figures 4 through 6.

The analysis of the first EMMI observations has just started but the preliminary reductions confirm that EMMI is up to or better than the target specifications (see e.g. the limiting magnitudes in Table 4 of the 1986 paper quoted above). The combination NTT-EMMI is likely to become a powerful tool for a wide range of astronomical programmes. Good luck to the future observers!

Acknowledgements

The successful maiden voyage of EMMI is the result of the efforts of several persons at ESO. Some contributed to a very specific task only, others have spent a large fraction of their working time in the last four years on the project.

The table at page 55 is an attempt to identify the EMMI project team and their tasks using a few words only: as such it is hardly exhaustive and it might be unfair to a few.

If someone discovers himself forgotten, would he please blame the stress of 20 days and nights of commissioning and forgive me. All have to be praised for their skill, patience and care: they managed very well indeed. A special, personal thank-you goes to Hans Dekker for overseeing the project with an optimism which fortunately is superior even to mine and to Jean-Louis Lizon for the infinite numbers of hours that he has spent in Garching and at La Silla carefully dealing with EMMI's 29 functions, one by one and together.

New 2D IR Array Detectors for Imaging and Spectroscopy at ESO

A. MOORWOOD, ESO

The lack of recent news in the *Messenger* may have created the impression among some infrared observers that perhaps not much has been going on in Garching to upgrade the performance of the infrared instrumentation on La Silla since IRAC was offered in April 1989. In fact, this has been a period of particularly intense activity aimed at expanding our infrared capabilities on La Silla in several areas considered to be both of immediate scientific interest and important preparatory steps on the road to implementing the VLT instrumentation plan. Our overall aim is to provide La Silla with first class imaging plus some low resolution spectroscopic capabilities throughout the infrared from 1 μm to ~17 μm plus an upgraded IRSPEC for 1–5 μm medium resolution long slit spectroscopy before we reach the period of peak effort required on the VLT instrumentation. This is an ambitious goal, at the limit of our resources, and a key element is of course the procurement of high performance array detectors which, given the rapid evolution in this field, their high cost and the need to obtain import/export approval, is not a trivial exercise by any means. In addition to our ongoing negotiations with Philips Components for a replacement 64 × 64 Hg : Cd : Te array for IRAC, therefore, we have also been in contact since early in 1989 with several other major detector manufacturers with the aim of procuring 2 D IR array detectors for the upgrade of IRSPEC at the NTT and to equip the new IRAC 2 cameras being developed to accommodate 256 × 256 format arrays. During the same period we have also been developing a new VME based acquisition system capable of handling the various different readout schemes and formats anticipated, expanding our laboratory test facilities, designing and tendering for the IRAC 2 cameras, preparing for the transfer of IRSPEC to the NTT and finalizing the technical specification of a 10-μm camera/spectrometer to be built in collaboration with the Service d'Astrophysique, CEN, Saclay.

Following a number of events within the space of a few weeks around the end of June and early July it is now possible to report here some positive results of these efforts. The most concrete is the delivery of an engineering and the first of two 58 × 62 InSb science grade arrays from the Santa Barbara Research Center whose procurement started with our request for quotation in January 1989 and is illustrative of the leadtime involved in obtaining such devices. Exhibiting dedication beyond the call of duty, Gert Finger braved 50 °C heat during one of the worst forest fires in Californian history to collect the latter at the beginning of July. Only a few days later, during a visit to Garching by Dr. K. Vural, head of the Imaging Devices Division of the Rockwell Science Center, we were able to draw up the technical specifications for a 256 × 256 Hg : Cd : Te array whose procurement had been approved by the STC and Finance Committee in May. Towards the end of July, in fact about a month after the effective kick off following the preliminary design review, the contract for the 10-μm camera was signed at Saclay. One disappointment has been the fact that we have been unable so far to replace the 64 × 64 Hg : Cd : Te array in IRAC both to offer improved performance to visitors and to avoid conflict with our other projects which are competing for the same limited manpower resources. Although the formal contractual delivery date (end July) had not expired at the time of writing, Philips Components had initially hoped to deliver earlier and we have thus been in a state of readiness to test and install the array on La Silla for several months.

Although several uncertainties in our overall programme still remain therefore, the prospects for substantially improved infrared spectroscopic and imaging capabilities on La Silla are currently looking good and this is an appropriate time to review their anticipated availability in order to give the community time to prepare for them.

IRSPEC Upgrade

At the time of its installation at the 3.6-m telescope towards the end of 1985, IRSPEC was the first instrument of its type to be equipped with a self-scanned monolithic array detector. During Period 46 (October 1990–April 1991) it is now planned to both transfer IRSPEC to the NTT and to upgrade it by replacing its present linear array with a 2 D InSb array. At the NTT the instrument will be permanently attached to the telescope structure at one of the Nasmyth foci and will therefore not be subject to flexure effects. An optical derotator installed between the slit and the telescope adapter will be used to compensate for field rotation, TV slit viewing will be retained and an integrating sphere equipped with a black body plus continuum and spectral line lamps located in the adapter will be available for internal calibration.

Replacement of the present 1 D array with a 2 D array will provide a new long slit capability, higher resolving power, better sampling, improved sensitivity and should substantially reduce the problems of object centring and sub-spectrum curvature (the so-called "vignetting") experienced at the 3.6-m telescope. The scientific performance and versatility of the instrument should therefore be considerably enhanced.

Both the SBRC 58 × 62 and the more recently developed Cincinnati Electronics 64 × 64 element InSb 1–5.6-μm arrays have been considered for the upgrade. A prototype array on loan from Cincinnati Electronics has already been tested in Garching and is the first device to be operated with our newly developed acquisition system. The actual array tested could be excellent for the thermal part of the IRSPEC range but, as known in advance, exhibits a large drop in quantum efficiency at the shorter wavelengths and requires cooling to ~10 K to avoid dark current limitations. At present, therefore, it is planned to install either the SBRC array already in-house or the second to be delivered in September. Table 1 summarizes the main instrument characteristics expected with this array, which has 76-μm pixels compared with 200-μm in the present linear array, together with the array performance data supplied by SBRC but which we have yet to confirm by our own tests.

TABLE 1: *IRSPEC Characteristics*

Wavelength range	1–5 (μm)
Pixel size	2 (arcsec.)
Slit length	2 (arcmin.)
Gratings	No. 1 300 l/mm, No. 2 600 l/mm
Resolving power	1300–3000 (2 pixels)
Detector	
Quantum efficiency	0.89 (2.85 μm)
Operable pixels	99.6 %
Read noise	350 e
Dark current (35 K)	100 e/s
Well capacity	1 E6 e
Overall point source sensitivity	5–10 gain below 3 μm (TBD)

IRAC

For more than 18 months now we have been faced with the problem of replacing the 64 × 64 Hg : Cd : Te array from Philips Components which was unfortunately damaged accidentally at La Silla before it could be offered to visitors. First test images with this array had been promising despite a rather large number (~10 %) of "hot" pixels, and its large well capacity was particularly attractive for imaging in the thermal infrared longward of 3 μm (Moorwood, Finger and Moneti, *The Messenger*, **54,** 56 (1988)). In fact, this was an experimental device still on loan from Philips who kindly agreed to write off its loss at their expense and to accept an improved and more formal specification for its replacement. This nevertheless took time and, subsequently, technical problems appear to have arisen in some of the development work undertaken to achieve our new specification. It has consequently not proved possible to obtain this array as quickly as appeared possible initially although it is still expected at any time and will be installed on La Silla as soon as possible. In the meantime the camera is still available with its 2.3 μm cutoff 32 × 32 array which had been supplied by Philips initially only for dark current tests and was not intended for operational use due to its smaller format and low filling factor which limits both its overall sensitivity and photometric accuracy. Nevertheless, even if not with the planned performance, this new capability on La Silla has produced new scientific results and provided valuable observational experience.

IRAC 2

The IRAC 2 camera under development in Garching is similar in concept to IRAC at the 2.2-m but provides a larger field (~3 arcmin.) and is designed to accommodate arrays of 256 × 256 pixels which have just recently become available. It will be equipped with standard broad-band filters, narrow-band filters, a K-band scanning Fabry Perot etalon for imaging spectroscopy at R ~ 1000 and typically 5 selectable image scales in the range ~0.1–2 arcsec/pixel depending on the array installed and the telescope (2.2- or 3.6-m). Actually, two cameras are being built with the idea originally of keeping one in Garching to provide the flexibility of upgrading the array as and when possible and then exchanging with the one of La Silla. As noted above, negotiations are now proceeding with Rockwell for the supply of a 256 × 256 Hg : Cd : Te array which, on the basis of our discussions so far could probably be delivered at the earliest by the middle of next year providing the necessary export approval can be obtained. This array will have a long wavelength cutoff at 2.5 μm and its outstanding features are its large format plus extremely low read noise and dark current (values of 20 e and <1 e/s respectively have been achieved with already existing arrays) which are more than sufficient to ensure background limited performance in all the modes foreseen for IRAC 2. In addition to making the array available to the community as soon as possible, however, we have an additional interest in evaluating it for the "short" wavelength channel of the VLT Medium Resolution IR Spectrometer/Imager to be built by ESO (Moorwood and Delabre, 1990, ESO Technical Preprint No. 13 – to appear in Proceedings of SPIE Conference 1235). Both InSb and Hg : Cd : Te arrays of this size and sensitive out to 5 μm are also under development and of obvious interest for the second IRAC 2 and for the long-wavelength channel of the VLT Spectrometer/Imager. In the meantime it is still planned to restore the L (3.8 μm) capability of IRAC as soon as possible and, depending if and when we actually receive the Rockwell array, to consider equipping one of the IRAC2 cameras with the second of our 58 × 62-element SBRC arrays.

10-μm Camera/Spectrometer (TIMMI)

This is a new instrument for the 2.2-/3.6-m telescopes to be developed, as mentioned above, in collaboration with the Service d'Astrophysique, Saclay, with an additional contribution from the Observatoire de Lyon. Again, in addition to providing a new observational capability on La Silla, this instrument is intended to provide technical feedback and observational experience in preparation for the VLT. In particular it is of interest to evaluate the 64 × 64 Ga : Si detector array to be supplied by LETI/LIR in Grenoble for this camera and which is a larger format version of the array developed for the Infrared Space Observatory but with a larger well capacity to handle the higher background levels experienced in groundbased use. TIMMI will provide for broad- and narrow-band imaging in the 10-μm window and probably out to the short-wavelength end of the 20-μm window and for grism spectroscopy at resolving powers of several hundred. First tests on La Silla are foreseen for April 1992 and a more detailed description of this instrument together with the meaning of its acronym will appear in a future issue of the *Messenger* when the project is more advanced.

The ESO MAMA Detector

M. CULLUM and E. J. WAMPLER, ESO

Introduction

For some time ESO has been interested both in improving the performance of the ESO detectors in the Ultraviolet spectral region, and in developing a working pulse counting detector, similar to the IPCS. A working MAMA pulse counting detector equipped with a low dark current, UV sensitive, bi-alkali photocathode is now available to the La Silla user community. It offers good UV sensitivity, freedom from readout noise and cosmic ray events, real time monitoring of the accumulating signal and excellent linearity for faint sources. For observations of faint sources with high resolution spectrographs in the spectral interval λλ3000 Å – 4000 Å, the MAMA detector is more than competitive with the present ESO CCDs and is therefore the detector of choice for ultraviolet CASPEC or the CES observations.

In common with other pulse counting detectors, the device saturates with bright sources. This translates into a requirement for long integration times for the flat field exposures needed to remove the pixel-to-pixel variations in detective efficiency. But, unlike the CCD detectors, long dark exposures are not needed to define the background.

The < 1 μsecond temporal resolution of the MAMA also provides a capability for future activities involving high time resolution observations (speckle, interferometry, adaptive optics, etc.) for which ESO has no other suitable detector available.

In late February, 1989, the MAMA detector was mounted on CASPEC where its performance was directly compared to that of ESO's #8 RCA CCD. At the beginning of the run the detector suffered damage to the anode array which reduced the available size of the detector format. After the observing session the detector was returned to Munich and then to the manufacturers, Ball Aerospace Systems Group, for inspection and evaluation. A second run with the same detector took place in early March, 1990. Because it has not yet proved possible to repair the damaged anode array, the tube in use on La Silla still suffers from a number of defective anodes that reduced the size of the detector field of view available. Here we describe our experience with the MAMA attached to CASPEC on the 3.6-metre telescope.

CASPEC Observations with MAMA

The MAMA detector was shipped to Chile in February 1989 and attached to CASPEC at the end of the month for a 6-night engineering run. On the afternoon of the first day, while the tube high voltage was slewing, the anode array suffered an electrical failure that physically broke the connection to one of the anodes and destroyed about 40 transistors in the associated pre-amplifiers. It took two days to replace these transistors. During this time CCD # 8, the standard CCD for CASPEC, was mounted and observations of SN 1987 A together with several quasars were made. After the MAMA was repaired, it replaced the CCD and the observations of the Supernova and the quasars were repeated. Thus, it was possible to make a direct performance comparison between this RCA CCD and the MAMA.

Despite the fact that CCD # 8 has rather good sensitivity in the near ultraviolet, there is no question that the MAMA gave a better signal/noise ratio than did the CCD for faint objects at wavelengths less than λ4200 Å. Because the MAMA count rate limitation translates to very long calibration exposures, and because we do not yet have very much information about the stability of the MAMA detector, it is not possible to compare the performance of the two detectors for high signal/noise ratio spectra[1], or for objects that have a high flux rate. The brightest magnitude that can be observed with the MAMA/CASPEC configuration without attenuation is about $m_U = 8$. Because of the encoded nature of the MAMA readout, the defective anode spoiled a band of columns 64 pixels wide situated towards one end of the detector field (see Fig. 1). Because we did not want to bridge the defective pixels in the data reduction process, we used the MAMA with the Short Camera and 79 gr/mm echelle so that a complete order could be recorded in the undamaged area. This resulted in a somewhat undersampled spectrum since the MAMA has 25 μm pixels as compared to the 15 μm pixels of the CCD. If the MAMA detector had the full format available, it would have been possible to use the CASPEC Long Camera to have obtained better matching of the MAMA format to the optical format of CASPEC. This option would have reduced the spectral coverage of the spectroscopic system.

[1] It should be remembered that photon-counting detectors are normally not optimum for high SNR applications.

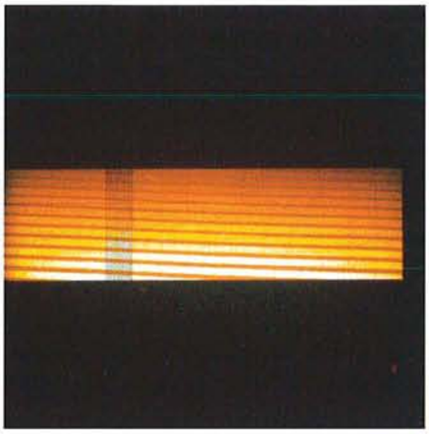


Figure 1: *A flat field image taken with the ESO MAMA detector. The spectral range runs from about λ3500 Å to λ4100 Å. The vertical dark stripes to the left of the image and the horizontal dark line that runs from the left to the centre of the image are due to defective anodes within the tube. Ultraviolet wavelengths are to the top.*

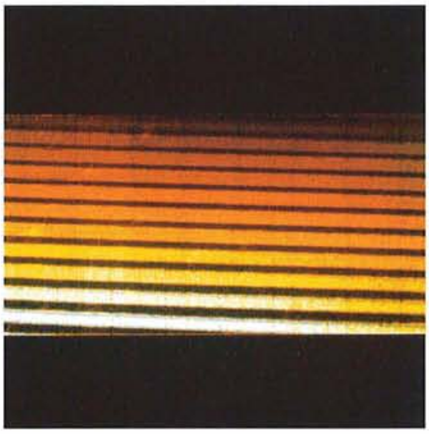


Figure 2: *An expanded view of Figure 1. The "chicken wire" structure seen in the flat field is due to small gain differences between the different amplifiers.*

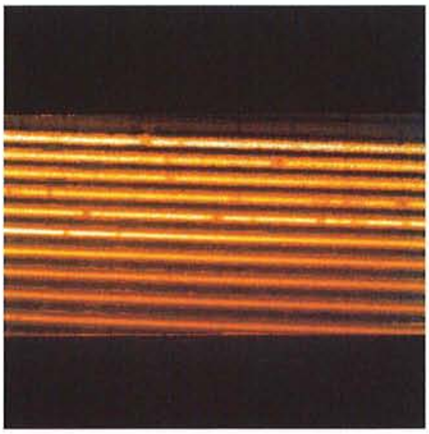


Figure 3: *A spectrum of the 16-mag quasar 1101-264. This spectrum has been divided by the flat field exposure shown in Figures 1–2. Note that the response is now very smooth.*

From a cosmetic point of view, the MAMA is comparable to CCD # 8. Evenly spaced across the detector format, a number of individual vertical columns showed about 20 % less response than their neighbours. However, typical differences between adjacent columns is ± 5 %. Similar behaviour exists also for the rows. These characteristics, due to the discrete nature of the anodes, are largely cosmetic since they do not significantly influence the detective quantum efficiency. The only uncertainty is their stability; they will be hard to remove if they are unstable. During our runs they proved to be stable in a given run, but we do not yet have enough experience to prove that they are, in fact, stable over a long period of time. In any event, amplitude of the fixed-pattern modulation was greatly reduced after the detector had been re-optimized before the March 1990 observing run. It may be possible to reduce these offsets even further so that they may not be a problem in the future, although this would necessitate changing the anode encoding scheme and, hence, the current MAMA electronics. Figure 2 illustrates the fixed-pattern modulation and Figure 3 shows a 5.6-hour spectrum of the 16-magnitude quasar 1101-264 after division by the flat field. Note that the spectrum is somewhat wider at far ultraviolet wavelengths than it is in the blue. This is probably due to the effects of atmospheric refraction differentially moving the UV spectrum relative to the blue during the long integration. Blue light was used to centre the quasar.

With the Short Camera, the MAMA detector showed a rather larger point-spread function than it showed in the laboratory in Garching. However, because the resolution obtained with the Long Camera (for which a more suitable field lens was available) was significantly better (FWHM ≈ 1 pixel), it seems clear that the field lens used for these observations was limiting the MAMA resolution with the Short Camera[2]. Also, sharp absorption features show increased residual central intensity in the MAMA spectra when compared to the CCD spectra. Possible explanations for this effect include: the non-optimum field lens used, scattered light in the MAMA tube, or due to scattering of photoelectrons in the tube. Again, the use of the CASPEC Short Camera taxed the resolution capabilities of the MAMA detector. Figures 4–5 illustrate these points.

The MAMA has a number of advantages over the CCD. ESO astronomers will probably find that the chief advantage of the MAMA is that in the UV spectral interval the MAMA has a higher Detective Quantum Efficiency than any other panoramic detector that has been deployed on La Silla. Another advantage is that since the accumulated spectrum is displayed as the integration proceeds, the astronomer can continuously monitor the overall system performance.

[2] A purpose designed field lens is currently on order and will be installed in the near future.

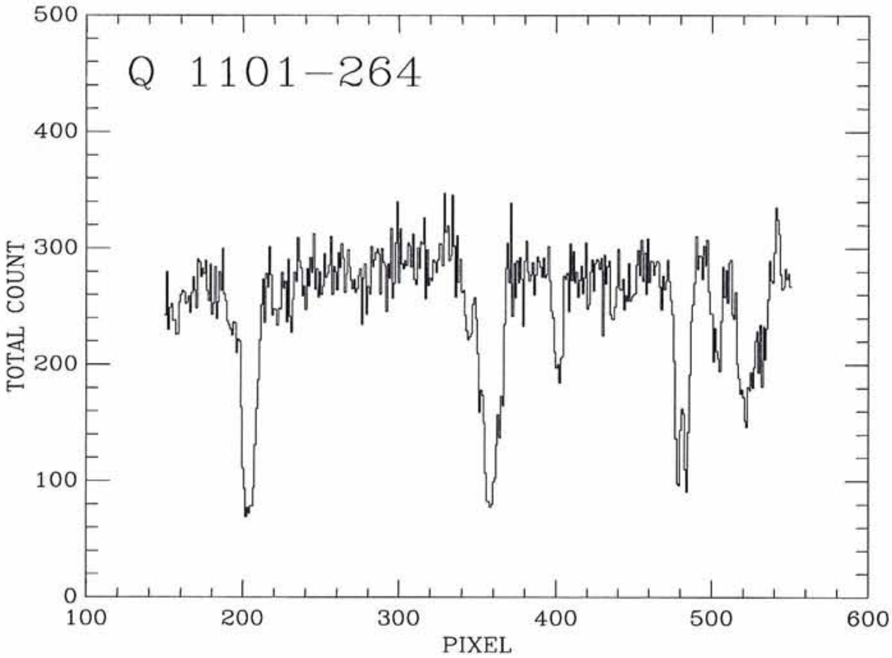


Figure 4: *A portion of the extracted spectrum of the quasar 1101-264. The scattered light background between the orders has been removed. This results in good scaling of the strong absorption lines.*

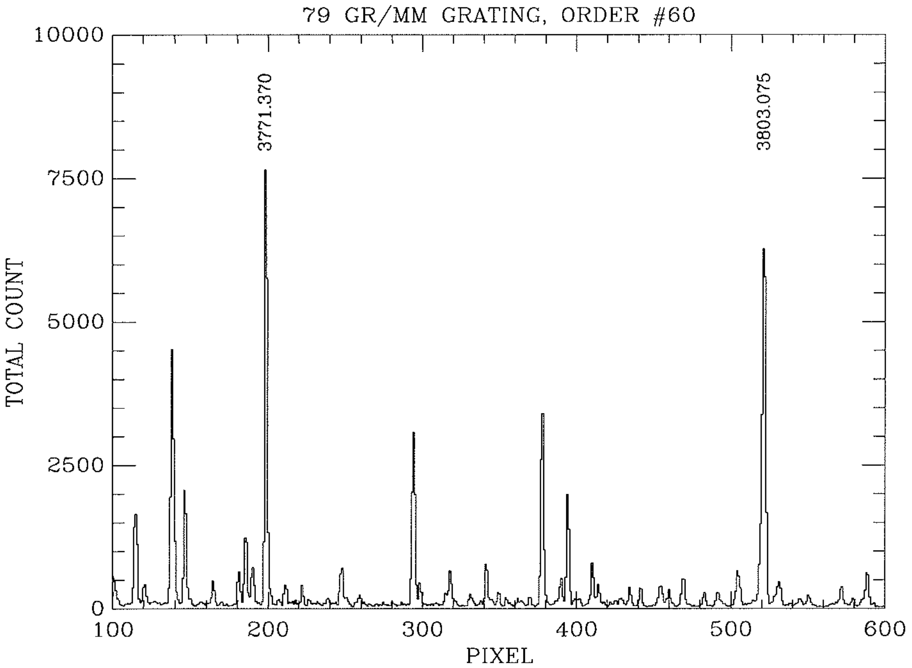


Figure 5: *The Thorium-Argon spectrum. It may be compared with that given in the ESO Atlas of the Thorium-Argon Spectrum (ESO Scientific Report No. 6 – July 1987).*

On-line monitoring of centring errors, clouds, etc. is possible when the ratemeter is attached to the detector. Because the astronomer can see the spectrum building up, the object identification is obtained early in the observation, and integration can be halted when it is judged that a sufficiently high signal/noise ratio has been obtained. It is therefore very well suited to those problems in which very long exposures of faint objects are needed. Because there is no readout noise, long exposures can be broken into short segments that are interspersed with calibration spectra. This is a significant advantage for instruments, such as CASPEC, that suffer from flexure problems. For spectra taken with very high spectral resolution, the rotation of the Earth smears long exposures. With the MAMA, long exposures of faint objects can be broken in order to obtain velocity calibrations. The MAMA has a very low dark background (about 0.1 event/pixel^{-1} hour^{-1} at 5 C), and it also discriminates against the cosmic rays that plague long integrations with CCD detectors.

The ESO MAMA detector has a somewhat smaller ($\approx 1000 \times 250$ pixels) format than the CCDs and the loss of a number of pixels leaves one with only about 670×250 contiguous pixels. To achieve overlap of the spectral orders the short Camera must then be used. This results in a less than optimal mapping of a high resolution image onto the relatively coarse resolution detector. If, in the future, the full MAMA format becomes available, the CASPEC Long Camera could be used and the detector pixel size would be better matched to the spectrograph optical resolution.

The present data taking software used with the MAMA does not allow access to IHAP during integrations. The computer is therefore not then available to perform other tasks, such as the precise estimation of the signal/noise ratio of an exposure as the integration proceeds, arithmetic on previous exposures, computing the continually changing atmospheric dispersion parameters, etc. The atmospheric dispersion parameters are needed to accurately centre the UV image of an object in the slit since the ESO TV cameras detect only the visual image of the object. Because the differential atmospheric dispersion is so large in the UV, the ability to calculate the position angle and amplitude of the dispersion is particularly important for a UV sensitive detector such as MAMA. Future minor revisions to the data taking software will allow the MAMA detector to be used more efficiently.

In conclusion, the ESO MAMA is a working detector with particular advantages for UV observations. A few minor modifications presently being undertaken will make the detector even easier to use. It thus fills a needed capability in the instrument compliment of ESO.

If there is sufficient user interest in the MAMA detector, ESO could purchase additional tubes with improved characteristics. We suppose that this will depend to some extent in the future availability of improved CCD detectors that could become competitive with the MAMA for the UV applications, as well as the interest in applications where the fast temporal response time of the MAMA can be utilized.

Deconvolution of NTT Images of E/S0 Galaxies

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Introduction

The New Technology Telescope (NTT) has recently become fully operational and subsequently made available by ESO to European astronomers in the standard scheduling procedure.

The first glimpses of the high quality images obtainable by virtue of the happy combination of advanced technology and excellent seeing conditions at La Silla have already been published (*The Messenger,* issues 56 and 58).

On the other hand, in recent years a considerable effort has been put into the development of highly sophisticated mathematical techniques to deconvolve images in one and two dimensions.

Although the effects of atmospheric

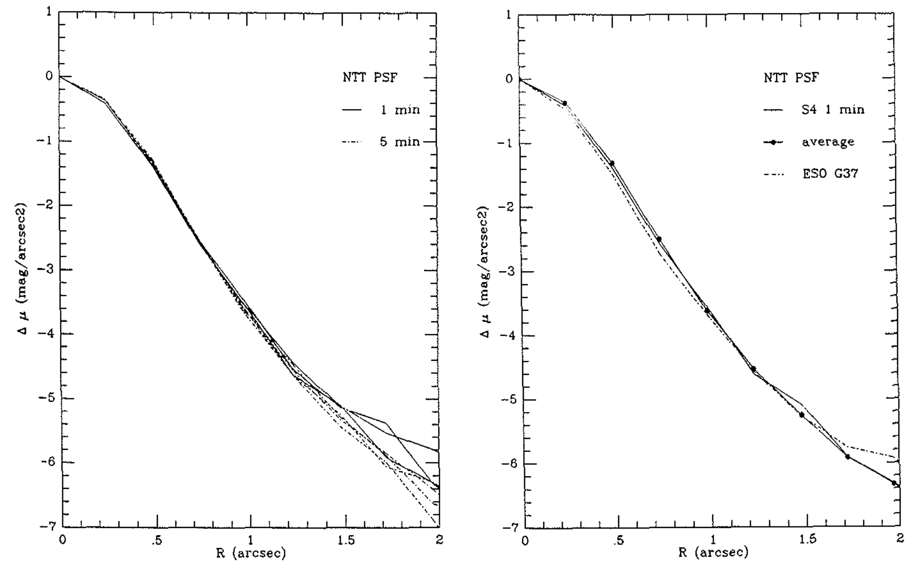

Figure 1: *(a) Brightness profiles of some stars near PKS 1209-52 from 5 and 1 minute integration time. (b) Brightness profile of the adopted (average) PSF (solid circles and line) compared with the one of the most luminous star in the 1-minute frame (solid line). The dashed line is the PSF derived from a star in the ESO 440 G 37 frame.*

turbulence which produces image blurring cannot entirely be abolished in any image taken with a ground-based telescope, one can aim, deconvolving with the Point Spread Function (PSF), at "cleaning" the observed image in order to approximate the "real" image, as it would be obtained in the absence of the atmosphere. This process has been applied on various occasions using a variety of deconvolution techniques and has been proven to be quite powerful. There still is a debate, however, on which mathematical technique works best. Combining high quality images with robust deconvolution processes, one can hope to reach a better understanding of both the relative power of the algorithms used and the goodness of the images obtained, or, in turn, to test the telescope characteristics.

During the first general observer NTT run, a few images of well-known bright galaxies were obtained in good seeing conditions by one of us (G. F. B.).

The present paper describes the observation of those objects and the three mathematical algorithms used to deconvolve their images. From the results obtained, conclusions can be drawn on the relative power of the deconvolution techniques used, the quality of the images the NTT is able to acquire and some interesting astrophysical aspects of the objects studied.

Observations

Five E/S0 galaxies: ESO 440 G 37, NGC 3115, NGC 3585, NGC 3904, NGC 3923 were observed. These images were obtained using the RCA # 15 CCD camera (515 × 313 pixels; Nasmyth focus) at the ESO NTT telescope in the V band. The images were acquired on the night of January 24, 1990. The typical seeing FWHM was 0.68 arcsec for the duration of these observations, and the sampling was 0.246 arcsec/pixel (rebinned images). A total of eight CCD frames were obtained with integration times ranging from 25 to 210 sec. Standard processing of frames for flat field and bias was used. In this note we discuss the deconvolution of these elliptical galaxies.

The Point Spread Function

Star images suitable for PSF extraction were not available in all frames. Two frames of the stellar field near PKS 1209-52 (1 and 5 minutes exposure time) were therefore used in order to derive an average PSF. Such Point Spread Function was used for deconvolving all extended objects in the present sample. The seeing conditions for this reference star field were monitored to be identical to those of the galaxy images.

The stability of the star profiles can be deduced from Figure 1 a, where some stars from both 1 and 5 minutes exposures are shown, and from Figure 1 b where the adopted average PSF from the 5-minute frame is compared with the most luminous star in the 1-minute exposure image as well as with a star in the field of the galaxy ESO 440 G 37.

The average PSF (HWHM ~ 0.34 arcsec) was fitted with a sum of 3 Gaussians (e.g. Bendinelli et al., 1987, 1989) as well as a Moffat (1969) function; the fit parameters are listed in Table I.

This comparison brings the conclusion that the NTT and the seeing conditions were considerably stable both within each single frame and from one frame to another.

The Deconvolution

Surface brightness profiles were extracted using the VISTA code.

All galaxies in our sample were deconvolved by means of three quite different techniques:

– Regularized numerical inversion of the convolution integral equation (RLS), applied to brightness profiles. Such method was previously used in the deconvolution of a variety of very different objects (see e.g. Bendinelli et al., 1986 and references therein). With a PSF expressed in terms of Moffat function.

– Regularized Multi-Gaussian (RMG), based on the analytical solution of the convolution integral equation when both object and PSF are expressed as a sum of Gaussian functions.

This method has two major advantages:

(a) it is insensitive to undersampling

(b) it runs a whole deconvolution cycle in a few seconds on a Personal Computer.

The major limitation of the RMG method, however, is that it is applicable only to round or elliptical images and does not work on images lacking symmetry.

– Deconvolution adopting a method devised by Hunt (1973) (HUNT). This is a bidimensional deconvolution and makes use of FFT, and basically is a generalization of Wiener's filter. As far as we are aware the HUNT method has only been applied to astronomical images once by Heap and Linder (1987) for deconvolving the image of SN 1987A.

The three deconvolution methods

TABLE I: *Parameters of the fitted average PSF*

FWHM (arcsec)	3-Gaussian fit L_i, σ_i, i = 1, 2, 3		Moffat fit α, β	
0.68	0.572 0.306 0.115	0.290 0.518 1.121	0.504	2.195
Note: σ_i, α in arcsec.				

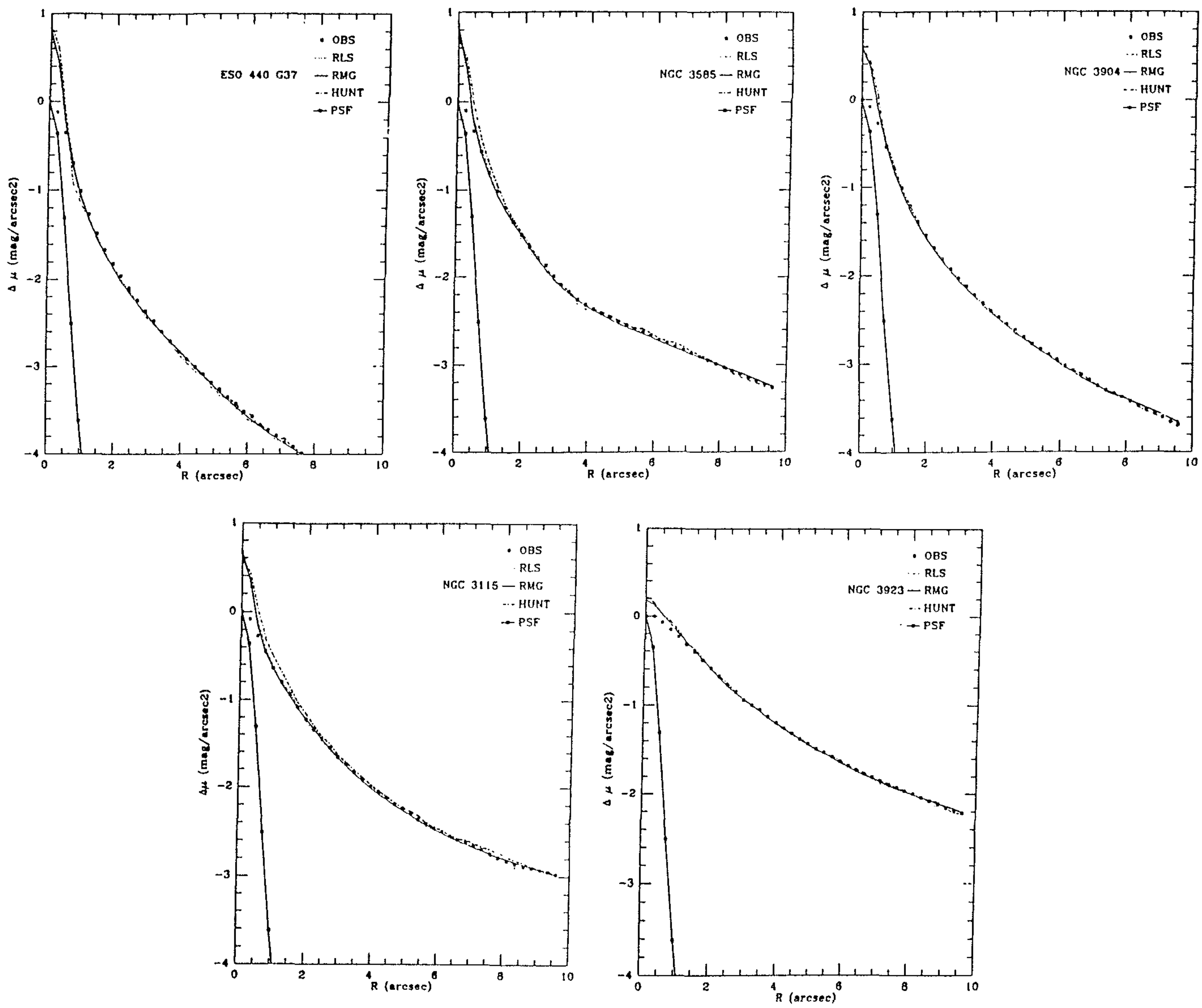

Figure 2: *Observed (solid dots) and deconvolved (lines) profiles of the five galaxies. Observed PSF profiles, normalized to the central brightness of the galaxies, are also shown as solid lines and dots.*

listed above are compared on the same image here for the first time although the first two (RLS and RMG) were discussed in Bendinelli et al. (1990).

Table II gives some of the relevant parameters of the deconvolutions: observed and deconvolved HWHM, in arcsec, for the different methods and the difference in observed and deconvolved central surface brightness.

If a *gain in resolution* is defined as the ratio between the HWHM of the observed and deconvolved profiles, then from this table values can be derived ranging from 1.3 to 3.7, depending on the relative dimension of galaxy and PSF.

In Figure 2 observed and deconvolved profiles of the five galaxies are presented.

The results do not depend on the functional form choosen for the PSF representation, confirming previous tests (Bendinelli et al., 1988).

Discussion of the Results

Table II should be regarded as the main result of this work which goes toward the analysis of core structure of early type galaxies, as outlined in Bendinelli et al. (1990).

Differences among the deconvolution methods are of the order of some per cent, small enough to justify the statement that with these images (i.e. pixel size, object size, PSF) all three methods work equally well.

This means that the unambiguous identification of a "point" mass in the centre of nearby galaxies, if present, is possible by a variety of methods, if well-sampled data are available. This central mass concentration with higher mass-to-light ratio than the stars that appear

TABLE II: *Parameters of the deconvolved profiles*

Galaxy	OBS	RLS		RMG		HUNT	
	HWHM	HWHM	$\Delta\mu$	HWHM	$\Delta\mu$	HWHM	$\Delta\mu$
E 440 G 37	0.75	0.42	0.73	0.38	0.80	0.40	0.86
NGC 3585	0.88	0.40	0.71	0.24	0.82	0.49	0.70
NGC 3904	0.90	0.52	0.59	0.50	0.59	0.57	0.58
NGC 3115	1.07	0.48	0.60	0.43	0.66	0.58	0.60
NGC 3923	2.27	1.80	0.18	1.80	0.18	1.74	0.22

Note: HWHM in arcsec; $\Delta\mu$ = (observed-deconvolved) in mag/arcsec^2.

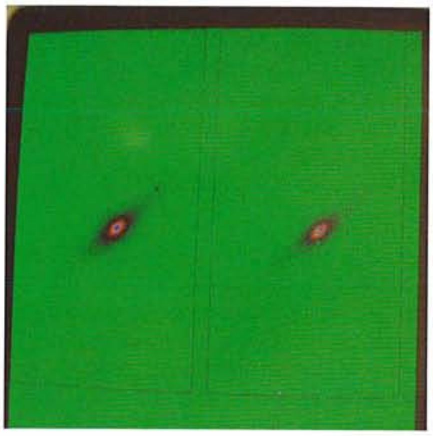

Figure 3: *NGC 3115-S0 galaxy;* $B_T = 9.75$. *Left panel: original CCD frame (1′.7 × 0′.9). Right panel: Hunt deconvolution.*

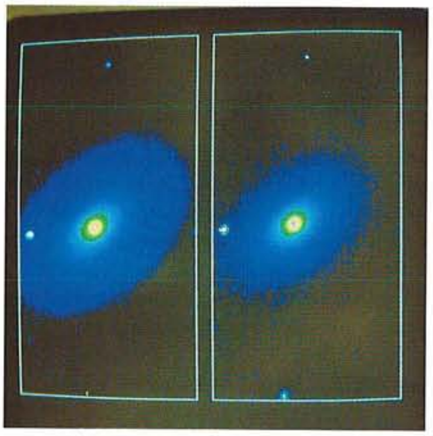

Figure 4: *NGC 3585, also ESO 502 G 25–E galaxy;* $B_0 = 11.40$. *Left panel: original CCD frame (1′.7 × 0′.9). Right panel: Hunt deconvolution.*

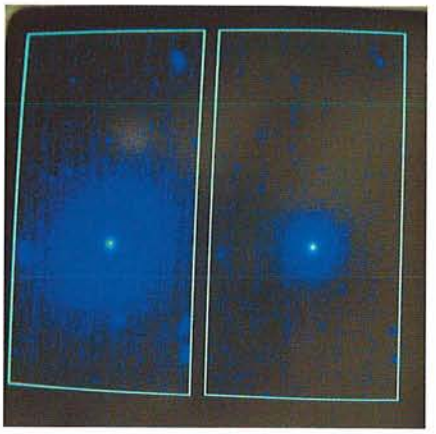

Figure 5: *ESO 440 G 37–E-S0 galaxy;* $B_0 = 14.30$. *Left panel: original CCD frame (1′.7 × 0′.9). Right panel: Hunt deconvolution.*

to dominate in any tested object the galaxy mass distribution on scales of tens to hundreds of parsec has tentatively been identified with a black hole by many authors.

The debate on the presence of black holes in the centre of galaxies is still quite open since the data seem only to imply that some additional mass is required on rather small scales in the centre of galaxies.

Hence any deconvolution method which will permit to constrain the mass distribution in the core of galaxies may be regarded as a step forward towards the understanding of galaxies themselves and the existence of black holes in their centres.

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MIDAS Memo

ESO Image Processing Group

1. Application Developments

The main efforts were placed on validation of basic MIDAS commands and the subsequent correction of problems reported. Since the next major release 90 NOV will be frozen in September already, only a limited number of these improvements will be available in that release.

The COPY/DISPLAY command which can produce hard copies of the image display has been upgraded to be able to provide output for colour PostScript printers. This makes it possible to get good working hard copies in both B/W and colour directly from the image display in MIDAS.

2. New Positions

Two additional short-term positions (with durations of up to two years) have been allocated to the MIDAS group. They will be used mainly for improvements and developments of new application programmes in MIDAS. Not only will this make it possible to have new algorithms and applications included into MIDAS after a period of limited improvements in this area, but will spread long-term, detailed knowledge of MIDAS in the community when people in these positions return to their home institutes.

In addition to these positions, it will be possible to invite people who have made interesting algorithms and programmes, to ESO for an implementation of them into the MIDAS environment. People interested in contributing and/or making new applications to MIDAS may contact the IPG with detailed descriptions.

3. Distribution Policy

The ESO Council, during its last meeting in June 1990, defined the policy for usage and distribution of MIDAS. It states that MIDAS is the image processing system of ESO to be used both for off-line data reductions and for on-line evaluation of data from ESO telescopes including the VLT. MIDAS is available to all non-profit research organizations. Such organizations must sign a User Agreement with ESO before obtaining the package. This agreement will regulate the usage of MIDAS and ensure that it is not exploited commercially. This policy will be implemented as of the 90 NOV release of MIDAS.

4. MIDAS on New Systems

The 90 MAY release of MIDAS was installed on an IBM System 6000 Model 540 (the new RISC CPU) made available by IBM. Only very minor problems were detected, all relating to the operating system AIX 3.1 which was a preliminary version during the tests. Those problems have been resolved in the official release of AIX 3.1. The system had an

X11 display manager and could be used directly for image display and graphics with MIDAS. The configuration included 128 Mb of memory which made it difficult to judge the disk I/O performance. The system gave a very good response with MIDAS benchmarks indicating a performance in the order of 3 times faster than other workstations.

Please note that the mentioning or testing of specific computer systems is not in any way an endorsement.

5. MIDAS Hot-Line Service

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

- EARN:MIDAS@DGAESO51
- SPAN:ESO::MIDAS
- FAX.: +49-89-3202362, attn.: MIDAS HOT-LINE
- Tlx.: 52828222 eo d, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

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

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 fourteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. The 3.5-m New Technology Telescope (NTT) has recently become operational and a giant telescope (VLT=Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.

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