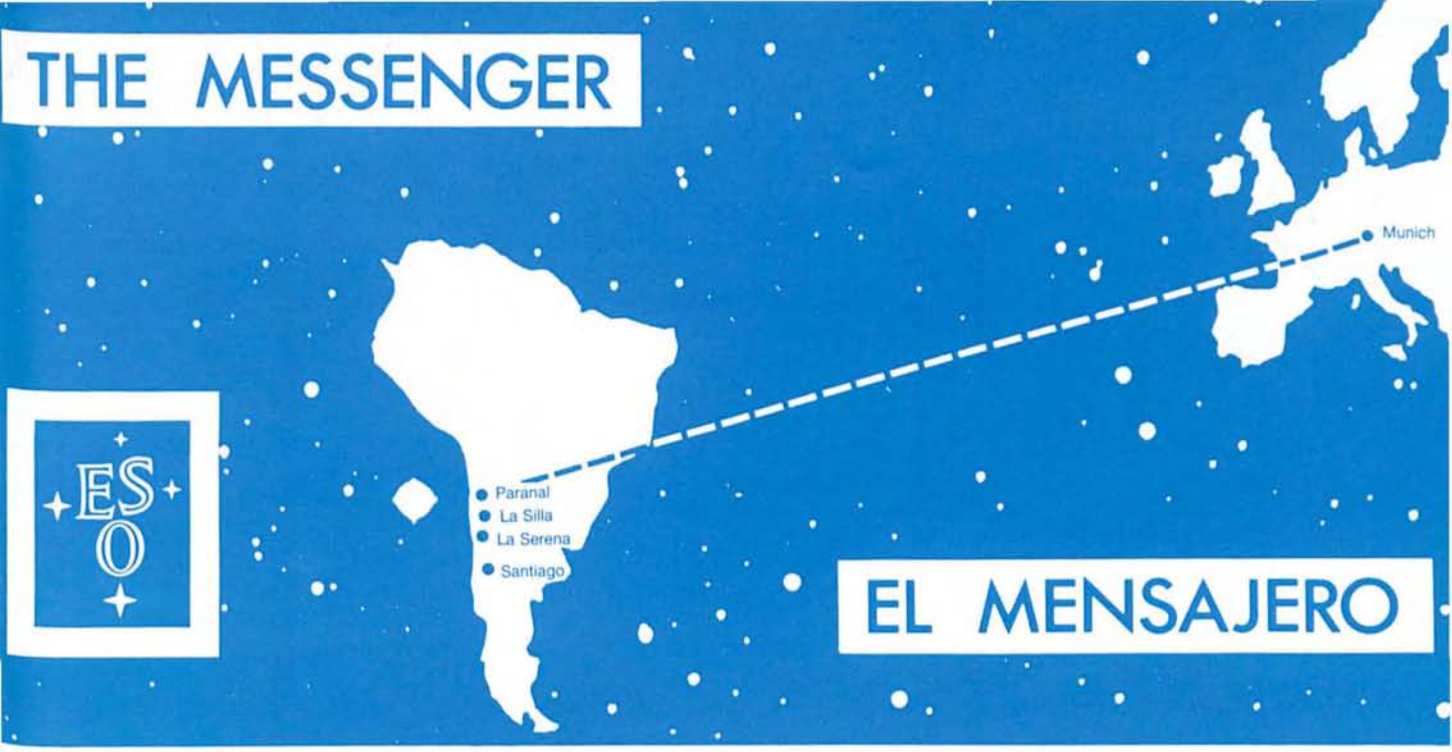

No. 80 – June 1995

Recent Developments

R. GIACCONI, Director General of ESO

Many significant events have occurred in the past few weeks and months which will affect the life of ESO for years to come.

The most important one has been the signing of the "Interpretative, Supplementary and Amending Agreement" to the 1963 Convention between the Government of Chile and ESO, by Mr. Roberto Cifuentes, Plenipotentiary Ambassador representing the Government of Chile and the Director General of the European Southern Observatory on April 18, 1995.

This Agreement, which will have the effect of widening and strengthening the cooperation between ESO and the Chilean scientific community, will be submitted for ratification by the National Congress of the Republic of Chile and by the ESO Council. Upon taking effect, this Agreement will ensure guaranteed access by Chilean astronomers to all ESO facilities up to 10% of the observing time. It is expected that for VLT/VLTI half of this time will be devoted to collaborative efforts between Chilean and European astronomers. In the field of labour relations, the Agreement will result in the incorporation of some fundamental principles of Chilean labour legislation in the internal ESO rules and regulations for the local staff in Chile. Chilean scientists named by a Chilean Committee will participate in all ESO scientific and technical committees. Joint Chile-ESO committees on the preservation of the environment for astronomical purposes and on programmes of development of Chilean astronomy and related technologies, will play an important role in our future cooperation.

In a joint press release the Government of the Republic of Chile and the European Southern Observatory expressed their desire to continue to work towards the resolution of common problems in a spirit of mutual respect and full collaboration. The signing of the Agreement occurred after months of dialogue between the parties and constitutes an important step towards the solution of some of the pending points on the current agenda for discussions between Chile and ESO. Among the remaining points the most important appear to be well on their way to solution thanks to the determined efforts of the Chilean Government.

The issue of ESO immunity of jurisdiction on Paranal which was violated on March 30, 1995 by the visit of a member of the Judiciary with the support of the police, has been dealt with an official expression of regrets by the Chilean Government and assurances by the Government that all necessary steps within the Chilean constitution would be taken to prevent the recurrence of such incidents.

The issue of imports and accreditation has been dealt with by the issuance of two notae clarifying the procedures, by the establishment of a point of liaison for ESO at high level in the Chilean Foreign Ministry and by the liberation of all materials which had been upheld at customs. The issue of the claims of ownership of Paranal by the La Torre family is being resolved by the Government of Chile in out of courts direct discussions which will hopefully lead to a settlement in a short time. The Government of Chile has given ESO both public and private assurances that Chile considers this problem as an internal Chilean issue which should not affect ESO-Chile relations. In any case, work on Paranal is proceeding at full speed.

This generally positive evolution of the situation in Chile has been the result of many efforts. The determined effort and resolve of the Chilean Government to deal with the issues in a decisive manner cannot be overemphasized. The actions by the Ambassadors and Foreign Ministries of the member states of ESO in clarifying to the Chilean Government the concerns of the European states for the difficult situation in which various events had placed the VLT/VLTI project were essential. Finally, the continued and patient efforts of many, many diplomats, scientists and administrators both Chilean and European have been essential to progress. We at ESO are extremely grateful to all of them.

The ESO Council, which met in Extraordinary Session on April 19, 1995, expressed its satisfaction for the many positive steps which had been achieved, its intent to ratify the Agreement and instructed the Executive to continue the direct negotiations with the Chilean Government to hopefully resolve all remaining issues prior to the regular Council meeting of June 7 and 8. Important and fundamental as the issue of Chile is to permit us to continue carrying out astronomical programmes, it was only one of significant events in the last few months.

The first comprehensive VLT management report based on a Work Breakdown Structure was presented to the ESO Scientific Technical Committee on May 4 and 5 and to the Finance Committee at its meeting of May 9 and 10. This report, which will be issued every six months at the request of Council, was very warmly received by both committees. Apart from its intrinsic interest for those who are involved in the monitoring of the technical and managerial aspects of the VLT programme, it represents the culmination of a very intensive effort by many groups at ESO to restructure the accounting, reporting and management information systems to cope with the challenge of the VLT project.

In the February ESO-wide annual review the same management principles were applied to the reporting of every ESO activity both in Europe and Chile. The efforts of the VLT Division, the newly created Instrumentation Division, Administration and Project Office, and of the Chile Administration were essential in making this possible. These new tools will be even more important to permit clarity of communication between ESO management and its oversight committees in the difficult financial times that one can see ahead.

While the overall technical progress on VLT is extremely encouraging, the difficulties in Chile in the recent past have resulted in both time and financial losses which are currently being evaluated. We expect the date of first light to be affected by 3 to 6 months. Financial losses have been experienced due to work stoppages, delays, increased costs for storage of components, rescheduling of planned activities, etc. Resolution of these financial issues will require considerable attention by the ESO Executive and Council over the next year.

In the technical areas the meetings of the Users Committee and of the Scientific Technical Committee have resulted in important decisions regarding the future of La Silla. STC has approved the construction of SOFI (a near infrared imaging spectrometer for the NTT) and the beginning of the assessment phase of the 3.6-metre upgrade plan. The La Silla 2000 group is completing its work of planning for the future of La Silla in the VLT era. The increased attention by ESO to the development and operation of optical detectors with competitive quantum efficiencies, speed of read-out and noise has already resulted in notable improvements. A plan for the continuation of this effort for the VLT instrumentation was enthusiastically endorsed by both UC and STC.

The VLT Science Operation plan was presented to the STC and received a very positive approval and recommendation to proceed even further in implementing the end to end approach to implementation of the science programme that it represents. In general, the increased attention to the planning for the utilisation of the VLT telescopes and instruments has resulted in a first cut study for the necessary software and hardware tools that will need to be developed. Increased attention to and formal representation of the data flow necessary to take us from proposal entry to scheduling, data reception, calibration, reduction and archiving has shown the considerable amount of work still in front of us. A recent ESO Workshop on Calibration and Data Management Techniques was extremely successful in permitting us to measure our progress with respect to past and current large projects in astronomy.

These past few months have been also extremely significant in the development of an even closer involvement of the Science Divisions both in Garching and La Silla in all technical aspects of ESO activities. Staff scientists and Fellows are expected and do contribute to operations, maintenance and upgrading of existing facilities, to the development of new instrumentation, to the development of new software for proposal processing, scheduling and implementation, to the development of physical models of the instruments, to trade-off studies between scientific requirements and engineering difficulties, to development of detectors, in short to all essential activities of ESO as an observatory. While this involvement is being strengthened by proceeding with the hiring to the budgeted staff level, the cooperation between ESO scientists and engineers in Chile and Europe is increasing. Slowly, the concept that ESO is a single observatory, with a single staff whether in Chile or Europe, is emerging. Detector development projects are the responsibility of people at La Silla as well as Garching, the NTT and the 3.6-m refurbishment efforts are being carried out by mixed groups, software development is being carried out jointly and so forth. We consider this approach essential to the successful operation of facilities such as the VLT/VLTI in the future.

I would like to conclude these brief notes by expressing my increasing confidence that ESO and the European astronomical community will prove equal to the challenges of the next century. I base this confidence on the evidence I see of increased cooperation between ESO and its Scientific and Technical Committee and the European astronomical community. On the solidarity which was expressed in difficult times by all member states. On the remarkable performance by the European hardware contractors. Finally on the splendid performance by the entire ESO staff everywhere and in every function.

TELESCOPES AND INSTRUMENTATION

News from the VLT Programme

M. TARENGHI, ESO-Garching

This has been an incredibly challenging period for the VLT Programme. The simultaneous difficulties in Chile and two major external contracts have taxed the management resources of both the VLT Programme and ESO as a whole. The most serious problems were related to difficulties with the import of material and equipment to Chile and the accreditation of contractor personnel. The second area of difficulty was the civil engineering work being performed at the VLT site by the Joint Venture Skanska-Belfi which was aggravated by the Chile situation. Finally, the loss by Matra Marconi of access to a

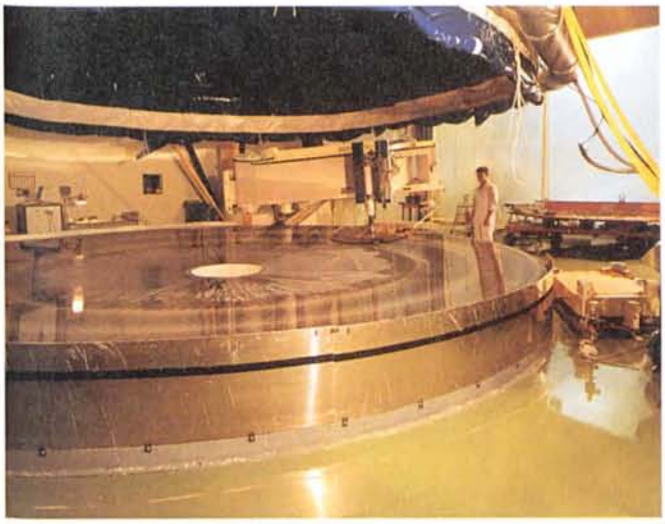

Figure 1: *Mirror No. 1 in the final stages of polishing.*

Figure 2: *Mirror No. 2 in the grinding stage.*

critical silicon carbide technology for the secondary mirror assembly of the VLT required ESO to negotiate a contract with Dornier, the second qualified bidder, resulting in both cost and schedule increases.

These problems have to date resulted in a projected schedule delay, with reference to the June 1993 baseline of 5 months to first light.

In spite of these problems, excellent work has been performed in most of the major areas of the Programme. For example, the heart of the VLT, its 8.2-metre primary mirrors, are progressing well (Figs. 1 and 2). The first two blanks have been delivered by Schott and exceed expectations. The third and fourth blanks are due in July and October 1995 and are proceeding on schedule. It should be remembered that this was originally considered one of the greatest risk areas of the Programme. Polishing of the first mirror is nearing completion at REOSC with the on-time completion of the remaining mirrors projected.

The contract for the main structure is also proceeding well. The AES consortium is scheduled to complete the unit one telescope subsystem by September 1995. Calculations indicate that the completed unit will deliver the best rejection of external disturbances ever obtained on a telescope of this size. The contractor is scheduled to complete erection of the unit telescope in Milan at the end of December 1995. The large mechanical structures for Main Structure Units 2, 3 and 4 have already been started and are proceeding according to plan.

The complex M1 Cell–M3 tower, which supports the 8.2-metre primary mirror, using 150 active supports which constantly maintain the correct shape of the mirror, is entering the manufacturing phase. This was considered the second area with many technical risks, and two contractors had entered into competition. After a design competition between Zeiss and GIAT, the GIAT design was found to fully meet the Programme requirements and be both superior in performance and lower in cost. The prototype produced by GIAT indicates that the final system will perform as required.

The secondary mirror M2 has been mentioned as one of the cost/schedule problem areas of the project. It should be pointed out, however, that the original impact caused by the MATRA problem (six months on first light) has now been reduced to only three months' delay. The contract with Dornier-DASA is proceeding on schedule, although with a higher price than ESO's original baseline project price projections because of the use of beryllium mirrors for the first unit.

The four telescope enclosures are also progressing well. The contractor has sent

Figure 3: *Paranal on 2 April 1995.*

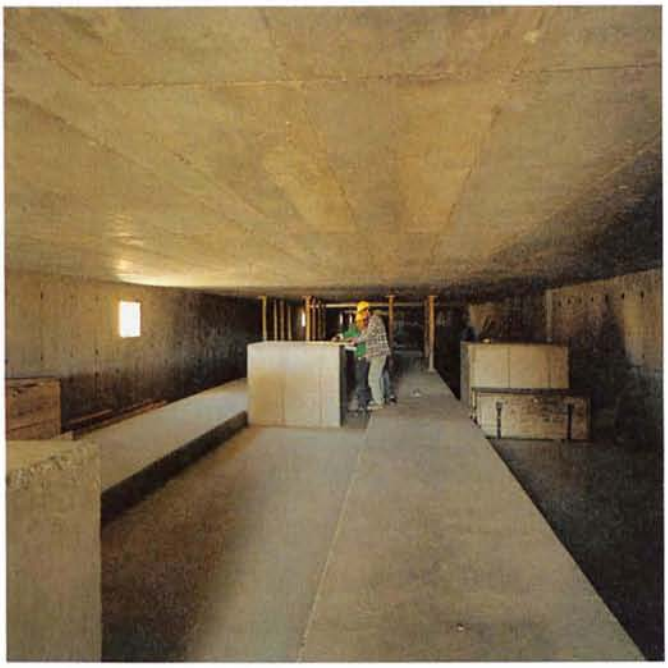

Figure 4: *The completed section of the delay line tunnel.*

Figure 5: *Inside the building of the first Unit Telescope.*

8 shipments with over 300 tons of material to the site to begin erection as soon as the importation and accreditation problems are solved. Work in Europe is proceeding as planned.

At the Paranal site, the work on the foundation for the first telescope is almost complete (Figs. 3, 4 and 5). The total site concrete work is 25% complete. Although significant problems with schedule have plagued this contract, we believe that the critical work for telescope No. 1 can be completed in May 1995 to allow the next contractor, SEBIS, to begin erection of the enclosure. It should be noted that the contractor has also been affected by the import problems.

One of the critical areas of the performance of the VLT and its scientific instruments is the CCD detectors. A new head of this group has been recruited. This group has been strengthened with additional manpower to ensure that this important area is properly covered. The new ESO CCD prototype system, ACE, has been tested on La Silla and is functioning well.

A number of management changes have also been implemented in the Programme. The VLT work was organised into work packages beginning in February 1994 with budget planning by work packages implemented with the 1995 budget. In January 1995, the accounting systems at ESO were modified to include cost collection by work package in addition to the traditional cost collection by nature of expense.

Another critical area was the system engineering. The vacancy of the head of the System Engineering Group has now been filled and the new head of system engineering brings in-depth telescope system experience to ESO and has now recruited personnel for the remaining open system engineering positions including the important area of configuration control.

Another positive development has been the selection of the VLT Programme Scientist which still has to be confirmed by Council. The VLT Programme Scientist will provide the nucleus for a small group of scientists to assist the VLT Programme in scientific issues. Also the new Project Scientist for the VLTI, F. Paresce, has begun work, adding senior scientific oversight to this important Programme area.

In February 1995, the third annual ESO Wide Review was held. In this Review, the work, schedule and cost for the year 1995 were reviewed. A key element of this Review was the introduction of clear quarterly progress milestones which form the basis for control by the upper management.

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Scientific Priorities for La Silla in the VLT Era

J. ANDERSEN, Chairman of the Working Group

In a previous article (*The Messenger*, No. 78, p. 3), the rationale behind the creation of the ESO Working Group (WG) on *Scientific Priorities for La Silla in the VLT Era* was outlined. At the same time, the WG solicited the views of the community on the main classes of science to be carried out from La Silla over the next five to ten years, and the facilities that will be needed to do so.

After analysing the replies, the WG has prepared a first draft plan to serve as a skeleton for the following discussions. We are grateful for the keen interest of the community and would like to present below a brief status report on our work and the plans for its completion.

The Questionnaire Survey

Nearly 150 replies were received by mid-February, a quite respectable turnout. While any such survey will inevitably be both incomplete and biased for a number of reasons, and cannot be an exact measure of the community's plans and wishes, this material is an invaluable guide for our work. Also, several thoughtful and pertinent comments were made on a variety of individual topics.

Some main trends are already clear from the answers:

• Strong demand for wide-field imaging (> 1°), visible and IR.

• Strong emphasis on survey-type work, both stand-alone and in preparation for VLT projects.

• Much demand for moderate- and high-resolution spectroscopy in the visible, moderate resolution in the IR. Strong interest in a wide-field, multi-object spectrograph (MOS) with > 400–500 fibers.

• Demand for long-term monitoring of variable sources, with requests to keep a photometric telescope on La Silla (some for polarimetry as well). Accurate standard stars for the VLT must be established.

• The role of La Silla in hands-on training of young astronomers is seen as very valuable, but second in priority to excellent science.

• Users are emphatic that La Silla must remain internationally competitive; small and medium-class telescopes continue to have valid and valuable roles to play.

General Policy Considerations

In trying to chart the course of La Silla into the future, we are guided by some of the landmarks previously set. Two of these are the report by the WG on *Scientific Priorities for the VLT Observatory* (1995) and that on *Scientific Priorities for La Silla Operations* (see *The Messenger* No. 74, p. 29, 1993). We must now carry the 1993 plans forward in mesh with the VLT project, guiding La Silla to a steady-state situation after the year 2000.

Some of the basic premises for the preparation of such plans are:

• The timetable of changes is driven primarily by the schedule of the VLT and its instrumentation.

• If preparatory work is required for VLT projects, the corresponding instrumentation on La Silla must be available in time.

• The VLT will completely outclass some current La Silla facilities. Yet, high-priority projects must be done on La Silla in the interim.

• New initiatives must be focused on the larger telescopes, which are both the main VLT partners and the most labour-intensive to run. For the smaller telescopes (< 1 m), the 1993 recommendations remain in force unless otherwise stated.

• At all times, facilities must be planned to achieve maximum operational simplification; this implies single-configuration telescopes and block scheduling of instruments as far as possible.

• The true financial impact of the proposed measures is not primarily in the direct costs, but in paving the way for a more cost-effective organisation of La Silla as a whole.

Draft Recommendations of the WG

A first rough timetable and list of actions was distributed to the Users Committee and STC in late April. It will no doubt undergo many revisions before a final version is reached, but some of its current main elements are the following:

• A careful tradeoff study of mirror size, image quality, and ease of operation is needed to define the future home of wide-field optical imaging on La Silla. Results so far indicate that the 3.6-m is unlikely to become a competitive facility.

• Wide-field imaging and medium/low-resolution spectroscopy in the near IR will remain vital. The proposed NTT instrument SOFI will cover these needs in a very cost-effective way, and the WG recommends that it be built.

• Until VLT+VISIR take over, TIMMI should be upgraded with a larger array, even temporarily, especially for ISO follow-up work.

• ADONIS should stay on the 3.6-m until CONICA + adaptive optics enter operation on the VLT.

• MEFOS and OPTOPUS lag behind contemporary efficiency by large factors and should both be retired. Competitive successors cannot be completed early enough, and time exchange agreements should be explored instead.

• A higher spectral-resolution option and efficient fiber link to the 3.6-m are essential for the long-term competitiveness of the CES.

Towards a Final Plan

The draft was discussed at length at the UC and STC meetings in May. There was a gratifying measure of support in both committees for the overall strategy of the draft as well as most individual proposals. The natural wish of users to maintain La Silla instruments in top shape until their VLT successors are in stable operation was stressed by both. The educational role of La Silla, defined as student training, met with some skepticism. The important issue is, however, the experience of those scientists who, 20 years from now, will teach a new generation of students. Hence, additional suggestions and comments will be solicited in the next version of the report.

After further discussion in the community, the WG plans to meet the UC, STC, and OPC together for a final review and refinement of the plan, and its financial implications will have consequences in the 1996 budget. Final presentation to the DG and Council follows after the November STC meeting.

In order to facilitate community access, later drafts of the report may also become available on the WWW.

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Is the Seeing Situation at the 3.6-m Telescope Irreversible?

M. FAUCHERRE, ESO-La Silla

1. Introduction

Image quality (IQ), or the sharpness of the point spread function (PSF) at a 3.6-m instrument focus, should not fall below one arcsec (″) FWHM when external conditions are excellent, and is worse than 1.15″ FWHM most of the time (see Fig. 1). Images are hardly ever as sharp as at the NTT, the 2.2-m or the seeing monitor. This situation could be improved, and we are convinced now that in one year's time it would be possible to obtain 0.8″ FWHM long exposures with EFOSC1 routinely. This would however require a large effort during that period.

Poor IQ at the 3.6-m is not due to the site itself or to the quality of the optics (≈ 0.45″ FWHM), but rather to "mirror seeing" and to the presence of the dome. The dome is so large (30 m diameter) that residual sources of heat produce internal thermal gradients which cannot be eliminated by using the wind or any forced dome ventilation from outside, just because the dome cannot be opened sufficiently – unlike the NTT dome. Besides, obtaining thermal equilibrium with the outside all the time by means of cooling and ventilation is not realistic,

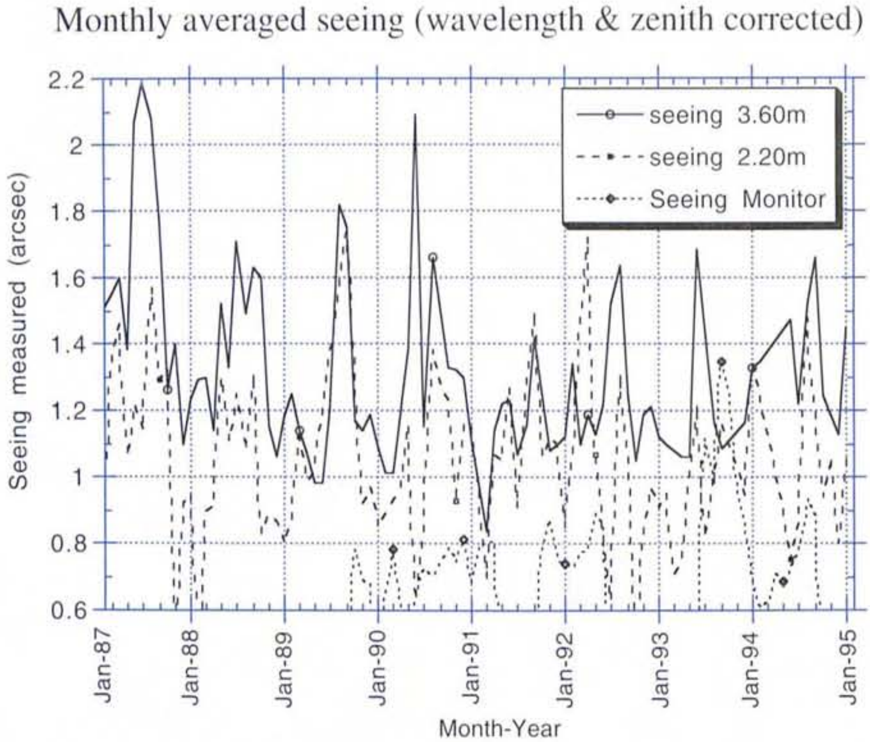

Figure 1: *Seeing recorded at La Silla 3.6-m, 2.2-m and seeing monitor telescopes from January 1987 to December 1994.*

given the enormous thermal inertia of the primary mirror (M1), the concrete floor slab and the yoke. Indeed, to obtain good images, there is only one recommendation, simple in theory: All temperatures (T°) in the dome should be within 1° and the average dome T° should remain lower than the outside temperature, by less than 1° (see ref. 1). This was widely confirmed by results obtained during seeing test runs.

Experience gained at other facilities (esp. AAT, CFHT and Kitt Peak) clearly showed the correlation between image spread and thermal inhomogeneities in the light path from the telescope slit environment to the detector. Most of the spread is caused by "local" seeing effects (dome, site, M1 or instrument). So what is needed to understand and possibly improve local seeing at the 3.6-m telescope are two sets of data, *image data* and *thermal data*. The lack of *image data*, in the form of reliable PSF FWHMs, has not permitted us up to now to tackle the seeing issue statistically. The "3.6-m Seeing Improvement Project" (ref. 2) is based on IQ measurements made by the observers themselves during their run, with the help of the night assistant. In March, observers were requested to dedicate 15 minutes per night to seeing measurements. Together with T° in the dome, seeing at other sites on La Silla and meteorological data, IQ data from EFOSC1, CASPEC and ADONIS would lead to the constitution of a database. From there, we would infer rules to set T° in the telescope environment, which would take into account changing external conditions, so that the IQ is always optimal. Cooling systems either already in place or presently being constructed (M1 surface cooling) will include fine T° adjustment capabilities for critical items such as M1.

2. A Historical Perspective

Twice in the past, a dome ventilation system was built and tested. No IQ improvement was noticed. Finally, in 1990 it was decided to build an Air Conditioning (AirCo) and a Floor Cooling (FloorCo) system, following recommendations by R. Le Poole, an engineer who studied the problem in some detail in 1990 (ref. 1). This system was operational in October 1993 just before a Come-On-Plus (CO+) run: It helped stabilise the bench T° and led to a noticeable IQ improvement (down to 0.9") as compared to previous measurements (April and July 1993 runs). Conversely, images obtained by EFOSC1 got worse (section 4). I review Le Poole's recommendations below, then present the AirCo system.

2.1 Le Poole's Recommendations

• *Actively cool M1.* M1 was 3 to 4° warmer than ambient (in 1990). It is recommended to build an active thermal control system, which will cool M1 down to the previous night's minimum less 1°. The alternative solution is to cool down dome and floor to such an extent that T° at a height of 5 metres is 1° below last night's minimum. This assumes that all heat sources have been removed from the Cassegrain cage.

• *Insulate observing floor.* Some large heat capacities should be shielded (concrete slab, control rooms, TIMMI room, telescope base). Calculations show that both the concrete slab

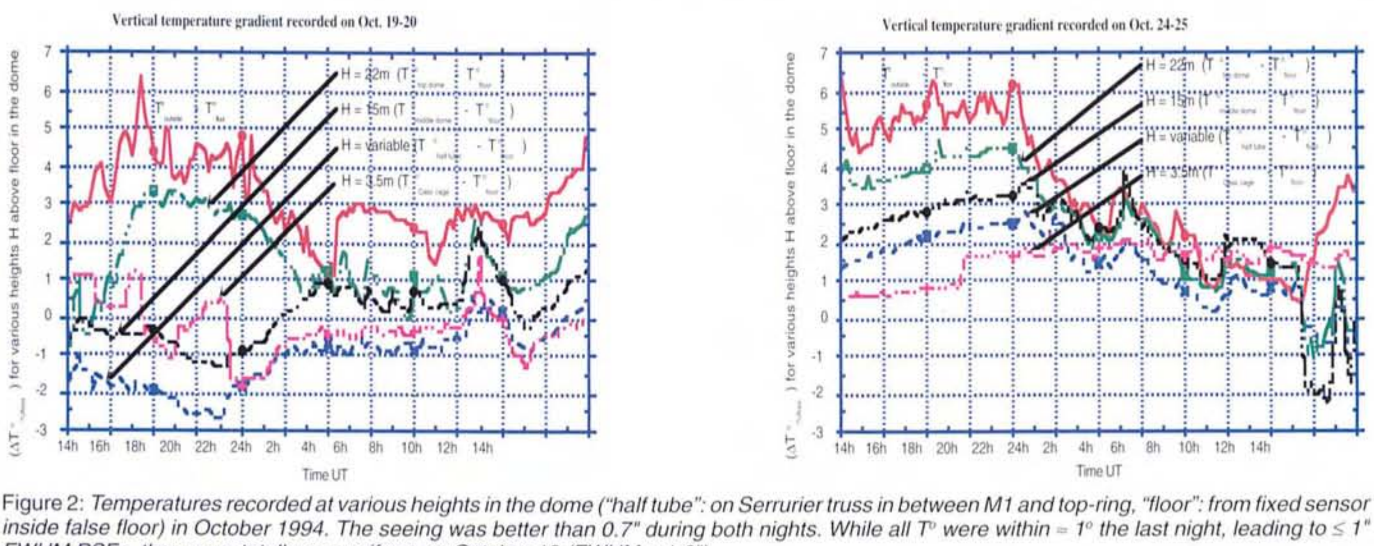

Figure 2: *Temperatures recorded at various heights in the dome ("half tube": on Serrurier truss in between M1 and top-ring, "floor": from fixed sensor inside false floor) in October 1994. The seeing was better than 0.7" during both nights. While all T° were within ≈ 1° the last night, leading to ≤ 1" FWHM PSFs, they were totally non uniform on October 19 (FWHM ≥ 1.6").*

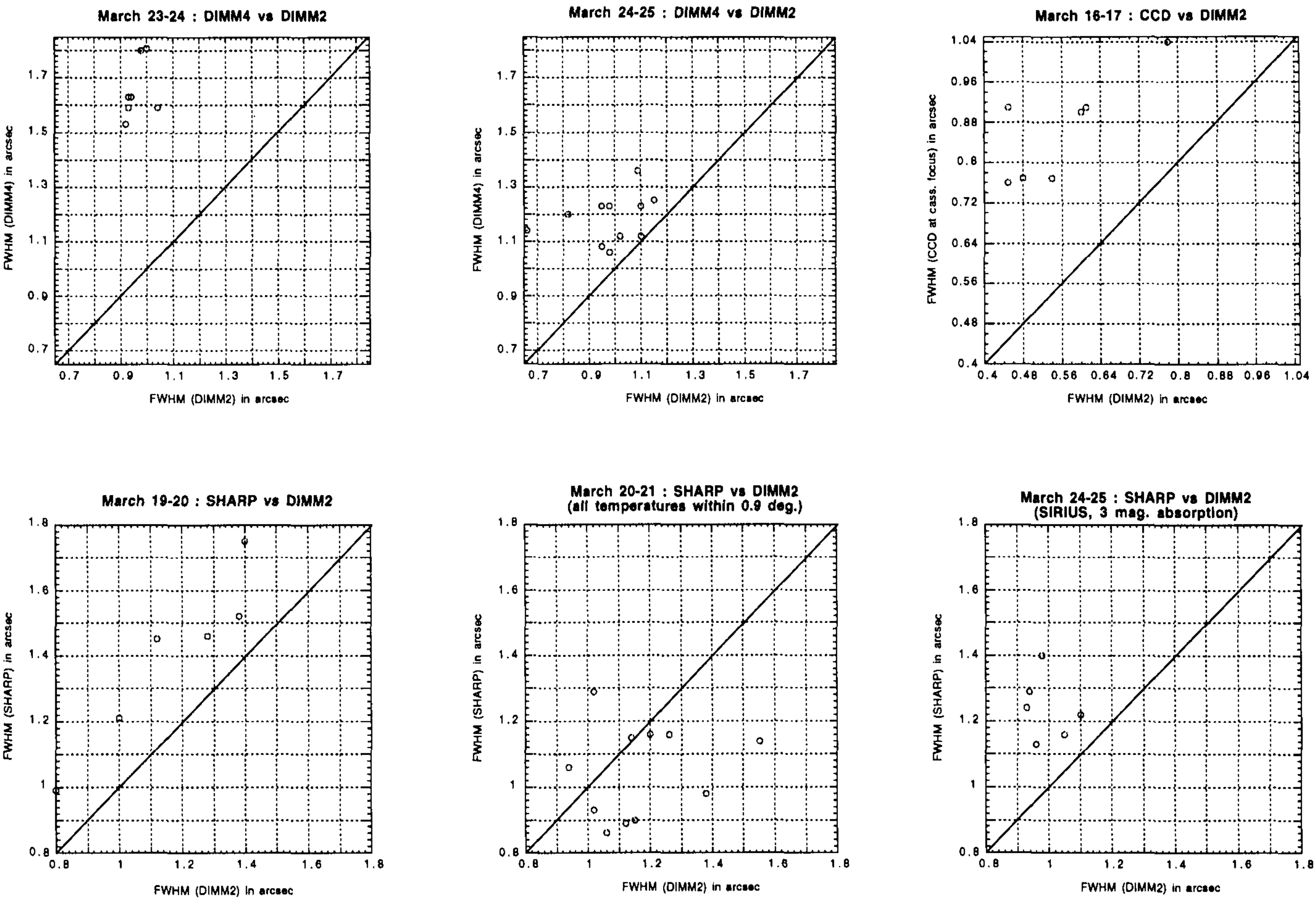

Figure 3: Seeing measurements made on several occasions in March 1995, with M1 cooled to ambient T° (T_a ±1°) and floor cooled to T_a –2°. Comparison with the seeing monitor DIMM2 gives an estimate of remaining M1 and dome seeing.

underneath the false floor and the primary mirror have thermal time constants of several days.

• *Cool dome floor and volume.* Le Poole suggests that we inject cold air upwards into the dome so as to produce a "bubble of cold air", which should help to reduce air turbulence in the open slit.

• *Ventilate dome using outside air.* 20 dome volumes per hour are needed. It was shown later that the cost – and moreover maintenance expenses – for such a system would be prohibitive, given the size and the form of the dome.

• *Cool the oil in the drives and eliminate small heat sources.* This last item refers especially to the Cassegrain cage. Still today, new instruments like ADONIS or TIMMI are mounted in the cage with large electronic racks including power supplies and other heat sources.

2.2. The "AirCo" System

All recommendations by Le Poole were implemented, except two: forced dome ventilation, for reasons given in the introduction, and M1 cooling. Indeed it was assumed that with the combination of "AirCo" and "FloorCo", M1 T° would decrease sufficiently. This did not happen: Even after reducing major heat sources in the cage in 1994 (especially by ventilating the cage and the four electronic closets inside), M1 T° still remained warmer than ambient by ≥ 1.5°. That is why it was decided in July 1994 to cool M1 (see section 5). Now, how does the AirCo system work? Cold air is injected both into the floor and at the top of the dome during the day; only the FloorCo is maintained during the night.

The system which was built for the dome is right from the "physics standpoint", even though the cold air produced is not uniformly distributed, as can be seen in Figure 2. As a result of thermal stratification, long time constant items cannot reach thermal equilibrium with their environment, because convection is inhibited. So, more ventilation is required in the dome. However, the system did not solve what was found to be the major issue: mirror seeing. For this, two systems were conceived. They are described in section 5. Also insulation would help a lot to reduce cooling expenses: Highly conductive materials should be used to avoid thermal radiation. It is suggested in particular that we wrap the telescope top end in aluminium foil.

3. "Mirror Seeing" and "Dome Seeing"

Mirror seeing is due to convection of air above the reflective surface of a mirror when it is out of temperature equilibrium with ambient air. Convective disturbances caused by a mirror being warmer than ambient cause serious image degradation: a factor of 0.35″ / °C of T° imbalance for a horizontal mirror (an average between different authors). Mirror seeing image broadening is produced by a turbulent boundary layer. Mirror seeing was identified as the major contributor to overall seeing in several conventional (pre-1985) facilities (CFHT, AAT, UH 88). It has been suggested by several authors that a flow of air across the surface of a mirror may substantially improve the seeing. The difficulty in the case of the 3.6-m mirror is that it will be impossible to maintain a laminar flow over a distance of more than a metre in the open air.

Dome seeing occurs when the air in the telescope beam up to the telescope slit is out of temperature equilibrium with outside air. Once again, this effect is worse when the dome is warmer, producing convection in the beam through the slit. It has been shown that most wavefront disturbances occur in the slit area. This was very clear on pupil images made at the 3.6-m, where bright patterns of flying shadows could be associated with both the slit area and the *immediate neighbourhood over M1*. This could easily be checked measuring the T° structure function in those two areas.

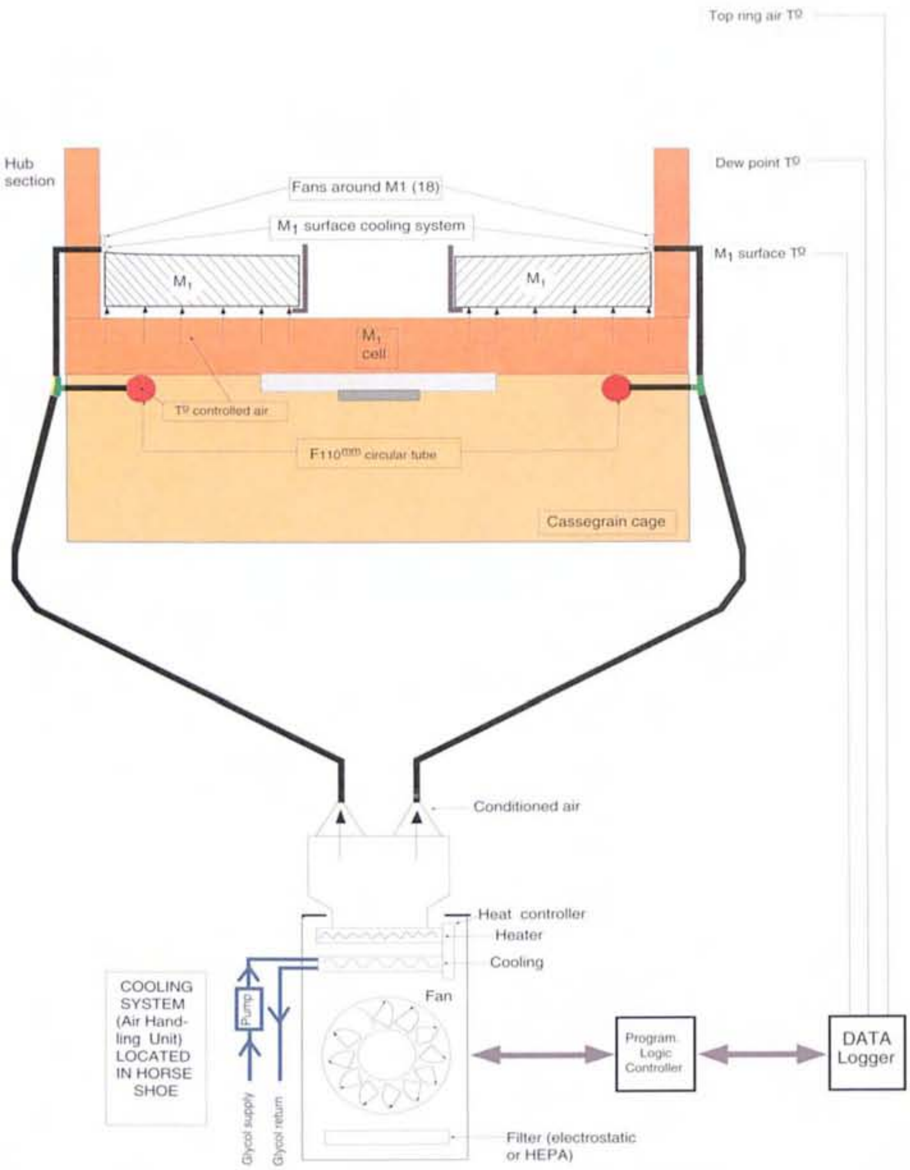

Figure 4: *M1 cooling system presently implemented (section).*

When there are no heat sources or long time constant items in the telescope beam neighbourhood, the overall seeing is not dominated by dome seeing, but rather by mirror seeing.

Those pupil images, recorded with the autoguider and an out-of-focus beam, were extremely useful in identifying problems. Several patterns of flying shadows, present on 3.6-m pupil images, never appear on NTT pupil images. Good seeing was always associated with vanishing of middle-scale flying shadow patterns. Since this phenomenon is dynamic, a picture unfortunately does not say very much.

4. EFOSC1, "Naked" CCD at the Cassegrain Focus and Come-On-Plus

The results obtained during a year with EFOSC1 and especially with Come-On-Plus (CO+) will not be presented here (see refs. 3). That will be the subject of another paper, actually in preparation. Nevertheless, Figure 3 shows the last results obtained in March with a thermal environment which sometimes approached perfection ($\Delta T \approx 0.9°$). The most significant lessons from those nights (10 nights were allocated to seeing measurements in period #54) are:

- Scientific runs: With the AirCo system alone, images got better for CO+ (0.3″ improvement on average) while EFOSC1 IQ was degraded (up to 0.5 arcsec). Internal ventilation of EFOSC1 helped, but was not enough. EFOSC1 is completely closed, CO+ completely open.
- When the dome was ventilated by the wind ($\approx$ 6 m/sec), and when M1 and the air above M1 had the same T° within 1.5°, the best images measured with a CCD were for a dome opened to the wind, telescope at 20° from zenith: $\approx$ 0.8" FWHM. This fact is well known to the observers: The wind helps the seeing!
- After reaching temperature equilibrium in the dome within 1.2° thanks to a particular T° setting (always recorded) in the dome, the same result was obtained without wind ($\leq$ 2m/sec).
- As soon as the primary mirror is warmer than the outside by $\Delta T \geq 2°$, an IQ degradation due to M1 w.r.t. the seeing monitor IQ was identified and detected: For $\Delta T = 2°$, Δ(FWHM)=0.45″ on average at the 3.6-m.

5. New M1 Cooling/Ventilation System at the 3.6-m

An air-handling unit (AHU) was installed in the telescope horse shoe. The cold air is presently sent inside a circular tube located underneath the M1 cell, and from there through the cell to the mirror bottom thanks to a number of holes in the cell up and down. A second system is under construction, where the air is split before entering the cage. The second part will feed a circular "garden hose" located above the mirror on the side. This air will be cleaned and dried before sweeping the mirror gently, day and night. T° homogeneity will be obtained during the day thanks to 18 ventilators located above M1. Calculations show that surface T° (5 cm in depth) can be changed by 1° in 3 hours, which would allow the outside T° to be followed in most cases. It is intended to use only this new system plus the FloorCo during the next few months in order to evaluate their impact on the seeing separately.

6. Conclusion

Tests made during more than a year to measure the seeing with a dome in better thermal equilibrium were encouraging: Many times we crossed the fateful threshold of 1″ with a regular instrument, reaching 0.8″ on four occasions, when in addition the primary mirror was cool. The next step is the constitution of a database, to record the seeing for a maximum of meteorological and seeing conditions. From those data and many others recorded at the same time, we will calculate a number of "IQ indicators" ($\Rightarrow$ image FWHM = f (parameter)), from which seeing properties will be inferred. From there, we should know pretty well how to tune up the ventilation/cooling system in order to get the best possible images. Then installing EFOSC2, whose pixel size is about half that of EFOSC1 (0.61″), at the 3.6-m Cassegrain focus, will allow us to really take advantage of the good seeing.

Acknowledgements

This article summarises the work of a team. Thanks to the many discus-

sions with E. Swinnen and G. Ihle, we eventually managed to obtain a more accurate picture of the 3.6-m thermal problem.

For the measurements I want to acknowledge: A. Gilliotte, T. Höög, M. Maugis, A. Pizarro and G. Timmermann. Special thanks go to C. Perrier who took the data with SHARP presented here.

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CAT/CES NEWS

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During the last week of March, a new CCD was tested on the Coudé Echelle Spectrograph's Long Camera. This CCD, ESO#38, is a LORAL/LESSER 2688 × 512 thinned, backside illuminated device (pixel size 15 × 15 μm) with anti-reflection coating. The quantum efficiency is about 80% throughout the visible wavelength range (350–800 nm) with a peak value of 90% at 700 nm. The values are better by a factor of 5 in the blue to 2 in the red than CCD#34 which is presently in use on the Long Camera (see Table 1). The high QE is obtained after flooding the CCD with intense UV light. In normal operations, it is expected that the CCD will need to be UV flooded once every month. The new chip is mounted in a continuous flow cryostat, with a hold time of about one week.

Efficiency tests were carried out which confirmed the high sensitivity of the CCD. We were, however, confronted with a degradation in resolution at high resolving powers. Specifically, a slit setting to yield a resolution of 100,000 resulted in an actual resolving power of about 70,000. The details are given in Table 2. According to the CCD detector group, the degradation in resolution is expected especially in the UV with backside illuminated devices. Due to a *field-free* region inside the device, photon-generated electrons spread to adjacent pixels, thus increasing the effective pixel size. This effect is more pronounced in the blue than in the red.

Given the above results it was decided not to offer CCD #38 to the ESO community at the start of the current period 55. For the moment, the Short Camera with CCD #9 and the Long Camera with CCD #34 are available. The stability of the UV-flooding of CCD #38 will be further tested and a solution has to be found for the degradation in resolution. Due to the very high performance of this chip, we plan to offer CCD #38 with the Long Camera starting in August 1995 after the "idle" period of the CAT telescope. The Short Camera and CCD #9 will be decommissioned and CCD #38 offered to the observers requiring a resolving power up to R = 70,000. For programmes requiring higher resolution CCD #34 will be retained. A new version of the CAT+CES Operating Manual containing the characteristics of the new configuration will also be distributed. The high QE, the low read-out noise (8 e/pixel), and the large size of CCD #38 would be a significant improvement in the performance of the CAT/CES spectrograph if a procedure for recovering the expected spectral resolution can be developed.

Some details of the characteristics of CCD #38 are provided in Tables 1 and 2.

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TABLE 1: OVERALL CAT+CES LONG CAMERA EFFICIENCY IN PERCENT

λ(Ångström)	CCD #38	CCD #34
3500	0.8	0.15
3589	2.3	0.47
4035	5.4	1.4
4435	6.9	1.1
5400	9.2	3.8
6450	10.4	5.2
8092	5.88	3.7

TABLE 2: CES LONG CAMERA + CCD #38 MEASURED RESOLUTION VS NOMINAL RESOLUTION AT 4435 Å

Nominal	FWHM (Pixels)	Measured	Meas/Nominal
40,000	5.8	39,300	0.98
50,000	4.9	46,500	0.93
60,000	4.1	55,660	0.92
70,000	3.75	60,800	0.87
80,000	3.6	63,300	0.79
90,000	3.35	68,000	0.76
100,000	3.18	71,800	0.72
110,000	3.0	76,000	0.69
120,000	2.96	77,000	0.64

The FORS Focal Reducers for the VLT – a Status Report

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Introduction

The FORS1 and FORS2 *FO*cal *R*educer/low dispersion *S*pectrographs are expected to be something like the workhorses of the VLT since they will offer a variety of observing modes in the visual and near ultraviolet wavelength range, namely

1. direct imaging (2 image scales)
2. low-dispersion grism spectroscopy
3. multi-object spectroscopy (MOS; up to 19 objects)
4. polarimetry (FORS1 only).

These modes can be combined e.g. to allow imaging polarimetry or spectropo-

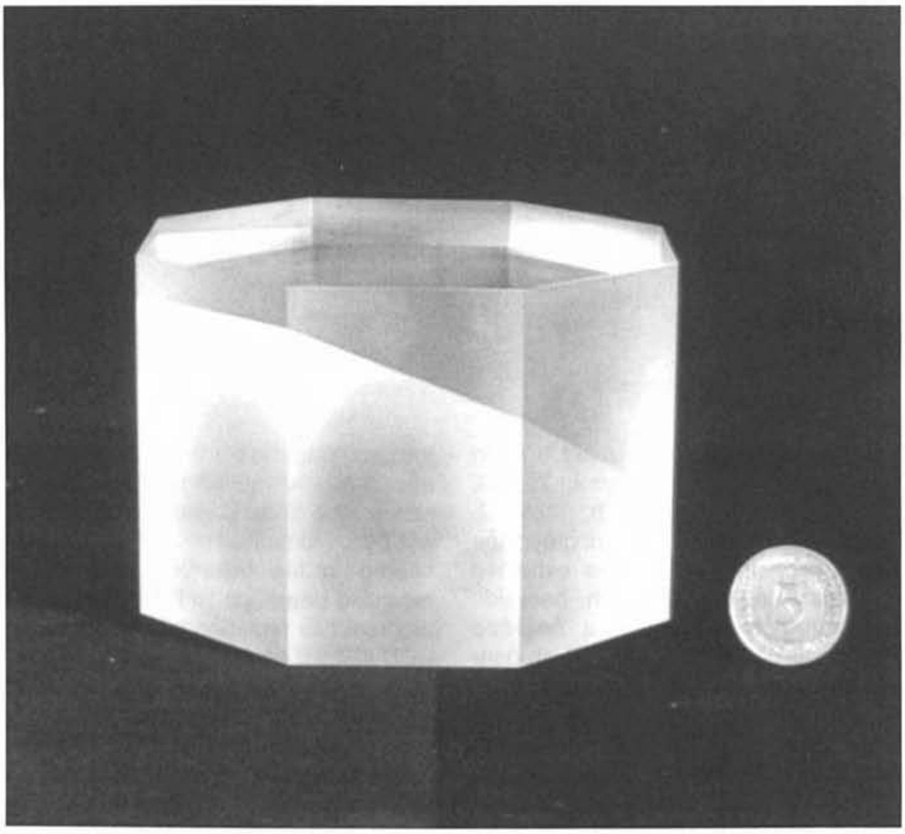

Figure 1: *The FORS Wollaston prism; note the enormous size!*

larimetry. In addition, a mode offering higher dispersion (possibly up to $R \sim 5000$) is envisaged for FORS2 which will therefore not be equipped with polarimetric optics. An overview of the FORS project can be found in [1]. A more comprehensive description of the expected instrument performance is given in [2] and [3] and more technical descriptions in [4] and [5].

Status of the Project

Work is progressing well at the three institutes (Landessternwarte Heidelberg, Universitäts-Sternwarte Göttingen, Universitäts-Sternwarte München) collaborating in a consortium. Already in April 1992 the Preliminary Design Review (PDR) was held, and in February 1994 the Final Design Review (FDR) followed for the instrument mechanics, electronics, the assembly, integration and test procedures, for handling and maintenance aspects and for safety and management issues. No serious problems were identified, so immediately afterwards the consortium began to transform the approved design into hardware.

Optics

In Heidelberg, the design of the imaging optics has been finished and the lenses (FORS is an all-dioptric focal reducer) are presently being polished by FISBA. Delivery is expected later this year. The optics for the polarimetric mode, which consist of a Wollaston prism of 132 mm (!) free diameter (Fig. 1) and two 3 × 3 mosaics with 135 mm free diameter of superachromatic retarder plates, have already been delivered to the consortium (by Halle). The standard set of grisms has also been designed and is presently being procured. The broadband and interference filters which will be provided with FORS are being defined in collaboration with the Instrument Science Team.

Since it became clear that atmospheric dispersion would significantly degrade the image quality of FORS, ESO decided to install atmospheric dispersion correctors (ADCs) in unit telescopes UT1 and UT3. A novel design called "Longitudinal ADC" consisting of two silica prisms with variable distance will be used. A paper giving full details is currently in preparation.

Mechanics

For reasons of economy, instrument components procured externally are always bought simultaneously for FORS1 and FORS2. The Göttingen workshop is therefore presently busy with the incoming inspections of the major mechanical components produced by industry. So far, the cylindrical housings for the instruments have been received (Fig. 2) as well as the focusing units made of cast aluminium and the mechanical components (spindles, linear bearings) for the multi-object spectroscopy units; also, a significant part of the manufacturing is done in Göttingen.

Electronics and Software

This part of the project is performed in Munich. Most electromechanical units

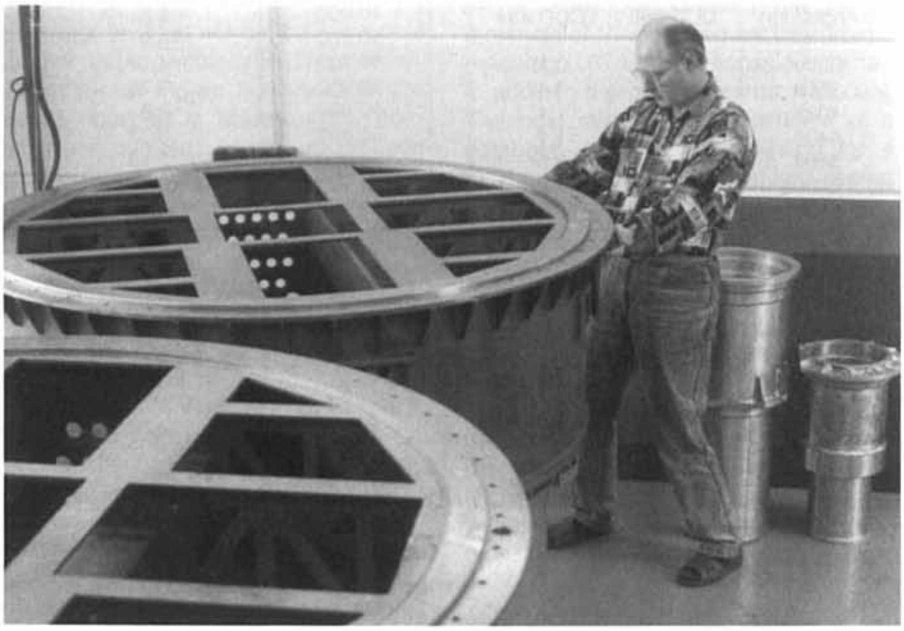

Figure 2: *Incoming inspection of the FORS1 and FORS2 top sections; they will house the multi-object spectroscopy units. At right are the tubes of the collimators for FORS1 needed to change the image scale.*

(motors and encoders) have been procured.

In September 1994 the FDR for some of the instrument control software modules was held and coding started immediately afterwards.

Data reduction software for FORS specific instrument modes (mainly MOS and polarimetry) is being implemented in Heidelberg. The first finished context (MOS) will be included in the 95NOV release of MIDAS.

Auxiliary Devices

Several auxiliary devices are under construction for FORS. The most important ones for the construction and test phase are the star simulator for the optics tests, which is partly finished, and the telescope simulator to be used mainly for the flexure tests of the integrated instruments; this one is under construction.

Another important device will be the transport carriage. It turned out that the requirements for handling the FORS instruments at the telescope are very similar to those of the Cassegrain adapters/rotators, e.g. weight to be transported, lifting height and mounting accuracy. In order to simplify maintenance procedures and to reduce the diversity of ancillary equipment at the VLT, the carriage is therefore being designed to accommodate both; two copies will be procured in 1995.

Detector

One of the most crucial components of an instrument is its detector. For FORS SITe (formerly Tektronix) 2048 × 2048 CCDs with 24 µm pixels were selected; the procurement of the CCDs including all peripherals (dewar, controller) is being done by ESO. So far we have received one CCD of grade 1 which is now awaiting full characterisation by ESO's detector laboratory.

Future Planning

Activities scheduled to happen in the near future include tests of the imaging optics and performance tests of the first MOS unit, both from a mechanical and control system point of view.

The long-term planning foresees the integration of FORS1 for 1996, system tests for 1996 and 1997, transport to the VLT Observatory in 1998 with an installation date on UT1 in the last quarter of 1998, according to the current VLT planning. FORS2 is then scheduled for an installation on UT3 in the year 2000.

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UVES (UV-Visual Echelle Spectrograph) for the VLT – a Status Report

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Introduction

UVES is a two-arm crossdispersed echelle spectrograph covering the wavelength range 0.3–0.5 µm (blue) and 0.42–1.1 µm (red), with a 2-pixel resolution of up to 90,000 and 120,000, respectively. It will be mounted at the Nasmyth of UT2.

Project kick-off for UVES was in spring 1992 with a plan [1] calling for two identical instruments, to go on UT2 and UT3, with a resolution of up to 70,000. An overview is given in [2]. In response to discussions on a redistribution of instruments at the foci of the VLT, it was decided in spring 1994 to build a single instrument with increased spectral resolution and versatility (by adding an Atmospheric Dispersion Compensator, an Iodine absorption cell, a depolariser and exposuremeters) [3]. The science objectives and expected performance of the upgraded instrument are given in Tables 1 and 2 and in [4].

UVES is being designed and built in-house. The instrument control and data reduction software is being developed in collaboration with the Observatory of Trieste. S. D'Odorico is the Instrument Scientist.

Status of the Project

Following the Preliminary Design Review in October 1993, UVES is now in the

TABLE 1. UVES SCIENCE OBJECTIVES

- Structure, physical conditions and abundances of interstellar and intergalactic gas at early epochs from the absorption spectra of high redshift QSO's
- Kinematics of gas and stars in galactic nuclei
- Kinematics and mass distributions of star clusters
- Composition, kinematics and physical conditions of the interstellar medium in the galaxy and in nearby systems
- Chemical composition and atmospheric models of galactic and extragalactic stars
- Substellar companions of nearby stars (high-precision radial velocity studies over long time scales)
- Stellar oscillations

TABLE 2. UVES OBSERVING CAPABILITIES AND PERFORMANCE

	Blue	*Red*
Wavelength range	300–500 nm	420–1100 nm
Resolution-slit product	40,000	40,000
Max. resolution	90,000	120,000
Detection efficiency	9% at 400 nm	10% at 600 nm
Limiting magnitude (3 h. exp. time, S/N = 10)	18 (R = 50,000) in U	20 (R = 45,000) 18.5 (R = 90,000 in V
Camera	dioptric F/1.8, 70 μm/″ field 43.5 mm diam.	dioptric F/2.5, 97 μm/″ field 87 mm diam.
Baseline CCD and pixel scale	2048 × 2048, 15 μm pixels (.215 ″/pix)	4096 × 2048 15 μm pixels, 2 × 1 mosaic (.155″/pix)
Echelle	41.59 g/mm, R4 mosaic	31.6 g/mm, R4 mosaic
Crossdispersers	CD1: 1200 g/mm, λ_b 380 nm CD2: 600 g/mm, λ_b 380 nm	CD3: 600 g/mm, λ_b 550 nm CD4: 316 g/mm λ_b 750 nm
λλ/frame (typ)	700 A in 20 orders	1000 A in 18 orders
Order separation (typ.)	> 15″ ↔ 70 pixels	> 15″ ↔ 100 pixels

detailed design phase. The Critical Design Review is planned for November 1995. Detailed status is as follows:

Gratings and Optics – In view of the new technology involved, a contract for the large (84×21 cm) echelles was placed already in December 1993 with Milton Roy (USA). They are monolithic mosaics: replicas on a single substrate of a 2 × 1 mosaic of submasters. The red echelle has recently been completed and is awaiting acceptance test. Manufacturer's preliminary test results indicate that this is one of the best gratings ever made (Table 3). Further testing, including the support system, is planned at ESO. The blue echelle mosaic will be delivered in 1996.

Offers from industry for detail design and manufacturing of cameras and preslit optics according to the ESO predesigns have been received; contract negotiations are in preparation. Deliveries are expected in 1996 (preslit optics) and 1997 (cameras).

Mechanics – Prototype drive units have been produced and tested. A first batch of 9 motorised functions (slides, filter wheels) has been delivered and electromechanically tested. Slit, derotator and crossdisperser units are in detail design and/or manufacturing. By the end of 1996, most fine mechanical and/or motorised units will have been delivered.

The detailed design of the table and support structures is almost complete. The earlier concept of the enclosure is being compared with a simpler concept with possibly lower cost and better thermal and light rejection performance. Also the handling tools are under review. A full-scale wooden model of UVES has been made to develop handling concepts, study cabling routing, etc.

Electronics and software – The first batch of UVES functions is under test. Electrical design for components that were added in the UVES upgrade (e.g. exposure meter) is in progress. An updated Electronic Design Report, addressing the new overall system architecture including the Scientific CCDs is planned for the 2nd quarter of 1995.

Various software specifications that between them address all aspects of operating UVES and reducing data obtained with it have been released. (*Software Requirements, Software Functional Specifications, Data Reduction Software Requirements*). A draft user's manual and a prototype Graphical User Interface are planned to be produced this year.

Detector systems – The parameters of the UVES cameras are matched to 2048^2, 15 μm pixel size chips (blue: single chip; red: mosaic up to 4096^2). The CCD detector systems for UVES are being developed by the newly created detector group within the Instrumentation Division.

ESO has placed a contract for the development of thin, 2K × 2K, 15 μm buttable CCDs with Thomson CSF in 1992. Recent negotiations with Thomson led to agreement on delivery within 1995 and a minumum QE of 75% at 600 nm (previously 60%). These devices would be well suited to the red arm. Another contract with the University of Arizona (Lesser) is in place that covers the need for a UV-blue sensitive 2K chip needed for the blue arm; several devices were recently supplied by this source with a QE of over 70% in the UV. ESO is closely following developments at SITe, MIT/LL and EEV; all potential sources of 2K × 2K or 2K × 4K chips with 13.5 or 15 μm pixel size.

The prototype ESO CCD Array Control Electronics (ACE) intended for use with FORS and UVES has been successfully tested at the NTT in early 1995. A prototype continuous-flow cryostat has been built and tested in the CCD detector laboratory and field experience with this system – containing one of the Lesser chips – is being obtained at the CES in La Silla.

Schedule

Important milestones for 1995 are the delivery of the red echelle and Thomson CCDs, placing of the optics contract and the Critical Design Review at the end of the year. 1996 and 1997 will be devoted to completion of hardware, software coding and lower-level testing. Extensive system testing, including calibration and data reduction procedures (using the Sun) will take place in 1998. Commissioning as instrument 1 on UT2 is planned to commence in July 1999.

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TABLE 3. PRELIMINARY MEASUREMENT RESULTS OF UVES RED ECHELLE (31.6 g/mm)

Spectral resolution	3.0 mÅ at 632.8 nm R = 2,100,000
Angular resolution in the direction of the slit	better than .1 arcsec on the sky
Blaze angle	75.07°
Ghosts	< .008%
Absolute blaze efficiency (including dead space)	72.4% at 550 nm

Result of The Phase A Study for the VLT Mid-Infrared Instrument: VISIR

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In March 1993, a contract for a Phase A study concerning the mid-IR instrument to be mounted on the VLT unit 2 (Refs. [4] and [5]) was signed between ESO and DAPNIA/CE Saclay, with as partners SRON at Groningen and the Kapteyn Observatory at Roden. The study is now finished and the main conclusions are outlined here[1]. Various observing modes are foreseen both in the N and Q atmospheric windows (10 and 20 μm):

- imaging over a field up to about 1 arcmin with various magnifications (< 0.08 arcsec per pixel to 0.3 arcsec per pixel),
- long (> 30 arcsec)-slit spectroscopy with various spectral resolutions (350, 2500, 25,000 at 10 μm and 1250, 12,500 at 20 μm),
- limited polarimetry.

The instrument will be an excellent tool for ISO follow-up studies. Even if its sensitivity will not compete with ISO, except for the high spectral resolution mode, its high angular resolution (diffraction limited) will make it very attractive.

1. Scientific Needs

Designing an instrument is not an easy task because many parameters (sometimes not completely rational!) have to be taken into consideration and trade off has to be made between scientific desiderata, technical and operational constraints, cost limitation, etc.

The easiest part is to get the scientific desiderata. If a large enough community is consulted, the answer is simple: *all*. More seriously, general tendencies of the observing programmes and associated observing modes can be cleared up[2].

First, we recall that the use of a mid-IR instrument on a large telescope will lead to a dramatic improvement in sensitivity. Indeed, the size difference between the VLT and a 3.6-m telescope leads immediately to an increase in sensitivity by a factor 5 for point source observations; this means that the same signal-to-noise ratio can be reached 25 times faster. When taking into account improvements in detector performances, telescope emissivity and image quality, "dome" seeing, etc., we can expect a gain in sensitivity by a factor 50 compared to the actual TIMMI sensitivity (Refs. [2] and [3]). Although the VLT mid-IR instrument will be much more sensitive than IRAS (band 1 and 2), it will not compete with the instruments on board the cryogenic cooled Infrared Space Observatory (ISO), except for the high spectral resolution mode. However, ground-based mid-IR instruments on a large telescope allows for a diffraction-limited angular resolution of 0.3 arcsec at 10 μm (1.22 λ/D), inaccessible with the small ISO telescope (60 cm). Thus, ground-based and space observations are complementary and we can foresee a lot of ISO follow-up observations. *This perspective leads us to stress the need for such an instrument soon after ISO.*

To be more explicit on the observing modes, we now discuss two types of observations: observations of dust and gas.

1.1 Dust Studies

The two mid-IR atmospheric windows are key domains to study relatively "warm" dust (400 K – 140 K). Indeed, a black body at 400 K has its peak of thermal emission at 7.5 μm (the beginning of the 10 μm atmospheric window), while a black body at 140 K has its emission peak at 28 μm (about the end of the 20 μm atmospheric window). Dust as cold as 50 K should still be detectable at 20 μm. The warm dust is an important component of the Universe, as shown by the IRAS satellite. The study of this dust is related to actual astrophysical problems dealing with star formation, planet formation, stellar evolution, AGN unified scheme, etc. and concerns various astronomical objects ranging from comets to quasars.

The observing modes related to these programmes are:

- diffraction-limited imaging both at 10 and 20 μm to locate the dust, measure its temperature,
- low spectral resolution (R = λ/δλ = 400) to constrain the composition of the grains (for example looking for the silicate dust features at 10 and 18 μm).
- polarisation to learn about grain size.

1.2 Gas Studies

A wealth of information about the gaseous component in a large number of various objects can also be provided by

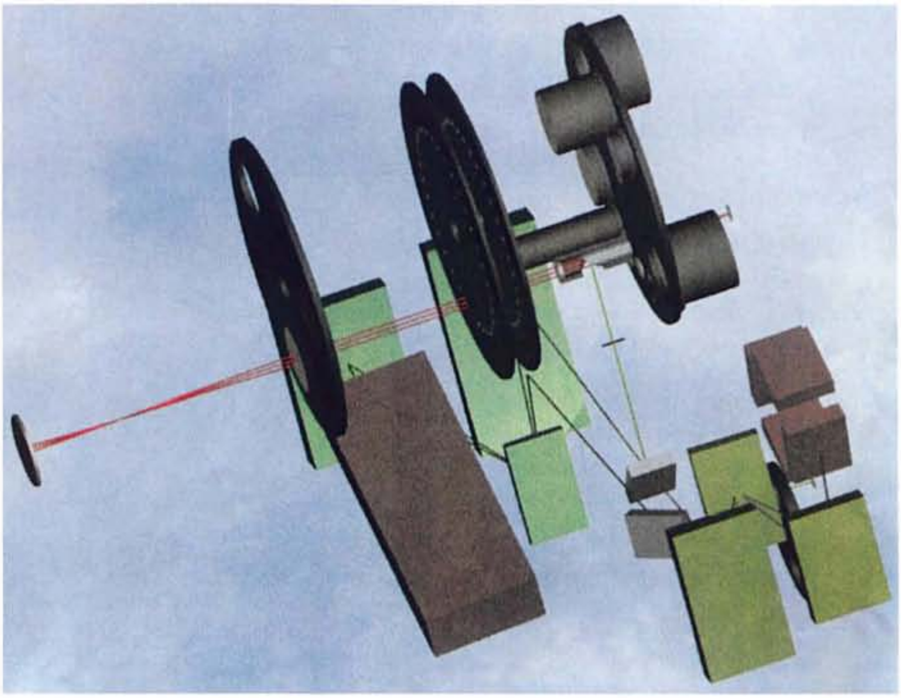

Figure 1: *Optical layout of VISIR.*

[1]The complete report is available upon request at LAGAGE@sapvxa.Saclay.cea.fr.

[2]Specific programmes can be found in the Phase A report, in the proceedings of the French meeting "L'exploitation astrophysique des fenêtres 10 et 20 μm avec le VLT", October 1993, D. Alloin and P.O. Lagage Eds., and in the proceedings of the ESO workshop about "Science with the VLT", June 1994, Danziger and Walsh Eds.

observations in the thermal infrared. Indeed, many molecular, atomic and ionic spectral lines are present in this wavelength range. Of special interest are several key interstellar and circumstellar symmetrical molecules (H_2, CH_4, CO_2, etc.) which have to be detected through observations of the (vibration-)rotation lines in the infrared. The linewidth varies from a few km/s in stars to a few hundreds of km/s in active galaxies.

Several spectral resolutions ranging from a few thousands to about 100,000 are needed to cover the various cases. Here again, observations both at 10 and 20 μm are interesting. For example, from the ratio of the H_2 lines intensity at 12 and 17 μm, the gas temperature can be derived. We have set two regimes, one for medium-resolution (2500 at 10 μm) and one for high spectral resolution, limited to 25,000 (at 10 μm) to avoid technical configurations which appear too risky.

2. Instrument Design

The optical arrangement of VISIR, an instrument which fulfills the previous scientific requirements, is shown in Figure 1. VISIR stands for **V**LT **I**mager **S**pectrograph in the **IR**. It is made of two sub-units: an imager and a spectrograph. The spectrograph has two arms, one for the low and medium spectral resolution, the other for the high spectral resolution. The whole optical bench is enclosed in a cryogenic/vacuum vessel to prevent internal background; (a black body at room temperature has its peak emission at . . . 10 μm). The vessel is a cylinder, 1.1 m long and 1.7 m in diameter. The total instrument weight is 1.5 tons. Closed-cycle coolers are foreseen to maintain the optical bench at the required temperature: 45 K for most of it and 15 K for the parts near the detector. The detector itself has to be cooled down to about 5 K (to prevent dark current). The same array will cover both the N and Q bands. The detector array used for the imager and the spectrograph will be different in order to be adapted to the quite different background flux received when observing in broad-band or at high spectral resolution.

2.1 Imager

The imager design is classical and based on lenses, in order to easily implement various magnifications. Indeed, given the state of the art in detector complexity (256 × 256), it is not possible to have both a large field and over-sampling of the diffraction pattern, while one or the other is required according to the programmes. For example, programmes aiming at detecting faint extensions around stars will prefer over-sampling of the airy pattern (PFoV < 0.1

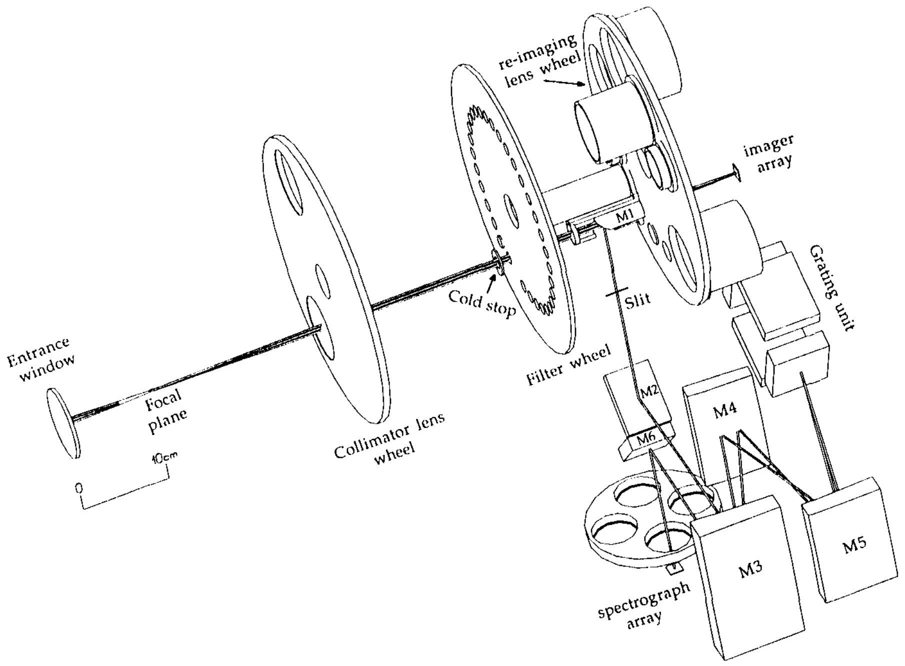

Figure 2: *Optical arrangement of the camera and the low and medium spectral resolution modes. In the imaging mode, the light goes first through a collimator lens which images the telescope secondary mirror onto a cold pupil stop. After passing the filter, the light is re-imaged on the detector array with various magnifications, thanks to one of the lenses of the second lens wheel. This wheel also holds a lens followed by a folding mirror to image the focal plane onto the slit unit with a magnification of 0.8. After the slit, a folding mirror, M2, selects one of the two spectrograph arms. Then the light enters a 3-mirror collimator of the ISAAC type, which produces a collimated beam of 55 mm on the selected grating. The selection and scan of the gratings are based on the mechanisms made for the ISO/SWS instrument. After reflection/dispersion on the gratings the light goes back throughout the 3 mirrors, which are now used to image the spectrum on the array, via the folding mirror M6. The magnification of the system is 1. (Note that in Figure 1, M6 has been inclined differently so that the spectrograph detector is near the imager detector for cryogenics reasons; a filter wheel cooled at 15 K has been included in front of the spectrograph array to limit the internal photon background emitted by the spectrograph optics cooled at 45 K.)*

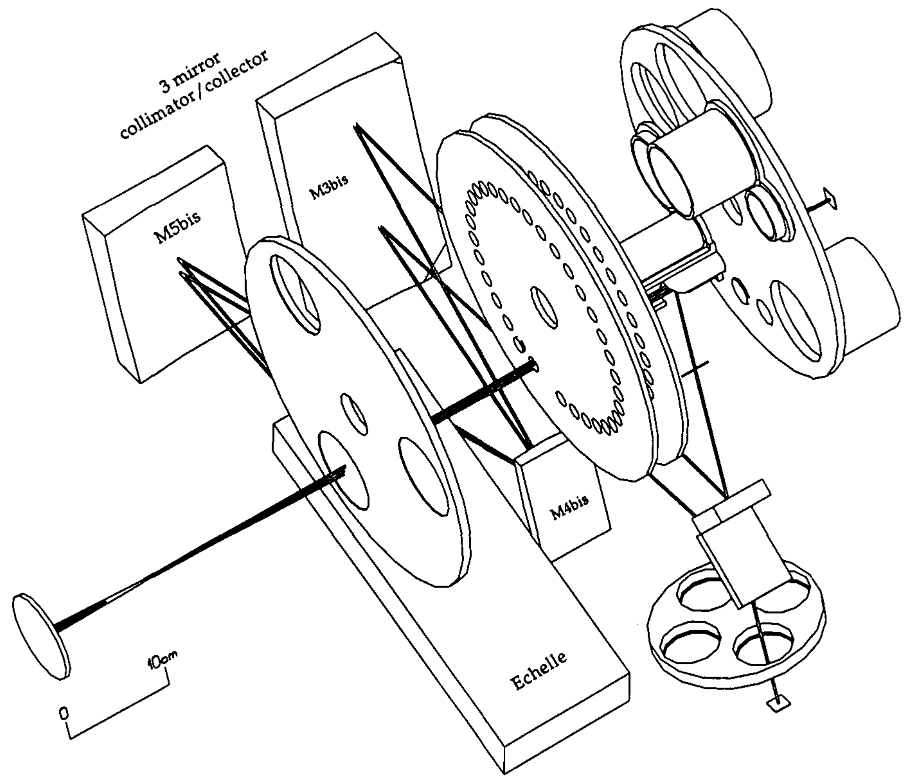

Figure 3: *Optical arrangement in the high-resolution mode. The beam goes through the imager as in the low and medium spectroscopic mode. The folding mirror M2 has been flipped by 90 degrees to deviate the light into the high spectral resolution arm, also made of a 3-mirror collimator/collector of the ISAAC type; the collimator beam is now 110 mm. The grating unit is made of two nearly similar echelles, mounted back to back. A second filter wheel has been included in the imager to sort out the various orders. The mirror M6 has also been flipped by 90 degrees to send the spectrum on the same detector array as in the low and medium spectroscopic modes.*

arcsec at 10 μm), even if the field will be limited to less than 25 arcsec. On the other hand, observations of objects quite extended or survey-type observations will require a larger field. With a simple two lenses design (see Fig. 2), it was possible to implement a field up to 80 arcsec with diffraction-limited optical quality.

In our two-lenses design, the first lens images the pupil of the secondary mirror of the telescope on a cold stop to prevent extra external background (as usual in ground-based IR instruments). The lens also acts as a collimator, so that the filter wheel located near the cold stop is in a parallel beam. Such a configuration relaxes the tolerances on the spatial homogeneity of the filters and leads to a focalisation which is independent on the filter whatever its thickness is. But the drawback of this configuration is a slight change in the wavelength transmission of the filter according to the position in the field (different angle of incidence on the filter). To avoid prohibitive shifts in wavelength for narrow-band filters (R = 50), the cold stop has been fixed to 15 mm. There is actually no good optical material that covers both the N and Q bands. We will use Germanium for 10 μm and CdTe for 20 μm; the two collimators will be mounted on a wheel. A second wheel will hold the lenses which re-images the focal plane onto the detector with various magnifications (0.08 arcsec, 0.16 arcsec, 0.3 arcsec). The antireflective coatings on the optical materials considered are very good (a few per cent of reflection), so that the efficiency of the optics will mainly be determined by the filter transmission. By an appropriate design, the ghosts resulting from light reflection on the lenses can be made negligible.

Limited polarimetry capability will be provided by 3 analysers in the filter wheel.

Several firms (LETI/LIR in France and now Rockwell and SBRC in the US) have developed detectors optimised for broad-band observations from the ground. In these detectors, the storage capacity of a pixel has been pushed to its maximum (> 3 10^7 electrons) in order to "absorb" the huge photon background generated by the telescope and the atmosphere (1500 Jy/arcsec^2), without being saturated.

2.2 Spectrograph

The design of the spectrograph and especially its high-resolution mode was the subject of many debates. To the 3 optical pre-designs internally made at ESO (Ref. [1] and references therein), we added a couple of alternative designs. Hereafter, we will only describe the final one (we should say the last one). The slit option with gratings was eventually found to be on the safer side.

When working at 10 μm, we are in a world where diffraction is around. To avoid diffraction at the slit, we have considered a 2 λ F-ratio entrance slit. Even with such a slit width, the optical elements of the spectrograph have to be oversized to avoid diffraction losses. It is also better to have the cold pupil stop in front of the slit because, behind it, the pupil is fuzzy. In Figure 1, the cold stop of the imager is also used for the spectrograph. In a previous design, a separate cold stop/re-imaging unit based on two off-axis paraboloids and two folding mirrors was considered. Both options are open. Note that the use of a re-imaging unit in front of the spectrograph has additional advantages; it provides the possibility to move the spectrograph entrance slit to a more convenient location; it allows to reduce the F-ratio (from 13.6 to 11) to keep the spectrograph dimensions within limits; it allows to inject the parallel beam of the internal (wavelength) calibration source, which will be quite similar to the source used for the ISO/SWS instrument.

The spectrograph is based on the 3-mirror collimator/collector design developed by ESO for the ISAAC instrument, one of the near IR instruments to be mounted on the VLT unit 1 (Moorwood et al., 1993). The light entering the slit goes through the three mirrors, which produce a collimated beam on the gratings; once diffracted/reflected by the gratings, the beam goes back through the 3 mirrors which now act as a collector to image the spectrum. The 3-mirror ISAAC collimator/collector has many advantages in terms of compactness, optical quality, straylight rejection, grating efficiency (grating in Littrow configuration), which overcomes the relatively large number of mirror reflections.

The compactness of the three-mirror ISAAC collimator led us to consider two arms for the spectrograph, one for the low and medium resolution with a collimator beam of 55 mm, and the other for the high resolution with a collimator beam of 110 mm (see Figs. 2 and 3). Four gratings are planned for the low- and medium-resolution modes; for efficiency reasons, two gratings are needed for a band (Q or N); but the same gratings are used for the Q and N sub-bands (1st order for Q, 2nd order for N). The high-resolution mode is also based on gratings, but used at high orders (echelle mode). Again for efficiency reasons, we plan to use the "duo-echelle" concept: two nearly similar echelles, mounted back to back, where the orders of one fit between the orders of the other echelle. It is worth mentioning the size of the gratings: 35 cm! The efficiency of the optics (including order sorting filters) should be around 40% for the low and medium spectral resolution and 30% for the high spectral resolution.

The detector array used for the spectrograph will be optimised for low background conditions. Indeed the flux received by the spectrograph can be up to 10^5 fainter than in the imager. It is more in the range of the flux received when imaging from space, and detector arrays have been optimised for these conditions. The pixel pitch of these detectors range from 30 to 50 μm. In the spectrum focal plane, 50 μm represent 0.115 arcsec on the sky, which samples correctly the airy pattern at 10 μm. To avoid additional complexity, we have not considered, at the present stage, a re-imaging system after the spectrograph. Note that the good image quality of the ISAAC 3 mirror system allows for the implementation of a detector up to 1024 × 1024 pixels.

The mechanical tolerances on the spectrograph are quite tight for a cryogenic cooled instrument. A finite-element mechanical study was made for the previous optical design studied in detail. The tolerances on the present design are tighter by a factor 3; (for example, the tilt between the 3-mirror collimator and the detector should vary by less than 1 arcsec when moving the telescope). We are in the range of the ISAAC tolerances, but we are not at the same focus (Cassegrain instead of Nasmyth), so that we have to wait for very detailed finite element calculations to fully address the mechanical question.

3. Sensitivity

The goal is to achieve the theoretical expectations based on background noise limited performances and a telescope emissivity of 10%. The sensitivity of the imager in broad-band observations of point sources should tend towards 1 mJy 10 σ 1 hour at 10 μm (or magnitude 11.5) and 10 mJy 10 σ 1 hour for the Q band. The theoretical sensitivity of the spectrograph is given in Table 1:

The high spectral resolution is driving the specifications in many domains: detector noise, internal background,

TABLE 1. SPECTROGRAPH SENSITIVITY (Signal/noise in 1000 s for a 1 Jy point source)

Mode	N band	Q band
High resolution	14	3
Medium resolution	24	5
Low resolution	80	18

mechanical tolerances, . . . The performances of this mode are the most difficult to achieve.

4. Perspectives

VISIR is an ambitious instrument which will require a total work of 100 man years with some hard time.

Rendez-vous in five years to report on the first telescope tests of VISIR, . . . hopefully.

Acknowledgements: We wish to thank the various colleagues who have contributed to the phase A study, either technically or scientifically and which are too numerous to be quoted here. We also would like to thank the ESO staff and especially A. Moorwood, B. Delabre, H. Käufl, J.-L. Lizon à l'Allemand for their valuable comments all along the study.

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NTT BITS & PIXELS

With this periodically compiled collection of short notes, the NTT Team intends to keep the community informed about changes in performance, configuration, and operation of the NTT and its subsystems.

First NTT Team Member To Leave

The first departure of members from their group often marks the transition to a new phase. This is also true for the NTT Team which started to come into existence about one year and a half ago. Since then, a fair number of improvements could be reported, and the operation of the NTT has stabilised considerably. Thanks to his astronomical expertise, Edmond Giraud has had his share in this progress. When Edmond heard about the NTT Upgrade Plan (*The Messenger* 75, 1), he spontaneously offered to spend a year on leave of absence with the NTT Team at La Silla. (Our colleague Miguel Albrecht has suggested the handy acronym "NTT UP" for the NTT Upgrade Plan, which henceforth we shall gladly use). That year has meanwhile become 14 months long, but now it is time for him to return to his home institute, the Observatoire de Marseille.

This is a good example of how ESO's role as a service organisation can be strengthened by the active support of the astronomical community. We thank Edmond for his willingness to help during a critical initial phase and wish him all the best.

Instrument Operators to Join the Team

On May 16 and June 1, Gabriel Martin and Roberto Aviles, respectively, will take up their duties as instrument operators. This is the first big step towards the operational part of Phase II and beyond of NTT UP which foresees that the NTT will be re-commissioned in service mode, much the same as is planned for the commissioning and operation of the VLT. Since this is a very important and complex type of work, for which there is only limited experience available, Gabriel and Roberto are joining us early in order to insure the proper commissioning of this operating mode.

An important aspect of this early start is that the training of the instrument operators will not be limited to ESO staff. Between now and the 'Big Bang' on April 1, 1996, Gabriel and Roberto will increasingly assist Visiting Astronomers in the operation of EMMI and SUSI. We hereby hope to achieve two goals: (a) The know-how transfer will also take place directly from the community to the instrument operators; (b) Visiting Astronomers can convince themselves that also in service mode their programmes will be in 'good hands'. (The scientific responsibility and supervision will always rest with an astronomer.)

We wish Roberto and Gabriel a successful start with their demanding work.

Postdoctoral Fellowship Available at La Silla

Given the proto-typical character of the NTT hard- and software and the operations model for the VLT, a few years of work with the NTT Team at La Silla should be the optimal practical and conceptual preparation for young astronomers with strong interest in observational work for the VLT era. Currently, we have an opening for a recent PhD recipient. If you are interested in a challenging job which offers an unusual diversity of experiences and research opportunities at a major observatory, consult the vacancy notice in the *Announcements* section of this issue of *The Messenger*.

Field Test of Work Component No. 5

During February 18–21, the latest test of another component of the VLT-like control software as defined in NTT UP was successfully completed. It consisted of two parts, (i) the control of the hydraulic system and (ii) the selection of video signals such as from guide probe or slit viewing cameras and their distribution to the requested local or remote destination. Apart from these specific applications, the scope of the tests also included checking the VLT LCU Common (LCC) and Central Control Software (CCS). Once again, no real problems were encountered during the installation so that most of the night time could be used for further optomechanical tests and other work with the telescope. As for all other tests of the new control system, the old control software was fully restored after completion of the tests.

R4 Grating for EMMI Now Offered

For a scaled-down prototype of the R4 grating to be used in UVES (H. Dekker and S. D'Odorico, *The Messenger* 70, p.13), the commissioning could now be completed. A year earlier, this had been made impossible by a problem with the calibration of the slit width which was noticed only after the completion of the observations so that the actual resolving power could not be assessed. This time, the nominal slit-resolving power product of 70,000 arcsec (corresponding to 2-pixel sampling with the F 5.3 camera of the red arm of EMMI, cf. Dekker et al., *The Messenger* 76, p.16) could be confirmed over the full spectral format. The combination of high spectral resolution and a wavelength coverage of 250 nm in the red and 450 nm in the 'blue' make this mode of EMMI a rather unique research tool. As of Period 56 (starting October 1, 1995), it will be offered to the community. However, in order to limit the additional operational overhead, it will be scheduled only if nights can be combined into one or more blocks of sufficient length.

Closed-Loop Operation of Active Optics System

Considerable progress has been made towards making the New Technology Telescope the optically fully active telescope as it was originally conceived. On an experimental basis, the parallel mode of the image analysis has, with much help from Lothar Noethe and additional advice from Krister Wirenstrand, been put into operation. This means that 80% of the light from the guide star is diverted to the image analyser which can thus be operated parallel to the scientific exposures. The results can be accepted by the observer during or after the exposure, with the former option currently not being advisable for direct imaging.

So far, image analyses was possible only at the centre of the field, thus excluding the simultaneous usage of the scientific instrument. As a result, even during nights of excellent seeing, most observers did not use the active optics system as often as would have been optimal. Therefore, the recent step improves both the operating efficiency and the practical optical performance of the NTT. Since the image analysis is more demanding on the brightness of the guide star than the autoguider alone, tools have also been developed to automatically select the brightest suitable guide star from a computer-resident catalogue. Miguel Albrecht will soon install this catalogue on a server at La Silla so that the problems which are now occasionally experienced with accessing this catalogue in Garching will no longer occur.

VME CCD Controllers

Visiting Astronomers Palle Möller and Steve Warren reported a strange problem which they noticed in data obtained with SUSI and CCD #25. In exposures with low light levels, the noise exceeded the value expected for Poisson statistics by up to 40%. In images with very uniform signal level, a weak chessboard-like pattern could be seen. In a remarkably quick and concerted action of the La Silla and Garching branches of the newly-formed CCD group, the problem could be traced back to cross talk involving the bus and analogue-to-digital converter of the VME controller. When the output of the A/D converter changed strongly, i.e. near powers of 2 where many bits flip, this effect was particularly noticeable. This explanation predicted that the same problem would occur also for CCD #31 in the blue arm of EMMI, since it is operated with the same type of controller. In fact, careful analysis confirmed this expectation, although to a lesser extent than in SUSI. By changing the timing of the readout and A/D conversion process the symptoms could be fully suppressed.

Image Quality Monitoring Programme and Enclosure Operations Model

We gratefully acknowledge the efforts by Wolfgang Eckert and Juan Carlos Piñeda to manufacture and install the mount for an additional CCD camera. Attached to guide probe 2 of side B (EMMI), it will be used to monitor the FWHM of the images delivered by the telescope. This approach was chosen because the image size does not come out of the image analysis nor can it be readily extracted from all scientific data, e.g., spectra. We thank Lothar Noethe and Francis Franza for their help with the procurement of the CCD camera and the optics, respectively.

In Garching, Volker Bäumer started to work on his PhD thesis which aims at establishing the link between model calculations for the wind flow in the NTT enclosure, measurements of wind speed and direction, temperatures, and the seeing. The mechanics workshop at La Silla has provided a platform for a mobile anemometer. Visiting astronomers will see it in operation mainly between the opening of the dome in the afternoon and the beginning of the observations. Logging of the data from the other wind and temperature sensors started already some time ago.

Rotator Bearings

The ball bearings of the instrument rotators in the two Nasmyth stations are operated under conditions which are very different from normal applications of such devices: the rotator bearings move continuously, but hardly ever turn through angles of 360° or more, run at very low speed and regularly change direction of motion. During the zero passages of the speed, the effects of the transition between static and dynamic friction are aggravated when, owing to the special operating conditions, the balls have settled at the bottom of the bearing. There are indications that rotating the bearing through 360° which rotates any cluster of balls from the bottom of the bearing to its top, can keep the incidences of increased friction at a low level. It should also be noted that these events have almost never affected the observations.

However, on side A (IRSPEC, SUSI), additional problems have been noticed for quite some time which are not covered by the simple model described above. In particular during beam switching for IRSPEC observations, the bearing got completely stuck a couple of times. After the electronics problems with the rotator control had been eliminated (*The Messenger* 79, p.10), this problem accounted for roughly 0.7 of the 1.8% of observing time lost because of technical failures in the first quarter of 1995.

To investigate this behaviour more thoroughly, it was decided to open the bearing (including the re-installation, this takes 3 days). Some small cracks were noticed in the bearing races. The evaluation of this finding has just started. Once the bearing was open, this opportunity was also used to replace the balls and install a different type of spacers which separate the balls. In the first week of intensive usage of SUSI after this intervention, not one overcurrent was recorded.

We thank Gerardo Ihle and the Mechanics Group for the effective support provided on relatively short notice. The above intervention was only possible because the same group had upgraded the crane to the capacity needed for the safe handling of the adapter.

The setting up of a test stand of a spare NTT bearing and motor in Garching was nearly completed. It will be used in the frame work of a research project at the Technical University in Munich to better understand the nature of the problem and to try out possible solutions. This was done by F. Franza, M. Ziebell, and B. Gustafsson. We are grateful to them for their continued support in analysing the bearing problems (and many other aspects of the NTT).

Because the altitude axis of the NTT is used in a similar fashion as the rotators, the behaviour of the altitude motors is now also being monitored.

Automatic Display of Incoming Images for Remote Observers

A few fellows and students in Garching now provide additional support to the operation of the NTT. As a first result, we can report the installation of software by Markus Kissler which, in analogy to the practice at La Silla, also in the remote control system automatically displays newly arriving images for inspection and further analysis with MIDAS. The convenience of this new feature has been appreciated not only by the NTT Team but, more importantly, also by various remote observers.

Electronic Operations Report System

The NTT Team has for quite some time been using a commercial system (*Razor*) for the tracking of technical and operational problems. Initially, the intention had been to use the same system also for the nightly operations reports by the observers. However, because of the way the system had been set up and a variety of technical problems with *Razor*, this was never implemented. Meanwhile, the technical problems could be solved, and we thank Joseph Schwarz for his constant support. A second database and form for night reports have also been prepared, and the system is now in routine operation. It serves us as an efficient and convenient source of references by means of which for instance a problem can be traced back in time and all relevant staff (plus visitors) at La Silla and in Garching can share the database.

Technical Feasibility Checks of NTT Proposals

For the first time, the NTT Team has attempted to perform technical feasibility checks of all observing proposals received for the NTT during Period 56. This was a laborious exercise. Only in a small percentage of the projects were potential problems noted; they were brought to the attention of the Observing Programmes Committee for evaluation. For us, the more important aspects were (i) to obtain an early overview of the operational requirements on us during the next period and (ii) the opportunity to assess under realistic conditions what kind of information will in future be required for observations to be carried out in service mode.

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VLT Insurance Contract Signed

At a ceremony in Paris on April 11, ESO signed an all-risk insurance policy for the VLT project with AGF, one of the leading French insurance companies. The policy was also signed by Messrs Fauchère & Jutheau, the insurance broker who has worked with ESO on this contract.

The signing ceremony, which took place at the AGF Headquarters, was preceded by a well attended press conference, featuring an interesting composition of jounalists specialising in scientific and in financial matters.

Topical Astrophysical Problems on Massive Stars for VLT Observations

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1. Introduction

According to current wisdom, luminous matter represents only about one per cent of the mass in the Universe. Among this one per cent, massive O and B stars contribute to about two thirds of the optical light of galaxies and thus play a key role in the exploration of the visible universe with the VLT. Their high luminosities make them visible at large distances, either individually or by spectral features in the integrated spectrum of galaxies. Let us note that if one assumes for the VLT a limiting magnitude $\ell \sim 28.5$ (for S/N ~ 2 in 10 hours, see Fusi Pecci et al., 1994), then 25 $M_\odot$ stars will be detected up to distances superior to ~70 Mpc, a value which shows how large the volume is where massive stars can be observed. Massive stars are the main sources of UV and ionising radiation, also they power the far-IR luminosities of galaxies through the heating of dust. Due to these properties and their short lifetimes, massive stars are conspicuous tracers of star formation at large distance in the Universe.

Massive stars so much modify the physical conditions and the dynamics of the ambient interstellar medium that they influence the process of star formation in galaxies. In addition to radiation, massive stars are also the main source of mechanical power in galaxies due to supernova explosions and to the winds of Wolf-Rayet (WR) stars, which on the whole are of comparable importance. Massive stars with $M \geq 10\ M_\odot$ are fast nuclear reactors, they are thus the main contributors to the nucleosynthesis of heavy elements and also play a leading role in the chemical evolution of galaxies. Thanks to its high imaging and spectroscopic capacities, the VLT will allow us to observe massive stars and their effects in new distant environments, like early evolution of galaxies, starbursts, galactic nuclei and star formation processes around quasars.

A major change has occurred in our understanding of massive star evolution in the last 10 years. The point is that these stars nearly fully evaporate during their evolution. As an example, an initial 60 $M_\odot$ star of solar composition will only host about 5 $M_\odot$ at the time of supernova explosion (cf. Maeder and Conti, 1994). This evaporation is due to the stellar winds in the various phases, OB stars, supergiants and WR stars. Such low final masses are well supported by the WR luminosities and by the study of WR masses, and they have major consequences for all stellar properties: lifetimes, luminosities, evolutionary links, wind compositions, chemical evolution, supernova progenitors and the nature of final remnants.

2. A Remarkable Case: The Populations of Massive Stars in Starbursts

Starbursts are giant events of star formation in galaxies, they may involve regions with masses as large as 10^5 the Orion Nebula (cf. Kennicutt, 1984; Leitherer, 1991). Classic H II regions like the Orion Nebula contain only a few ionising stars and have a total mass of several tens of solar masses, while giant H II regions, like 30 Dor, have about 300 to 400 ionising O stars and a total mass of about $6\ 10^5\ M_\odot$. They are even dwarfed by starburst galaxies, like M82, Arp 220, NGC 6240, NGC 7714 where the total mass involved in the burst is a few $10^8\ M_\odot$. The luminosity associated to starbursts, like in M82, is as large as $7\ 10^{10} L_\odot$ (cf. Rieke 1991). Such a value leads to important "evolutionary corrections" on the luminosity of distant galaxies and we need to correctly appreciate the frequencies and intensities of the starburst phenomena, especially at large redshifts, through the Universe both for cosmological reasons and for the study of the early evolution of galaxies.

Fortunately, there are several observable signatures of starbursts: the UV light, the nebular lines, the Hα emission, the He II 4686 emission line, the far-IR emission, the CO line, etc. Even when a galaxy cannot be resolved into stars, it is possible to learn about several properties of massive star populations (cf. Kunth and Sargent 1981; Arnault et al. 1989; Vacca and Conti 1992). Indeed, the flux of the Hα or Hβ lines in the integrated spectrum of a starburst provides an estimate of the total number N_{Lyc} of Lyman continuum photons, and N_{Lyc} indicates the number of present O stars. Typically, an O7V star provides 10^{49} Lyman photons per second. Refinements of this figure according to metallicity, upper mass limit and initial mass function (IMF) slope are feasible. The number of WR stars, when present, can also be inferred from the integrated spectrum; the broad emission line He II 4686 of WR stars remains visible with an equivalent width of a few Å despite the large dilution effect by billions of other stars. In particular, the ratio of the late WN stars (WNL) to the number of O stars is measured by the ratio of He II 4686/Hβ. Even further, the ratio of WN to WC stars (i.e. of those stars exhibiting products of CNO burning to those with products of He burning) can be estimated from the ratio of the He II 4686 to CIII/IV 4650 lines. A test of this method has been performed by Vacca (1991) using 30 Dor in the LMC. The number of O stars in a field of $7' \times 7'$ centred on R136 was found to be about 400 (cf. Parker and Garmany 1993). The analysis of the spectral lines in an integrated trailed spectrophotometric exposure of about the same area led to an estimate of some 330 O stars, a result which inspires a certain confidence in this procedure (cf. Vacca and Conti, 1992).

Such line ratios, which give in turn ratios of star numbers, are extremely informative on the properties of starbursts, like the star formation rate (SFR), the age and duration of the starbursts, the IMF and the metallicity Z. Generally, a higher Z leads to higher mass-loss rates for OB stars and supergiants, since there are more spectral lines and thus more momentum transferred by radiation. These higher mass-loss rates generally lead to larger numbers of WR stars at higher metallicities (cf. Maeder and Meynet, 1994). The critical line ratios will be observable in distant galaxies with the VLT, they will provide very useful information on the process of star formation through the history of the Universe. Also, we may hope that further spectral features containing information on other kinds of luminous stars like AGB stars, red supergiants, LBV, etc. will become accessible with VLT observations. All these features should be intensively searched for and studied, and the infrared spectra from the VLT might be particularly useful for this purpose.

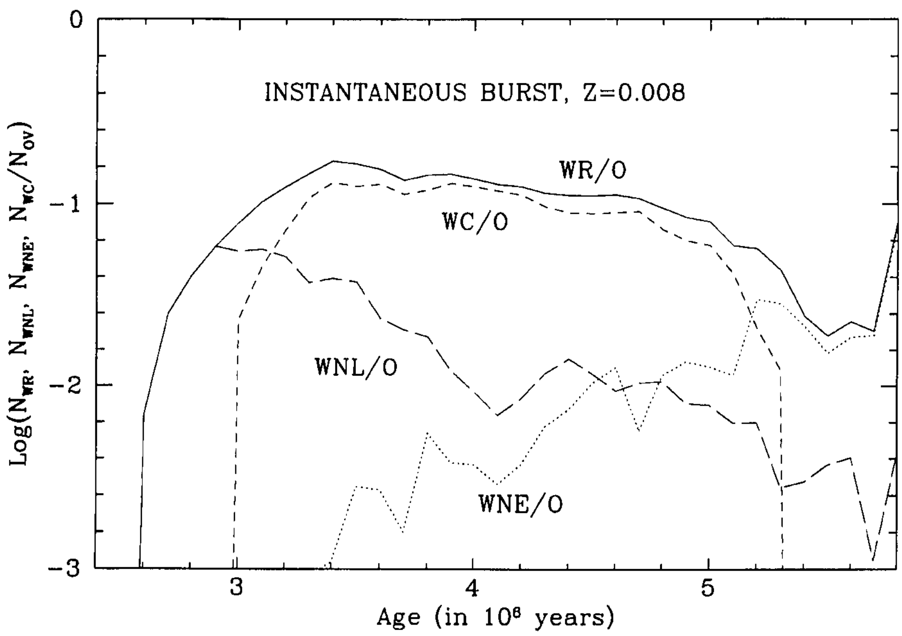

Figure 1: Evolution as a function of time of the number of WR, WNL (late WN), WNE (early WN) and WC stars divided by the number of O-type stars in the case of an instantaneous burst occurring at time t = 0. The stellar models used are those of Meynet et al. (1994) for Z = 0.008. The IMF used is $dN/dM \propto M^{-2}$.}

3. SFR, IMF, Age, Duration and Metallicity in Starbursts

One big hope for future observations of massive stars with the VLT is to disentangle the various parameters characterising the starbursts. As a first example let us examine the didactical, but not unrealistic case of an instantaneous starburst. According to recent models (cf. Maeder and Conti, 1994; Meynet, 1995) we may distinguish four different epochs in the initial evolution of a starburst (see also Fig. 1)

1. *O phase:* for an age $t \leq 2$ Myr, only O stars are present, giving rise to H II regions without WR features.
2. *WNL phase:* from t = 2 to 3 Myr, a large number of WNL stars are present.
3. *WN and WC phase:* from t = 3 to 7 Myr, the various subtypes of WR stars (WNL, WNE, WC) coexist with fractions depending on mass loss and metallicity Z.
4. *Late O phase:* for $t \geq 7$ Myr, WR stars have disappeared, but up to 10 Myr there are still O stars. They produce H II regions with nebular emission lines, but the equivalent width of the Hβ line for example should be much smaller than for the early O phase.

It has to be noted that the ratio WNL/O is much larger in a starburst (up to 6 times for solar Z) than in the case of constant SFR (see also Fig. 2), where there is always an equilibrium between stars entring and leaving the WR stage. Surprisingly also, if an observed H II region consists of a burst plus a region of lower but constant SFR, we shall observe over the 2 Myr after the burst a much lower WR/O ratio than in the case of constant SFR, since at this time the WR stars from the burst have not yet appeared. From the information provided by the WNL/O and WN/WC ratios we can make an estimate of the age of the burst and put some bounds on its duration in a given area. These number ratios are also sensitive to the slope of the IMF for a given metallicity Z.

An interesting application, which should be extended in future to more distant galaxies, is that of H II or WR galaxies (cf. Kunth and Sargent, 1983; Conti, 1991a); these are emission-line galaxies which show a broad emission feature at He II 4686. This line is also often shown by AGN's, but in WR galaxies the nebular lines are narrow, as caused by stellar ionising radiation in giant H II regions. Some of these WR galaxies show signs of collisions, mergers, jets, some are double, one is an IRAS galaxy. These H II or WR galaxies generally show, as derived from the line ratios, large excesses of WR stars with respect to O stars; Figure 2 shows the model predictions by Maeder and Meynet (1994) and Meynet (1995) compared to the observations by Vacca and Conti (1992); see also Maeder and Conti (1994). Burst models with two different IMF slopes are shown, where the IMF is defined by dN/dM = AM ($^{\Gamma-1}$). Figure 2 shows that the observed WNL/O ratios in these starburst galaxies are above the predictions for constant SFR and in nice agreement with burst models. The uncertainties are for now probably too large to enable us to infer Γ values for starburst regions. In this context it might be worth recalling that comparisons of clusters in the SMC, LMC and the Galaxy show no systematic change of G with metallicity Z, but the possibility that G is influenced by the intensity of the SFR is not unlikely (cf. also Scalo, 1989).

These examples illustrate the high potentialities of future spectroscopic studies on massive stars with the VLT. But further information could also be obtained from other lines, for example the Si IV and C IV UV lines in O stars (cf. Leitherer and Lamers, 1991; Mas-Hesse and Kunth, 1991) or from far-IR emission by the dust in H II regions. HST observations at λ 2200 of the WR galaxy He 2–10 by Conti (1994) reveal knots of intense star formation. The application of the method mentioned above for estimating the mass and age of the knots has led these authors to the fascinating result that one is just observing globular clusters at birth in this galaxy, since these knots have a mass of a few 10^5 $M_{\odot}$ and ages certainly below 10^7 years.

A prerequisite before interpreting any observation of massive stars in distant galaxies is that the models well apply to the Milky Way and to nearby galaxies. It is well known that large differences in massive star populations exist which can be interpreted by means of stellar models (cf. Maeder and Meynet, 1994). For example, the number ratios WR/O and WC/WN differ by factors 10 and 20 respectively between the SMC and inner regions of the Milky Way or of M31. Comparisons have shown that these large differences could be accounted for by metallicity effects which enhance the mass-loss rates and in turn influence stellar evolution.

4. SN-Dominated Galaxies and Nucleosynthesis

An interesting result of starburst models to be explored is that there should be a phase dominated by supernova (SN) explosions in the subsequent life of a starburst. A rule of thumb (cf. Meynet, 1995) is that one should have about one SN per century for the birth of 13,500 O-type stars. Applying this to the powerful starbust galaxy NGC 1614 in the list of Vacca and Conti (1992) one could expect about 12 SN per century. In the extreme case of the IRAS galaxy 01003–2238 (Armus et al., 1989) one would have about 45 SN per century. Do we observe such "SN galaxies" in a consistent way with existing starbursts? If not, why? If yes, the effects of such extreme situations on the interstellar medium and on the chemical enrichment of galaxies are fascinating topics about which almost nothing is known at the present time.

The chemical evolution due to starbursts is also an unexplored subject.

High-resolution spectroscopy from the VLT could bring a lot of new information. The key effect in the interpretation of past chemical abundances rests on the fact that massive stars have short lifetimes. In the early phases of galactic evolution, only massive stars contribute to the chemical enrichment due to their short lifetimes. As time goes by, smaller stellar masses come into the game: firstly, only SNII contribute to the chemical enrichment (mainly in O, Ne–Ca elements and r-process elements), then appears the production of the intermediate-mass stars (with mainly C, N and s-process elements); they are followed by the contributions from supernovae SNIa (mainly Fe injection). Thus the ages at which stars of a given mass release their nucleosynthetic production are generally considered as the major effect regarding the changes of stellar yields as a function of time (cf. Matteucci, 1991). One should, however, also take into account the fact that the chemical yields are changing with initial Z and may this way influence the picture of chemical evolution of galaxies (Maeder, 1992). A schematic sketch of the various interplays intervening in galactic evolution is given in Figure 3.

In the case of a starburst the chemical contribution of the burst is only that of massive stars above some limit which depends on the age of the starburst. These yields are thus different from the average yields, especially if starbursts have a top-heavy IMF.

It is interesting to note that the study of the chemical evolution of starbursts may also have some relevance to understanding some of the abundance ratios observed in QSO's and AGN's. Prominent lines of OVI, NV and CIV are seen in QSO's with redshifts as high as $z \simeq 5$ (cf. Schneider et al., 1991). Analyses of a large sample of QSO's (cf. Haman and Ferland, 1992) suggest a sizeable overabundance of N, implying metallicities of the order of or larger than the solar value. If this is true, we need a fast initial chemical enrichment and a vigorous star formation in order to account for these metallicities.

In conclusion we may say that whatever the central engine of QSO's may be, a major challenge for future VLT observations will be a better understanding of the nature and properties of the stellar populations responsible for the heavy elements in QSO's.

As already mentioned above, the understanding of these remote regions of the Universe requires a thorough study of the massive star populations in the Milky Way and in the galaxies of the Local Group. Many questions related to the massive star evolution remain to be solved, and in the last sections of this paper we shall discuss a few points related to stellar physics to which observations with the VLT could make substantial contributions.

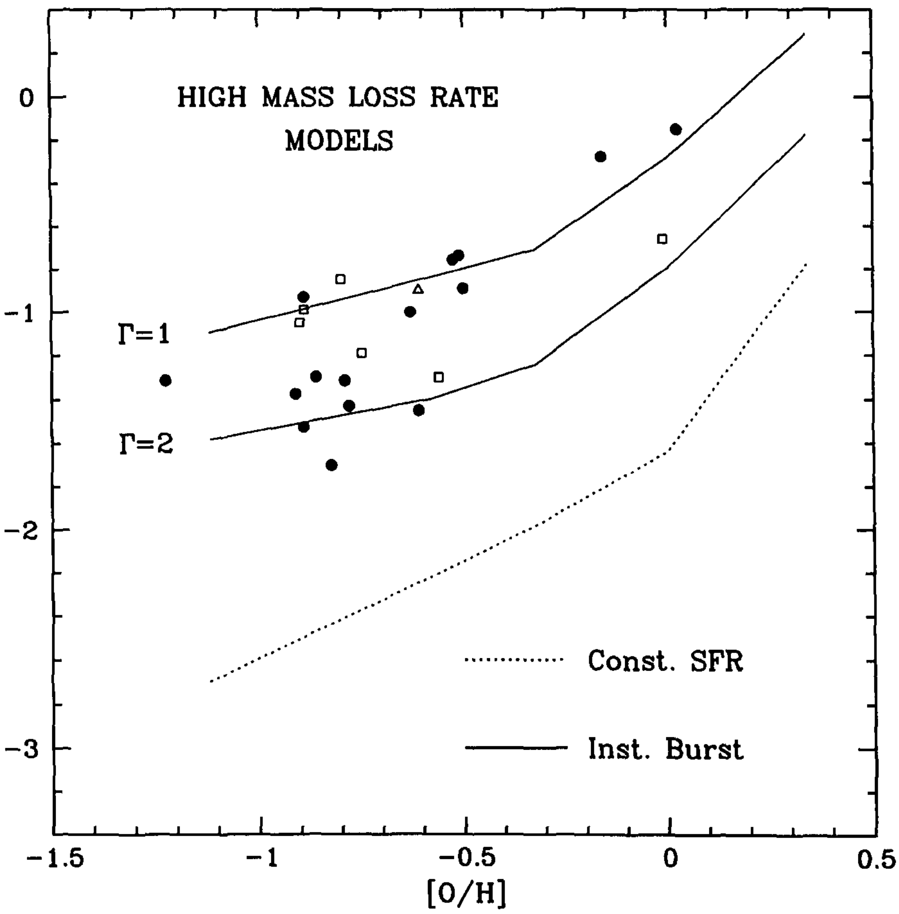

Figure 2: Relative number of WNL to O-type stars as a function of the relative abundance of oxygen expressed in terms of [O/H]. Filled circles are observed values as given by Vacca and Conti (1992). The open triangle represents 30 Doradus (from Vacca 1991) and open boxes are observations from Vacca as reported by Conti (1994). The dotted line presents theoretical values obtained in the case of a constant star formation rate with an IMF, $dN/dM \propto M^{\Gamma-1}$, with $\Gamma = -2$. The continuous lines are the predictions for an instantaneous burst with $\Gamma = -2$ and $\Gamma = -1$ (see Maeder and Conti, 1994; Meynet, 1995). Salpeter's value is $\Gamma = -1.35$.

5. Massive Star Formation

According to Churchwell (1991), the formation process of massive O and B stars are very poorly understood. Theoretical models (Stahler, 1983; Palla and Stahler, 1992) show that accretion of matter during the pre-main-sequence phase plays a major role in determining both the evolutionary track followed during the formation process as well as the position and the structure of the star when it becomes optically visible. The apparent lack of stars more massive than about 40 $M_{\odot}$ in the vicinity of the theoretical ZAMS (Garmany et al., 1982; Massey et al., 1994) might be related to the fact that massive stars spend their entire pre-main-sequence lifetime and even probably the beginning of their H-burning phase, still enshrouded in the dusty molecular clouds out of which they formed.

The infrared facilities offered by the VLT will be of great help to reveal the structure of massive star nurseries. As an example, CO band absorption spectroscopy at 2.3 and 4.6 μm offers a powerful method of searching for conclusive evidences of gas infall in star forming clouds. The determination of temperature and luminosity function of young objects using multiband infrared imaging photometry will provide data to be compared with pre-MS stellar evolutionary tracks. The large VLT aperture will provide unprecedented high-resolution data. Its expected infrared resolution, with adaptative optics, of 0.06″ at 2 μm corresponds to 9 AU at the distance of the closest star-forming regions, i.e. Ophiucus Taurus. In view of these performances, the VLT will certainly reveal itself a powerful tool to investigate this still poorly known stage of massive star evolution.

6. Massive Stars in the Hertzsprung-Russel Diagram

The most recent HR diagrams for supergiants in the solar vicinity and in the LMC obtained by Blaha and Humphreys (189), Fitzpatrick and Garmany (1990)

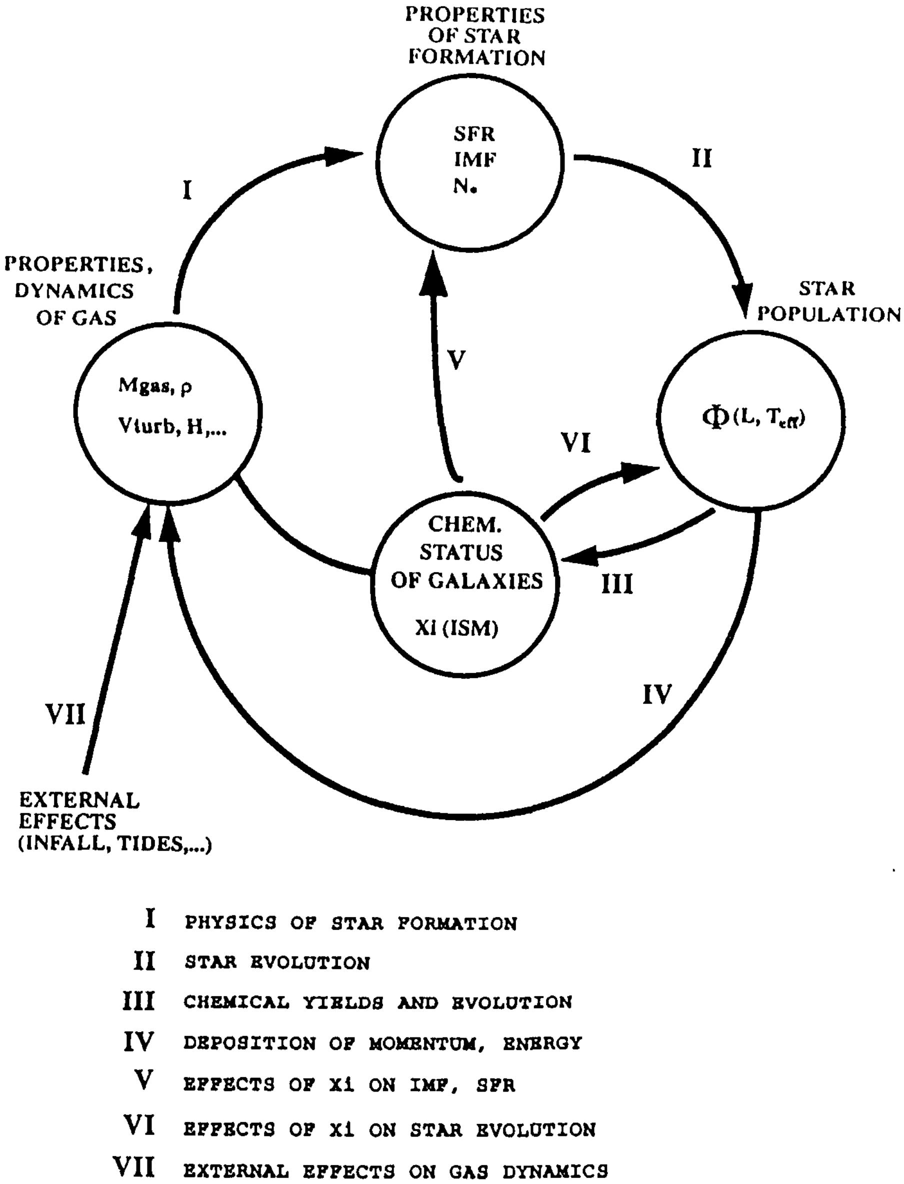

Figure 3: *Schematic illustration of the interplay between star formation, stellar population, chemical and dynamical evolution of the interstellar medium.*

show a significant stellar population just on the red side of the main sequence (log T_{eff} = 3.9 to 4.1) for initial mass stars between 10 and 20 $M_\odot$. The presence of numerous stars in this part of the HR diagram is quite puzzling since, according to standard numerical simulations, evolution is quite rapid at this stage (blue Hertzsprung gap). Several different possible explanations have been proposed in terms of enhanced opacities (Nasi and Forieri, 1990), of scatter in mass-loss rates (Meynet et al., 1994), extended atmospheres and binaries (Tuchmann and Wheeler, 1989, 1990). Some incompleteness effects and problems of calibration relations between B–V and log T_{eff} may also be responsible for at least part of the problem. However, our feeling is that no good solution has been found yet and that new evolutionary tracks are needed to account for this important fact.

The number ratio of blue to red supergiants is an increasing function of the metallicity Z in galaxies, typically increasing by a factor of 10 from the SMC to the solar neighbourhood (cf. Humphreys and McElroy, 1984). Langer and Maeder (1995) showed that if, at a given metallicity, it is possible to account for the observed blue to red ratio, by changing the mass-loss rates or the mixing mechanism, no assumption on stellar model physics explored so far is able to cope with the general trend. All models do the opposite, i.e. many more red supergiants are predicted at high Z than at low Z. Langer and Maeder (1995) suggest some connection of the blue to red problem with internal mixing. Indeed they found that a restricted scheme for mixing (Ledoux) looks generally better at low Z, while an extended scheme might be better at high Z. The question is of course to know what is the physical mechanism producing this kind of behaviour.

7. Chemical Abundances at the Surface of Massive Stars

Very luminous and massive stars (which are of particular importance for extragalactic studies) are often too faint for detailed studies with existing telescopes (see Appenzeller, 1986). The great aperture of the VLT will enable us to obtain the high-resolution spectrograms ($R = \lambda/\Delta\lambda$ between 10^4 and 10^5) with high signal-to-noise ratios ($S/N \sim 10^2$ to 10^3) necessary to the measurement of reliable abundances at the surface of extremely bright stars in extragalactic systems of different chemical composition. These observations can then be used as standards for lower resolution studies of more distant stellar systems.

A lot of very interesting observational facts concerning the surface composition of massive stars have been collected in the past years. In particular, the recent finding of Herrero et al. (1992) that all fast rotators among O stars show surface He-enrichments is a very important result. It shows that rotationally induced mixing is strong enough to transport the newly-processed elements to the surface during a fraction of the main-sequence lifetime. This implies that all stellar properties are influenced by this effect: lifetimes, luminosities, nucleosynthesis, etc.

Walborn (1976, 1988) showed that ordinary OB supergiants have He- and N-enrichments as a result of CNO processing. Only the small group of peculiar OBC-stars have the normal cosmic abundance ratios (cf. also Howarth and Prinja, 1989; Herrero et al., 1992; Gies and Lambert, 1992). There are two alternatives to explain the He- and N enrichments in supergiants and both bring about new problems (Maeder, 1995).

(1) The first alternative is that blue supergiants are on the blue loops after a first red supergiant stage where dredge up has occurred producing the observed surface enrichments. The problems related to this hypothesis are the following: (a) At Z = 0.02, current grids of models (Arnett, 1991; Schaller et al., 1992; Alongi et al., 1993; Brocato and Castellani, 1993) only predict blue loops for masses equal to or lower than 15 $M_\odot$. At higher masses there are no blue loops and no predicted enrichments. (b) Even on the blue loops the predicted enrichments do not seem high enough to account for the observations.

(2) Another possibility is that the mixing responsible for the surface abundances of these supergiants occurred already on the main sequence. We may, for instance, assume that the

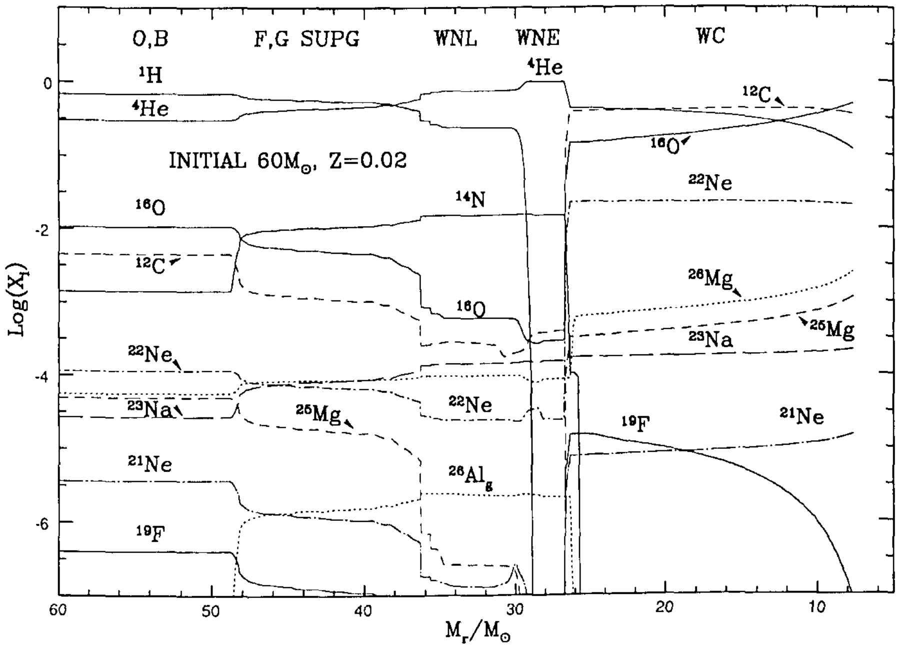

Figure 4: *Changes of surface abundances (in mass fraction) versus the remaining stellar mass in solar units for a 60 $M_\odot$ model with Z = 0.02. At the top, the corresponding evolutionary stages are indicated.*

effects producing enriched O stars (see above) are also active in lighter lower mass stars and that they lead to surface enrichments in supergiants resulting from a larger range of initial masses.

Whatever the solution, there is no doubt that, as for the problem of the blue to red supergiant ratio, mixing processes play a key role in understanding these observations.

8. Luminous Blue Variables and Wolf-Rayet Stars

Some of the most luminous stars have sporadic, violent mass-loss events whose causes are not understood. These evolved hot stars are called luminous blue variables (LBV) and their instability may shape the appearance of the upper HR diagram (Humphreys and Davidson, 1995; see also Maeder and Conti, 1994). Presently, these stars are interpreted as a short stage in the evolution of massive stars with initial masses M > 40 $M_\odot$. A likely scenario is (cf. Maeder and Conti, 1994).

$$\text{O star} \rightarrow \text{Of/WN} \rightarrow \text{LBV} \rightarrow \text{Of/WN} \rightarrow \text{LBV} \ldots \rightarrow \text{WN} \rightarrow \text{WC}$$

Are these violent eruption stages responsible for some of the rings observed around WR stars? Marston et al. (1994) have found that of the 145 galactic WR now surveyed, more than a quarter have associated ring nebulae. Several WR are shown to be surrounded by multiple rings (2 or 3) which suggests the occurrence of multi-ejection stages as is thought to occur during the LBV phase. More observations are required to go ahead with this hypothesis.

Among the stars with extraordinary mass outflows, WR stars certainly occupy a first-rank position. These stars are nowadays considered as bare cores left over from massive stars by mass loss; however, the exact cause of this extreme mass loss is still unknown. Recent works have succeeded in explaining the large observed changes of the number ratios WR/O, WC/WN in galaxies of different metallicities (cf. Maeder and Meynet, 1994). These changes are due to the larger mass-loss rates at higher Z. Also, the models were able to explain the observed trend of WC9, WC8 and WC7 to be located in inner regions of the Galaxy.

The sequence of WR stars nicely corresponds to a sequence of more advanced chemical processing becoming visible at the stellar surfaces (see Fig. 4). The standard models (cf. Schaller et al., 1992) predict an abrupt transition from WN to WC stars, since the He core is growing and building up a steep chemical discontinuity at its outer edge. Thus the standard models predict almost no (< 1%) stars with intermediate characteristics of WN and WC stars. However, there are about 4% of such intermediate stars (Conti and Massey, 1989). It has been shown by Langer (1991) that a mild mixing like that produced by semiconvective diffusion can account for these stars. The existence of WN/WC stars undoubtedly shows that an extra-mixing process is at work, even during the short He-burning phases.

Except at very low metallicity, WC stars are expected to present very high level abundances of ^{22}Ne at their surface as a result of the transformation, at the beginning of the He-burning phase, of the ^{14}N left by the CNO cycle (Maeder, 1990). However, the infrared observations by Barlow et al. (1988), for the WC8 star γ-Vel give Ne/He = 0.005 (in mass fraction), i.e. at least 6 times less than predicted. (However, this is twice the solar ratio). Let us note that the issue of this problem does not only concern a detail of stellar structure but is also important for the nucleosynthesis of s process elements in massive stars, since the ^{22}Ne is the major neutron source in these stars. It has also some implications on the understanding of the high values for the isotopic ratio ^{22}Ne/^{20}Ne found in cosmic rays, which has been interpreted as the signature of a WR contribution (Maeder and Meynet, 1993).

At present, observations of mass loss, of ejected shells, of surface chemistry, of LBV and WR properties are rather scarce and much safer conclusions on the last stages of massive star evolution in galaxies of different metallicities are still very much needed.

9. The Supernova 1987A, Stellar Remnants

According to McCray (1993), the light curve of SN1987A, powered by ^{44}Ti decay (t_{44} = 78 yr), should remain steady around m ≃ 19 for decades and thus be quite well observable with the VLT. There is no doubt that this zone of the sky will reserve further surprises when studied with this powerful instrument. First of all one could be able to test the hypothesis of the presence of a companion. Indeed, some authors (Soker and Livio, 1990; Podsiadlowski, 1992) have invoked the possibility that Sk–69 202 was a binary. If not disrupted by the explosion, its mass must be inferior to 2.5 $M_\odot$, otherwise we should see its light in the optical continuum. Another very interesting question will be to know what kind of remnant this explosion has left, a neutron star or a black hole? An optical pulsar might be detected (with $m_V \leq 23$) if it has a luminosity $L_{opt} \geq 3 \times 10^{34}$ $ergs^{s-1}$ (McCray, 1993). It is also expected that when the supernova ejecta will interact with matter expelled by the progenitor, very spectacular outputs will be produced. Luo et al. (1993) estimate that a shock will strike the ring of matter which surrounds the supernova at a radial distance of ~ 0.7 lt-yr, in 2004 ± 3. At that time, strong radio, optical and UV emissions are predicted to occur (Luo and McCray, 1991; Suzuki et al. 1993; Luo et al., 1992). After the initial impact, the ring will become a bright source of soft X-rays and infrared continuum.

The importance of the mass limits for neutron stars and black holes for the chemical evolution of Galaxies has been recently discussed by Maeder (1992).

The yields in heavy elements strongly decrease with the lowering of M_{BH}, the lowest mass limit for black hole formation, since then more heavy elements are swallowed by black holes. Comparisons with observational data, in particular with the DY/ DZ ratio suggest a value of M_{BH} around 20 or 25 $M_{\odot}$. The dependence of the yields and supernovae types on metallicity and on the value of M_{BH} is a key problem in stellar astrophysics with many implications. Much theoretical and observational work is still needed in this area.

10. Massive Stars in Galaxies as Distance Indicators

As already emphasized above, massive stars are fantastic tools to explore the remote universe. The VLT will be able to observe long-period Cepheids up to a distance of 70 Mpc and red supergiants up to 700 Mpc. Type Ia supernovae will be detected up to 7000 Mpc (Moorwood, 1986).

Cepheids, because of their importance in the determination of the cosmological distance scale, deserve particular attention (cf. the recent detections of Cepheids in galaxies of the Virgo cluster by Pierce et al., 1994, Freedman et al., 1994, Saha et al., 1995). Since different modes of pulsation follow different period-luminosity relations, it is crucial to obtain accurate distances to be able to discriminate between these modes. The effects of the chemical composition has also to be fully understood. In this context it is interesting to emphasize that the Cepheid models predict different surface He-contents and N/C ratios according to metallicity Z and masses (cf. Schaller et al. 1992). The difference in helium content, $Y_s = 0.243$ at $Z = 0.001$ compared to $Y_s = 0.33$ at $Z = 0.020$, should have some consequences for the driving mechanism and thus for the amplitudes of Cepheid pulsations at different Z. Such differences of amplitude distributions between Galaxy, LMC and SMC are known to exist (cf. van Genderen, 1978) and we may suspect a relation with the different helium contents.

The possibility for the VLT to perform infrared observations will also be important in this context. Indeed, in addition to the fact that, in the infrared, the standard distance indicators are subject to much lower extinction uncertainties than in the visible, Cepheids, in this wavelength range, exhibit a tighter period-luminosity relationship which is less metallicity-dependent (Moorwood, 1986).

11. Conclusion

A universe without massive stars would be nearly a dead universe with such long evolutionary time scales that it would appear quite unevolving. Indeed, even if massive stars are quite rare objects, they are nevertheless the main engine of many active processes, as stated in the introduction. Their role in the study of star formation and evolution of galaxies, as well as the many problems which still need to be clarified on their internal and external physics, make massive stars first-rank goals for VLT observations.

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Monitoring of Active Galactic Nuclei: the Why and the How

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1. Introduction

Over the past twenty years, ground-based optical observations as well as ultraviolet, X-ray, and γ-ray observations from space-borne telescopes have revealed the variable nature of the continuum and emission lines in the spectra of active galactic nuclei (hereafter referred to as AGN). Variability is now recognized as one of the distinctive features of these important but poorly understood objects.

2. The Why of Monitoring Campaigns

2.1 Some basics

In the study of AGN, variability affords a potentially valuable probe of the properties of both the continuum source itself and the broad-line emitting region surrounding it.

Knowledge of the continuum variability pattern in different wavebands from γ-ray to radio wavelengths can provide a way to probe the various physical processes at the origin of the continuum emission. The variation time scales in particular give some indication of the size of the emitting regions, an indirect clue to the likely emission mechanisms. Of potentially greater interest is the possibility of eventually measuring time lags between continuum variations in different wavebands because this can tell us about the connection between various mechanisms producing continuum photons in these systems.

In the framework of the so-called standard model, based on a massive black hole and accretion-disk system, we assume that accreting material is distributed throughout the line-emitting regions: the broad-line region (hereafter BLR) and the narrow-line region (NLR), which are somewhat arbitrarily distinguished by the width of the lines they emit (ranging from as much as a few 10,000 km/s for the broadest lines to only a few 100 km/s for the narrow lines). An important probe of the inner structure of AGNs is provided by measuring in detail how the emission-line fluxes change in response to changes in the continuum flux. The broad emission lines respond with small but measurable time delays (days to weeks) to variations of the central continuum source, making it possible to use the technique of "reverberation mapping" to probe the structure and kinematics of the BLR. In general, the narrow lines do not vary in flux since the size of the NLR is usually too large to provide a coherent response to changes in the level of the continuum flux.

The fundamentals of reverberation mapping were described by Blandford and McKee (1982), but it has been only over the last five years or so that the first tentative applications of this technique to real AGN have been possible, as severe conditions on the amount and quality of the data have to be met (Peterson, 1994).

Some experiments, undertaken by the "International AGN Watch" collaboration, have been conducted in part with telescopes at the European Southern Observatory (ESO), and these form the subject of this report.

Similar programmes, albeit with a sometimes different overall emphasis, have been undertaken by other informal organisations during the same time frame. For example, the European consortium LAG ("Lovers of Active Galaxies") which was initiated by the late M.V. Penston, has carried out a spectroscopic and photometric monitoring of several AGN on the Canary Islands telescopes within the framework of the CCI 5% international time programme (Robinson, 1994).

2.2 A bit of recent history

In the early eighties, a number of groups involved in AGN studies undertook ultraviolet and optical monitoring programmes in an effort to probe the physics of AGN (for a review, see Peterson, 1988). We note in particular the results of the so-called NGC 4151 collaboration (Ulrich et al., 1984; Clavel et al., 1990). One of the major surprises of the monitoring campaigns of the eighties was that the BLR seemed to be an order of magnitude smaller than the value generally predicted by photoionisation equilibrium calculations. This conclusion demanded even denser sampling for AGN variability programmes.

In 1987, two successive workshops in Segovia and Atlanta featured lively discussion of results obtained from AGN variability studies. It became apparent to the community that the goals of spectroscopic monitoring programmes could in fact be achieved only if sufficient observing time could be devoted to such an approach.

Cooperation of observers on a scale that was unprecedented in extragalactic astronomy, i.e. with very large collaborations involving around 100 astronomers, became a necessity.

To deal with a collaboration of this size and a highly time-constrained programme, new ways of working and cooperating had to be invented. The International AGN Watch was therefore established with the goal of focusing attention on a few AGN for intensive monitoring efforts and maintaining communication among the various individuals and groups that carried out the actual observations. A key factor in the success of these efforts has been the ability to communicate and exchange information promptly via modern computer networks. The role of the AGN Watch has been multifold: (a) to define the scientific questions to be addressed, conceive the observational projects and coordinate the submission of the appropriate observing proposals, (b) to ensure that data are collected in a manner consistent with the scientific goals, (c) to reduce the observational data and make these data sets available to the entire community, and (d) to perform the measurement and analysis of the data and publish the primary scientific results.

It was decided that detailed and model-dependent interpretation would be left to individuals or sub-groups of the

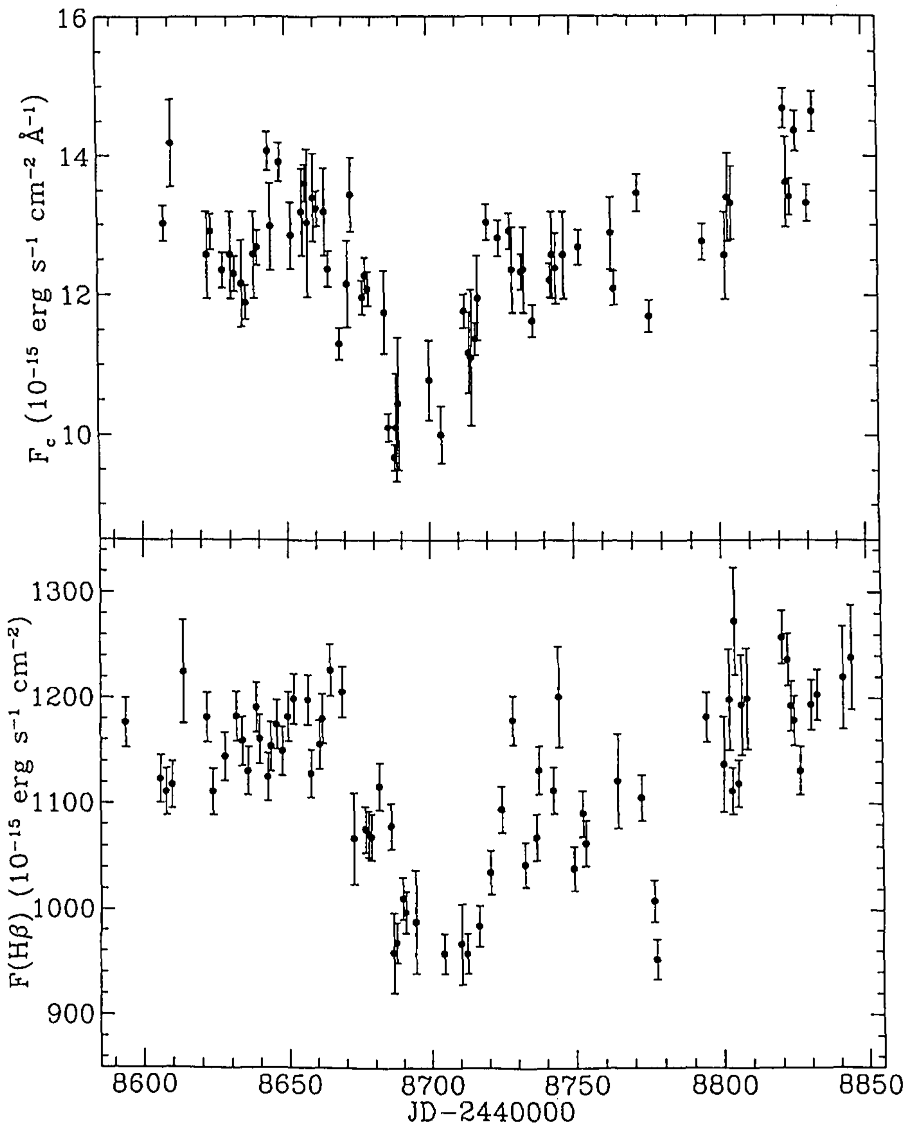

Figure 1: *The light-curves of the optical continuum (top panel) and of Hβ (lower panel) from the AGN in NGC 3783 during the ESO campaign.*

AGN Watch collaboration, as well as to other interested parties. The AGN Watch data are at the disposal of the entire community once the primary scientific results have been published by the collaboration.

The How

As many of the strongest and most important broad lines in AGN spectra are located in the ultraviolet domain, space-based observations are critical for understanding the BLR. Therefore, the initial focus of the AGN Watch efforts was UV spectroscopy using the International Ultraviolet Explorer (IUE) and, later, the Hubble Space Telescope (HST). However, concurrent observations of the optical lines and continuum are essential for a complete description of AGN behaviour, and therefore each of the AGN Watch campaigns was organised to ensure that adequate data would be obtained at both ground-based and space-based observatories.

3.1 First experience, the NGC 5548 campaign

The first AGN Watch project was an eight-month monitoring campaign (AGN Watch campaign I) on the Seyfert 1 galaxy NGC 5548. IUE observations were made once every four days between December 14, 1988 and August 7, 1989, for a total of 60 epochs.

Ground-based observations were collected with various telescopes in the northern hemisphere during this entire period, and the ground-based component of this programme is in fact still continuing. The success of this original programme (see Peterson, 1993, for a detailed summary) led to a similar programme of NGC 3783 (AGN Watch II, described below), and to a follow-up programme on NGC 5548 (AGN Watch III) using both IUE and HST to obtain ultraviolet spectra at a higher rate than in the original programme, once every two days with IUE between March 16 and May 27, 1993; during the second half of this campaign, HST spectra were obtained with an even higher frequency, once per day. Detailed results of the campaigns on NGC 5548 can be found in Clavel et al. (1991), Peterson et al. (1991), Korista et al. (1995) and references therein. The main conclusions reached are as follows:

1. The ultraviolet and optical continua vary with little, if any, phase difference between them. The continuum becomes bluer as it becomes brighter and the shorter-wavelength continuum bands show sharper variations.
2. The variations of the highest ionisation lines (He II, NV) lag behind the variations of the ultraviolet continuum by slightly less than 2 days, implying an inner radius of somewhat less than 2 light-days for the BLR. Its outer radius, from the CIII] and Balmer lines, is somewhat larger than 20 light-days.
3. There are some indications that the higher radial-velocity gas (line wings) responds more rapidly than the lower radial-velocity gas (line core), suggesting a virialised BLR cloud system.

3.2 Where ESO comes on the stage, the NGC 3783 campaign

In order to improve our understanding of the size and structure of the BLR and to test the generality of the NGC 5548 results, it was deemed to be desirable to carry out similar programmes on other AGN in order to map the AGN luminosity vs. BLR size plane.

Therefore, two other targets with different absolute luminosities were selected, NGC 3783 (AGN Watch II) and Fairall 9 (AGN Watch IV), both observable from the southern hemisphere. These AGN Watch campaigns relied heavily on ESO telescopes for the ground-based component.

The AGN Watch campaign II was set up to monitor NGC 3783 with IUE for 69 epochs from December 21, 1991 to July 29, 1992, once every 4 days for the first 172 days and once every 2 days for the final 50 days. Simultaneous optical and near-infrared observations were collected from ESO and CTIO (Chile), CASLEO (Argentina), Lowell Observatory (USA), Vainu Bappu Observatory (India) and SAAO (South Africa). The ground-based campaign started on December 3, 1991 and was completed on August 9, 1992.

An application for the ESO observing programme was submitted through the normal Observing Programmes Committee (OPC) channel, with special requirements regarding the dates to be scheduled and the time-slot to be allocated to the programme, i.e., once every 4 nights (concurrent with the IUE observations), 2 hours of time placed such that NGC 3783 would be at its meridian transit (in order to minimise the air mass).

The project was recommended by the OPC and carefully scheduled by ESO on the 1.5-m telescope. All PIs of other regular successful 1.5-m telescope proposals were informed in advance by ESO about these two-hour blocks of time and were required to schedule their own observations around this interruption. A detailed handbook had been prepared for the AGN Watch observations, describing briefly the purpose of the observations, the experimental conditions to be strictly followed, and providing information for all the necessary contact persons. A group of ESO postdocs, students, and cooperants present at La Silla over this period of time was organised under the responsibility of Dr. B. Altieri to actually take care of the AGN Watch observations. Dr. B. Altieri was also in charge of collecting and reducing all the AGN Watch data on-line in order to ensure that the programme was being carried out as designed and was producing useful data.

This organisation turned out to be extremely satisfactory and efficient. The ESO staff was found to be very cooperative, which was certainly one of the primary reasons for the success of the campaign. The observers of regular proposals had to deal with some interruption of their own programmes and consult with the ESO AGN Watch team with regard to details of the programme in order to carry out both the PI and AGN Watch programmes as efficiently as possible. We are pleased to report that we found a highly cooperative spirit among the regular observers. Altogether, the experience has been quite positive in our relations with the ESO staff and the European astronomical community. We owe them many thanks and certainly some part of the credit for the success of the campaign.

After reduction, the ESO data were then merged with similar data sets collected at other ground-based facilities (Fig. 1). There was in particular a very close collaboration with CTIO, as researchers in charge of the AGN Watch at both sites were in continuing contact.

The NGC 3783 campaign was also distinguished from the AGN Watch campaign I by two important features:

1. The availability of HST allowed us to obtain a high-resolution, high signal-to-noise ultraviolet spectrum that proved to be crucial in disentangling features in the IUE data by using the HST spectrum as a model.

2. Under the auspices of the "World Astronomy Days", sponsored by ESA in the context of the International Space Year, it was possible to arrange a nearly simultaneous multi-wavelength snapshot of NGC 3783 which included observations from GRO, ROSAT, Voyager, IUE, HST, optical and infrared ground-based telescopes, and the VLA. These data were also essential to a better understanding of the continuum source in NGC 3783 and complemented the AGN Watch data set.

The results of AGN Watch campaign II are described in detail by Reichert et al. (1994), Stirpe et al. (1994), and Alloin et al. (1995). We note here the salient conclusions:

1. As in the case of NGC 5548, significant variations were detected, both in the continuum and in the emission-line fluxes. We observe in NGC 3783, however, rapid fluctuations of relatively higher amplitude than in NGC 5548, while the longer-term modulations appear to be comparatively less well defined.

2. The continuum fluxes appear to vary simultaneously in all four measured ultraviolet/optical bands. The slope of the ultraviolet continuum is found to vary in the sense that the fractional amplitude of the continuum variations decreases with increasing wavelength.

3. Cross-correlation analysis indicates strikingly short time delays for most of the strong emission lines. The peaks of the cross-correlation functions occur at lags of 0 ± 3 days for He II+OIII], 4 ± 2 days for Lyα and CIV, 8 ± 3 days for Hβ, and 8–30 days for Si III] and CIII].

4. The continuous emission of the genuine AGN in NGC 3783 appears to be rather flat from soft γ-ray to infrared wavelengths with index $\alpha \approx 1$. The ultraviolet and near-infrared excesses can be understood in terms of thermal emission from an accretion-disk surface and a hot dust component, respectively.

3.3 A high luminosity object, the Fairall 9 campaign

AGN Watch campaign IV was devoted to an AGN of much larger absolute luminosity, Fairall 9, which was already known to exhibit long-term large-amplitude variability (Clavel et al., 1989). In the ultraviolet, this object was observed with IUE once every 4 days from April 30 to December 26, 1994. Because Fairall 9 is a southern source, again the 1.5-m ESO telescope played a key role in the ground-based effort. Again the standard procedure of time application through the OPC channel was followed, without calling for a key project. Time was granted to the campaign, 2.5 hours once every 4 days from May 2 to September 27,1994 but with two consecutive epochs missing due to a large block of time scheduled with an instrument which was not suitable for our project. Again, the ESO schedule matched as well as possible the IUE observation times, with special care being taken to maintain the regular sampling that is desirable in these monitoring programmes. The AGN Watch observations were scheduled even when the telescope was otherwise idle, and we greatly benefitted from this high level of cooperation by ESO.

The on-site organisation of the campaign was roughly similar to that set up for AGN Watch II, with Dr. C. Mendes de Oliveira and Dr. E.Chatzichristou being successively responsible for the interaction with PIs of the regular proposals scheduled on the 1.5-m telescope at every AGN Watch epoch, and for the data collection. Again, the campaign went on smoothly as the ESO staff and most of the regular observers were extremely cooperative and helpful.

Data from the ground-based campaign, from all participating observatories, are now being reduced and will be compared soon to the ultraviolet continuum and emission-line light-curves. Preliminary results from the IUE campaign show that Fairall 9 did vary significantly and that high frequency variations are superimposed on the longer-term trend.

4. Conclusions

Although the observational effort demanded in such campaigns is quite large, the AGN community is convinced that the scientific returns are sufficiently important that such campaigns are worth the trouble. Through these large-scale coordinated efforts, we have been able to acquire data sets of high quality and reasonable homogeneity which are suitable for further statistical analysis. The AGN Watch data sets are available to the entire community, and there is no doubt that they will be used by many more astronomers in the future.

The AGN Watch campaigns have demonstrated that there is no delay, to the accuracy measurable so far, between the ultraviolet and optical continua. This result rather argues in favour of reprocessing models and seems to rule out simple, geometrically thin, optically thick accretion-disk models for AGN. In at least three AGN, it has been confirmed that the size of the BLR is an order of magnitude smaller than predicted on the basis of the standard photoionisation equilibrium models of AGN. In NGC 3783, it is found that the BLR extends from about 1 to 2 light-days upwards to around 30 light-days, and is radially structured with the highly ionised material closest to the centre.

Carrying on such large campaigns requires good will, excellent organisation and communication among the astronomers involved in the pilot group, and a broad consensus in the community on the importance of the project. We have been fortunate in benefitting from the interest, encouragement, and support of the staff of various observatories at which these observations have been made. In addition to the tangible scientific return from these programmes, we believe that the large-scale international collaborations in the AGN field have greatly enhanced the mutual interactions of the astronomers involved in the project, have led to a much more efficient use of telescope time, and have resulted in a better coordination of programmes, thus leading to faster and unquestionable progress in our understanding of the AGN phenomenon.

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On the Variability of Narrow-Line Seyfert 1 Galaxies

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1. Introduction

Narrow-line Seyfert 1 (NLS1) galaxies are characterised by the relatively low projected velocities of their line-emitting nuclear gas. We describe a spectroscopic programme based on a search for variability, which attempts to constrain the causes of their difference with respect to other Seyfert 1 galaxies.

Active galaxies which are classified as Seyferts (characterised by a luminous nucleus of stellar appearance, with a non-stellar blue continuum and strong emission lines) are divided into two categories according to the widths of their lines: in Seyfert 2 galaxies, forbidden and permitted lines all have the same width (~ 1000 km s^{-1}), while in Seyfert 1 galaxies the permitted lines have an additional component of much greater width (~ 10^4 km s^{-1}). The difference is attributed to the presence of both a broad line region (BLR) and a narrow line region (NLR) in the nuclei of Seyfert 1's, while only the latter is present, or visible, in Seyfert 2's. The BLR is characterised by higher densities, higher velocities of the gas which forms it, and by a smaller size than the NLR: in fact, BLRs are so compact (≪ 1 pc) that even in the closest active galactic nuclei (AGN) they cannot be resolved spatially. The large velocities present in the BLR are generally attributed to the gravitational effects of a massive (>10^7 $M_\odot$) accreting black hole, which is the prime cause of the nuclear activity.

The distinction between type 1 and type 2 Seyferts is by no means clearcut. Spectropolarimetry (e.g. Antonucci & Miller, 1985) has revealed that several (though not necessarily all) Seyfert 2's contain BLRs which are hidden to conventional spectroscopy by obscuring material (possibly a dust torus). This has sparked a debate on the possibility that all Seyferts may be described within a unified model, in which the orientation of the nuclear axis determines the aspect of a source's spectrum, and therefore its classification. Within this framework, Seyfert 2 nuclei are viewed at large inclination angles, and Seyfert 1's at medium and small ones.

1.1 What is a narrow-line Seyfert 1 galaxy?

The broad components of Seyfert 1's display a great variety of profiles and widths (e.g. Osterbrock & Shuder, 1982, Stirpe, 1990), and it is tempting to explain it on the basis of projection effects. In particular, the so-called 'narrow-line Seyfert 1 galaxies' (Osterbrock & Pogge, 1985) are at the lower end of the broad line width distribution in the Seyfert 1 class. While they are clearly distinct from Seyfert 2's because of the different widths of permitted and forbidden lines, and because of the presence of Fe *II* lines (which are not emitted by the NLR and are therefore absent in Seyfert 2 spectra), the width of their broad components is barely larger than that of the forbidden lines[1] (FWHM ≤ 1000 km s^{-1}). Studies of NLS1s have shown that the broad components of the lines have ratios similar to those of 'normal' Seyfert 1's and, on average, lower equivalent widths (Osterbrock & Pogge, 1985, Goodrich, 1989); this last property, however, is the extension to low FWHM of a trend observed throughout the Seyfert 1 population. Some NLS1 galaxies present in their spectra high ionisation iron lines like [FeVII] λ5721, λ6087 and [Fe X] λ6375 (Osterbrock, 1985, Osterbrock & Pogge, 1985), in some cases with high intensity: these are properties common in Seyfert 1 galaxies, but quite rare in Seyfert 2's. NLS1s comprise approximately 10% of optically selected Seyfert 1's, but a significantly higher percentage ~ 16–50%) of soft X-ray selected Seyfert 1 samples (Stephens, 1989, Puchnarewicz et al., 1992). Boller et al. (1995) report the observation with ROSAT of a sample of NLS1s, finding that the objects in this class have generally steeper soft X-ray continuum slopes than normal Seyfert 1's, and rapid soft X-ray variability.

[1]It is important to realise that we are referring to objects whose maximum observed velocities from the BLR are low, not to objects in which the broad component of the emission lines is very weak compared to the narrow component, but also very broad: the FWHM of the permitted line (broad + narrow component) can be similar in objects of these two types, and sometimes a low signal-to-noise ratio in a spectrum can mask a weak but very broad component, and cause an object to be misclassified.

The question which we wish to address is what causes NLS1s to have such narrow lines: this can provide insight into the more general problem posed by the great diversity present among the broad emission lines of AGN. Some of the possible answers are:

1. NLS1s are not intrinsically different from other Seyfert 1's, and the low velocities in their lines are caused merely by projection effects. If, for example, the BLR has a flattened configuration in which the gas moves preferentially in the plane perpendicular to the axis of symmetry (as in an accretion disk), our line of sight towards NLS1s should form a small angle with the axis itself.

2. The main difference between NLS1s and normal Seyfert 1's is the mass of the central black hole, which is smaller in the former type of object, and therefore causes the BLR gas to move at lower velocities.

3. The broad line gas in NLS1s moves at lower velocities because it is on average at larger distances from the black hole than in normal Seyfert 1's. In this scenario, the BLRs of NLS1s have a larger emissivity-weighted radius than those of normal Seyfert 1's.

4. The inner region of the BLR, in which the gas moves at the highest velocity, is hidden from our sight by orientation effects: it is possible, within the Seyfert unified model, that NLS1s are objects seen at relatively large inclination angles, and that only the outer part of the BLR is observed.

1.2 Variability

A common characteristic of Seyfert 1 nuclei is their strong variability: the UV/optical continuum and emission lines vary on time scales of a few days if not less. Normally the emission line variations lag those of the continuum by a few days or weeks, indicating that the size of the BLR is less than a few tenths of a parsec. A great effort has been invested during recent years in the monitoring of Seyfert 1's (see Robinson, 1994 and Alloin et al., 1995, and references quoted in both reviews), in an attempt to unravel the structure of the BLR through the technique of reverberation mapping (Blandford and McKee, 1982). Because of the large amounts of telescope time required for adequate monitoring campaigns (which typically consist of one observation every few days for several months), care has always been taken to select targets which were well known to be highly variable, e.g. NGC 4151, NGC 5548, NGC 3783, Fairall 9. All the targets chosen for monitoring have broad components of normal widths, so the results obtained so far do not necessarily generalise to the Seyfert 1 population as a whole, and in particular to NLS1s. In fact, it is not even known whether NLS1s are optically variable, except for one case (NGC 4051, Peterson et al., 1985). Yet this information could be very useful to constrain the hypotheses listed in the previous section on the nature of NLS1s, as pointed out by Robinson (1995). A lack of widespread variability, in fact, would suggest the absence of broad line-emitting gas very close to the central black hole, and would therefore indicate that the BLR is located at higher distance from the centre than in normal Seyfert 1's, or that the inner and most responsive region of the BLR is obscured. If instead variability is as common in NLS1s as in Seyfert 1's, this could imply a smaller central mass or an anisotropic kinematic structure for the BLR.

Therefore, we have performed a simple observational programme to determine whether variability is a common characteristic of NLS1s.

2. Observations and Preliminary Results

The programme consists in the observation of a sample of NLS1 galaxies at two epochs separated by about one year. For each object we obtained spectra covering the main optical lines, and compared the integrated line fluxes measured for the two epochs. The results of this search for variability for our sample were then compared with those of a larger existing data-base on 'normal' Seyfert 1's, obtained with the same (relatively long) time scale. The sample we have chosen consists of 12 objects, and is formed by all the NLS1s known in the literature with $m_V \leq 16.0$ and intrinsic luminosity comparable to that of known variable Seyferts, and which were suited to our observing conditions. The observations were performed at the 1.52-m ESO telescope located at La Silla, Chile, during two observing runs in early October 1993 and late September 1994. In both cases we used the same instrumental configuration, covering the 3700–7500 Å range at a resolution of ~ 1.9 Å/pxl. The S/N ratio of ~ 50 allows us to detect or exclude flux variations down to a level of ~ 10%.

The spectra were taken with standard procedures, and reduced making use of the standard IRAF reduction tasks. Before being able to compare the spectra obtained at different epochs, however, we performed a sort of 'internal' calibration to correct for differential slit losses in each couple of spectra, making use of the strong forbidden lines present in the Seyfert spectra: as mentioned previously, the forbidden lines are emitted by the NLR, which is much larger than the BLR, and therefore remain constant on time scales of decades. Imposing that the integrated flux of the forbidden lines chosen for the calibration is the same for the two spectra of each object, we could therefore find a scale factor to correct for in one of the two spectra, so making it comparable to the other one. The calculation of the correction parameters is performed by a Fortran code (see van Groningen & Wanders, 1992) which makes use of a chi-square minimum research procedure on the difference spectrum in the wavelength range including the forbidden lines; together with a scale factor and a shift in pixels, it also gives in output the FWHM (in pixels) of the Gaussian with which one of the two spectra may be convolved to best match the other. We found that this method gives better results, i.e. smaller residual fluxes in the difference spectra in the region of the chosen forbidden lines, than the method of direct evaluation of the forbidden line fluxes through a (e.g. Gaussian) fitting of the line profiles, not only since allowance is made for a slight shift in wavelength, but also because there is no need to make hypotheses on the shape of the lines, which is often far from being Gaussian. A problem with this method may exist, however, when the NLR is spatially resolved and its extension is comparable with the projected slit width: in this case, in fact, a different seeing effect in observations separated in time may cause different portions of the narrow line fluxes to enter the instrument, and therefore lead to errors in the calibration. We are currently testing our data against this source of error, by a quantitative evaluation of the spatial extension of the nuclei; however, the appearance of the bidimensional images seems to exclude the presence of light losses caused by the seeing, since our galactic nuclei are compact and the observing conditions were quite good. An exception is represented by NGC 1365: its extended and composite nuclear structure requires special attention in the analysis of the narrow lines.

To achieve an accurate calibration in the covered spectral range, we applied the internal calibration method separately to the Hα part of the spectra, making use of the [S II] λ6717.0, λ6731.3 Å lines, and to the Hβ region, through the [O III] λ4958.9, λ5006.8 Å lines. To actually calculate the integrated flux for the strongest optical lines (mainly Hα and Hβ), we first fitted and subtracted the continuum under the lines, and then evaluated the flux through an interactive IRAF task.

The major sources of uncertainty on the estimated line fluxes are due to the process of internal calibration mentioned above and to the evaluation (by hand) of the fluxes themselves. Notice that, the [O III] lines being very intense compared to the [S II] features, the calibration of the

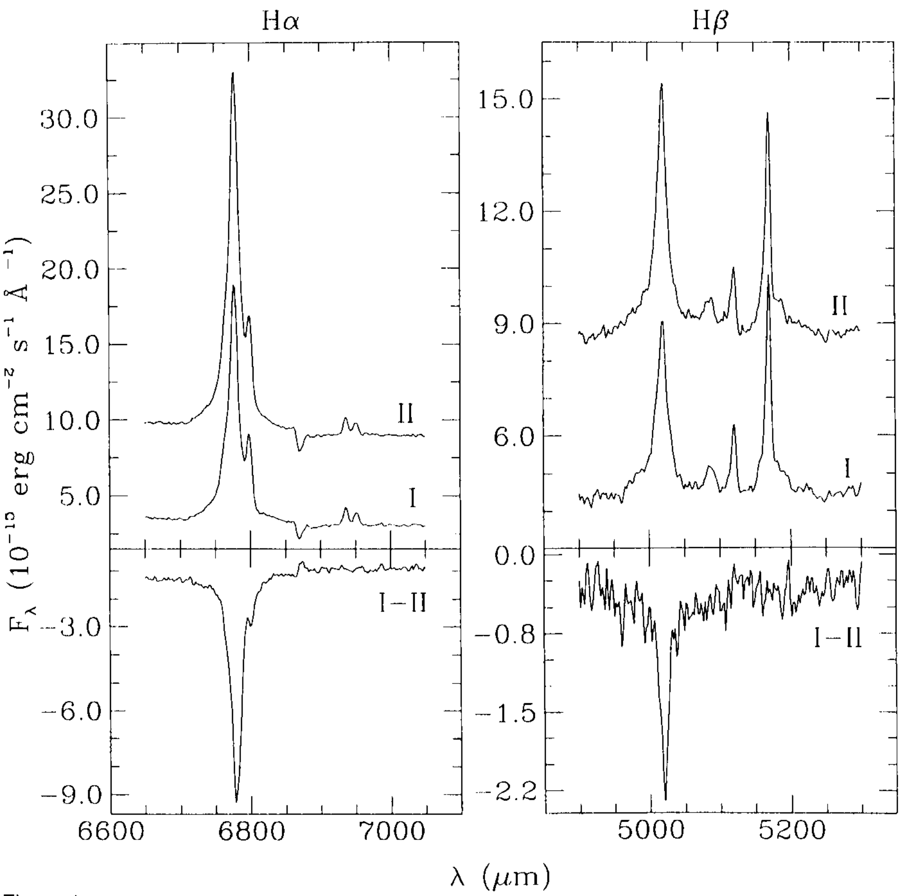

Figure 1.

Hβ region is usually more accurate than that of the Hα region.

We considered reliable only the measured flux variations above 3σ, where σ is the estimated uncertainty on the variation, finding that out of 12 objects, 9 show appreciable variations between the two epochs. In particular, two objects (IRAS 0345+0055 and NAB 0205+024) show no variation and another one (Akn 564) displays a very weak decrease below our threshold; four objects (ESO 012–G21, Mkn 359, Mkn 915[2] and NGC 1365) underwent strong increases in luminosity (in the range 20–40%). We detected a marginal variability in H 0707–495 and Mkn 1044 (in the range 10–20%), while for three objects (IRAS 0444–052, Mkn 1126 and Mkn 896) we observed a clear variation only in one of the two main emission lines (Hα and Hβ).

In Figure 1 we plot the two spectra (1993 and 1994) of ESO 012-G21 and the difference spectra showing clearly the line flux increase both in Hα and Hβ.

3. Comparison with the Seyfert 1 Sample and Discussion

The de Ruiter and Lub dataset with which we compared our results consists of a sample of about 20 Seyfert 1 galaxies, selected with no previous knowledge of variability characteristics: they were all Southern Seyfert 1's which were known when the programme was started (1979). The objects have been spectroscopically monitored at the 1.52-m ESO telescope on long time scales, more precisely from one year to the next for about 15 years.

To use this optical spectra data-set as a comparison sample, we first evaluated, approximately with the same criteria used for our sample, the Hβ flux for each object and each observation epoch (sometimes calculating the mean value of more observations taken a few days apart) constructing an Hβ light curve for each Seyfert 1 galaxy. We then calculated the relative variation of the line flux for each 1-year interval. Since this time range is much greater than the typical time scale of line and continuum variations, which ranges from days to months (see § 1.2), we can assume that the annual relative variations are independent, being probably associated to different 'events' (bursts or declines of luminosity). We therefore constructed a global histogram, including all the annual relative variations (in absolute value) for all the objects, which in this way forms a statistically meaningful sample on variability data.

The data on the Hβ line flux show that virtually all the monitored galaxies display significant variability, at least in some of the time intervals covered. To determine how the NLS1 galaxies behave as a class, compared to the 'normal' Seyfert 1

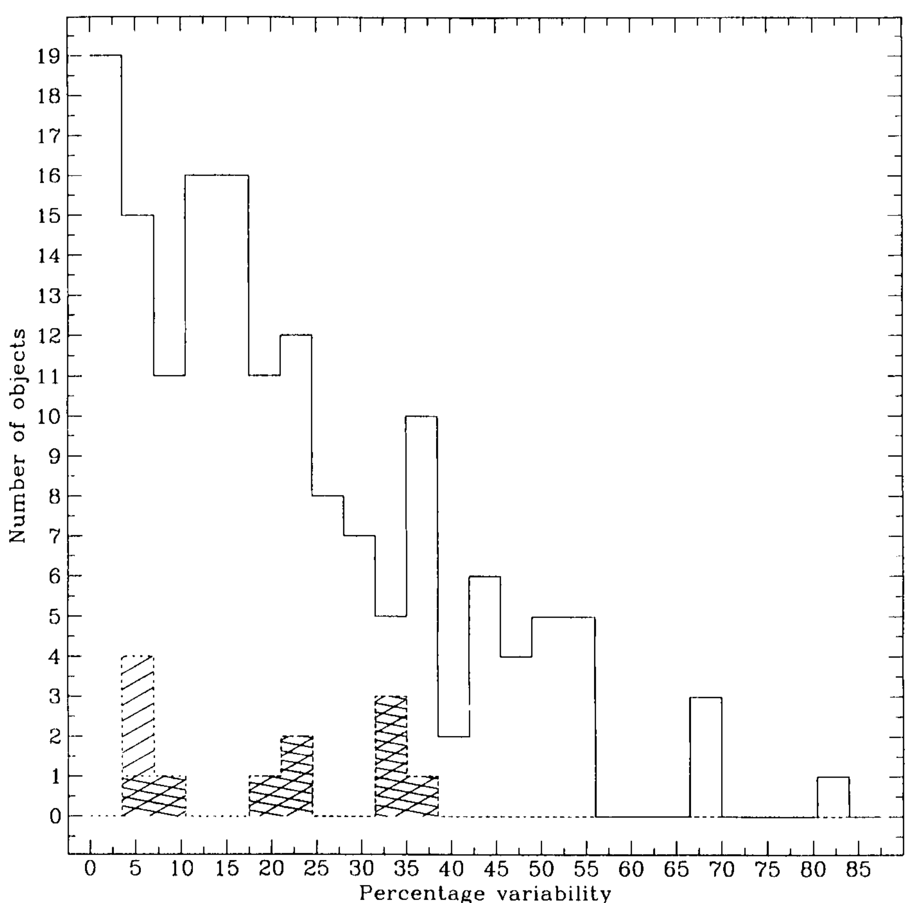

Figure 2.

[2]Notice, however, that this object may have a very broad but weak component in its emission lines (which in our spectra appears only in the Hα line), and therefore may have been misclassified as a NLS1 (see note 1).

population, we drew a histogram as described above for our results too: the number of objects in the sample is too small to easily analyse the observed variability from a statistical point of view; nonetheless, there is no apparent trend of the NLS1s towards weak or absent variability characteristics; on the contrary, the objects for which we clearly detected a flux variation appear to distribute in the histogram in a similar way with respect to the comparison sample, e.g. they can reach relative variations around 30–40%. In Figure 2 we plot the two histograms described above, which show no evidence for a weak variability in the NLS1 sample, especially when only the flux variations above 3σ are considered.

While the absence of variability, or a significantly lower variability with respect to 'normal' Seyfert 1's, would have had strong implications on the interpretation of the NLS1s' spectrum, excluding that a smaller central mass or projection effects could be responsible for the narrower lines, the presence of variability on a time scale of one year does not entirely exclude the possibility (among the four listed in § 1.1) that we are actually observing broad line emitting gas located at relatively high distance from the centre (which represents the whole or only the outer part of the BLR); this gas could in fact be insensitive to variations on short-time scales, but responsive to long-term trends similar to the ones easily recognisable in the Hβ light curves of the de Ruiter and Lub data-set. To discriminate between the competing models it would be necessary to monitor a variable NLS1 (e.g. NGC 4051) with quite short time scales (days or weeks), such that the presence of variability would surely imply that the line-emitting gas is located very close to the centre (as in 'normal' BLRs), and therefore that a small black-hole mass or projection effects are to be responsible for the low FWHM observed. In a relatively long monitoring, moreover, it would be possible to measure the lag between the line and continuum light curves to have a better estimate of the BLR size, and compare it to that of other Seyferts.

At this stage we can set, for the size of the observed BLR in NLS1s, an approximate upper limit of the order of the light-year, since we would not observe any significant variations if the line-emitting gas would be located tens or hundreds of parsecs from the centre (as happens in the NLR). The observed BLR could represent therefore the outer part of a 'normal-sized' but partially obscured BLR, or the entire BLR in a type of object in which for some reason there is no line-emitting gas in the inner parsec region.

We can notice, however, that the annual relative variations measured in our comparison sample appear to belong to a long-term trend approximately in 30% of the cases (estimated by taking the events in which at least 4 points in the light curve show the same variation sign); therefore, a common variability in NLS1 galaxies, as that displayed by our data (~ 75% of objects varied in luminosity between the two epochs), is more probably consistent with models in which a BLR with 'canonical' size produces smaller observed velocities of the line-emitting gas, either for projection effects or for intrinsic reasons. We therefore tend to favour these types of explanation, that should be theoretically modelled to be able to compare in detail our predictions with the observed line profiles.

The fact that variability is detected in so many NLS1s is in any case a strong indication that these objects are not radically different, in size and nature, from normal Seyfert 1 galaxies.

Acknowledgements

We are grateful to Hans de Ruiter and Jan Lub for allowing us to use their data in advance of publication.

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The DUO Programme:

First Results of a Microlensing Investigation of the Galactic Disk and Bulge Conducted with the ESO Schmidt Telescope

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Summary

We present the first results of a search for microlensing amplifications towards the Galactic centre region, aimed at investigating the populations of the disk and bulge in a wide field.

For this purpose, we used a first set of Schmidt plates taken on La Silla from April to September, 1994, digitised with the MAMA microdensitometer, and analysed with a software specially developed for highly crowded fields.

Some ten microlensing candidates, including what appears to be an amplification by a double lens, could be present in the data produced by the reduction of half of the field. Thousands of variable stars are also evidenced by this survey.

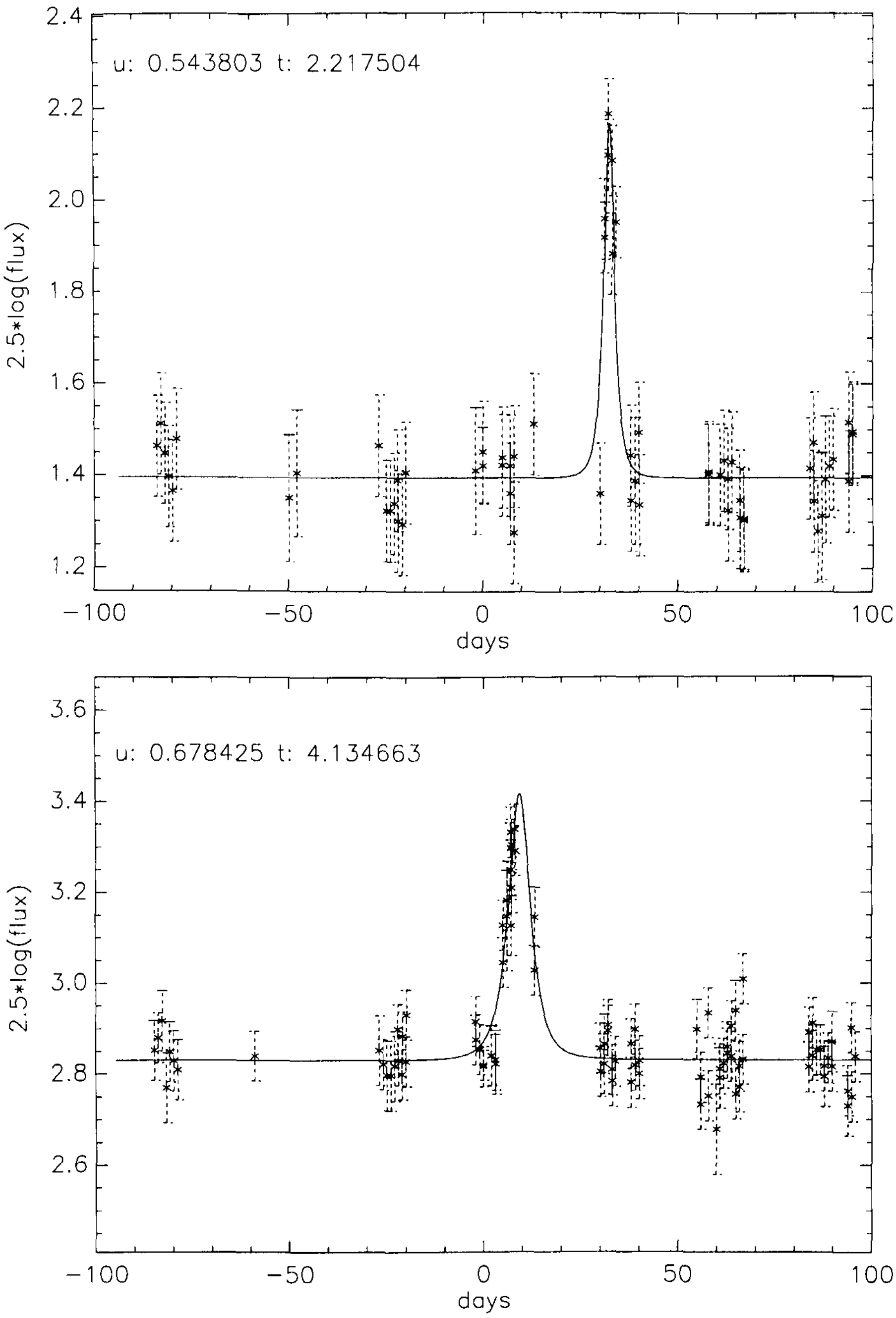

Figure 1: Two examples of microlensing candidates so far extracted from the data. Data from blue plates. The amplifications are close to 0.8 and 0.6 mag. respectively. At rest, star #a (top) is fainter than star #b (bottom) by about 1.4 mag, hence the larger error bars. For significance of the parameters, see Paczynski (1991): t the time it takes the relative positions of the source and lensing star to change by the apparent Einstein radius Re; u is the impact parameter (R/Re).

This wealth of information will contribute, together with the results obtained by the OGLE and MACHO groups, to improve our knowledge of the stellar populations and galactic structure in this region.

1. The DUO Project and its Objectives

The French DUO ("Disk Unseen Objects") project (Alard, 1995a, Alard et al., 1995) takes advantage of the large field of the ESO Schmidt telescope to investigate the stellar populations between the Sun and the Galactic centre. The area of one photographic plate (30 square degrees) covers a wide range of galactic coordinates, in the case of the DUO field : from *b*II = –4 to *b*II = –10, and from ℓII = 0 to ℓII = +6.

In this respect, DUO is complementary of the MACHO and OGLE CCD projects, which can benefit, among others, from a denser time sampling, but over a more restricted area.

In the region surveyed here, the stellar density is particularly large, but the extinction is moderate and relatively homogeneous, allowing monitoring of about 12 million objects on each Schmidt plate.

As was done for the EROS project (Aubourg et al., 1993), digitisation of the photographic material is performed with the fast and accurate microdensitometer MAMA (Machine Automatique à Mesurer pour l'Astronomie), designed and operated by INSU (Institut National des Sciences de l'Univers/CNRS), and located at Observatoire de Paris.

The scientific objectives of this project include:

– detection of low luminosity (if not dark) objects through microlensing amplification.

The EROS and MACHO groups reported the detection of microlensing candidates towards the Large Magellanic Cloud (Alcock et al., 1993, Aubourg et al., 1993), in the course of investigations aiming at searching for baryonic dark matter in the Galactic halo.

Towards the region of the Galactic centre, microlensed as well as microlensing objects can *a priori* be located either in the bulge, or in the disk. It is worth noting that our knowledge of the faint end of the stellar luminosity function is presently rather poor, even in the solar vicinity.

The OGLE and MACHO groups have already reported the detection of candidates in this direction using CCD detectors (see, for instance, Szymanski et al., 1994 and references therein, Alcock et al., 1995a). The unique feature of the DUO programme is its wide field which will allow us to produce a large-scale map of the microlensing optical depth. This is particularly important in order to disentangle the contributions of lenses situated in the disk and in the bulge, since their spatial distributions are very different (see, for example, the theoretical maps calculated by Evans, 1994 and Kiraga, 1994)

– structure of the bulge, and particularly of the Bar, the characteristics of which still remain largely unknown at the present time.

– study of stellar populations in general, using the multi-colour photometry which will be available for a large number of stars.

– short-period variables.

– long-period variables.

Several types of short- as well as long-period variables are interesting distance indicators. As a consequence, extensive monitoring of a large number of objects is expected to significantly improve our knowledge of the 3-D distribution of stellar populations in the bulge, particularly if the extinction can be estimated from visible and/or infrared multiband photometry.

Similar "by-products" of microlensing experiments are being obtained in the EROS, MACHO, and OGLE projects

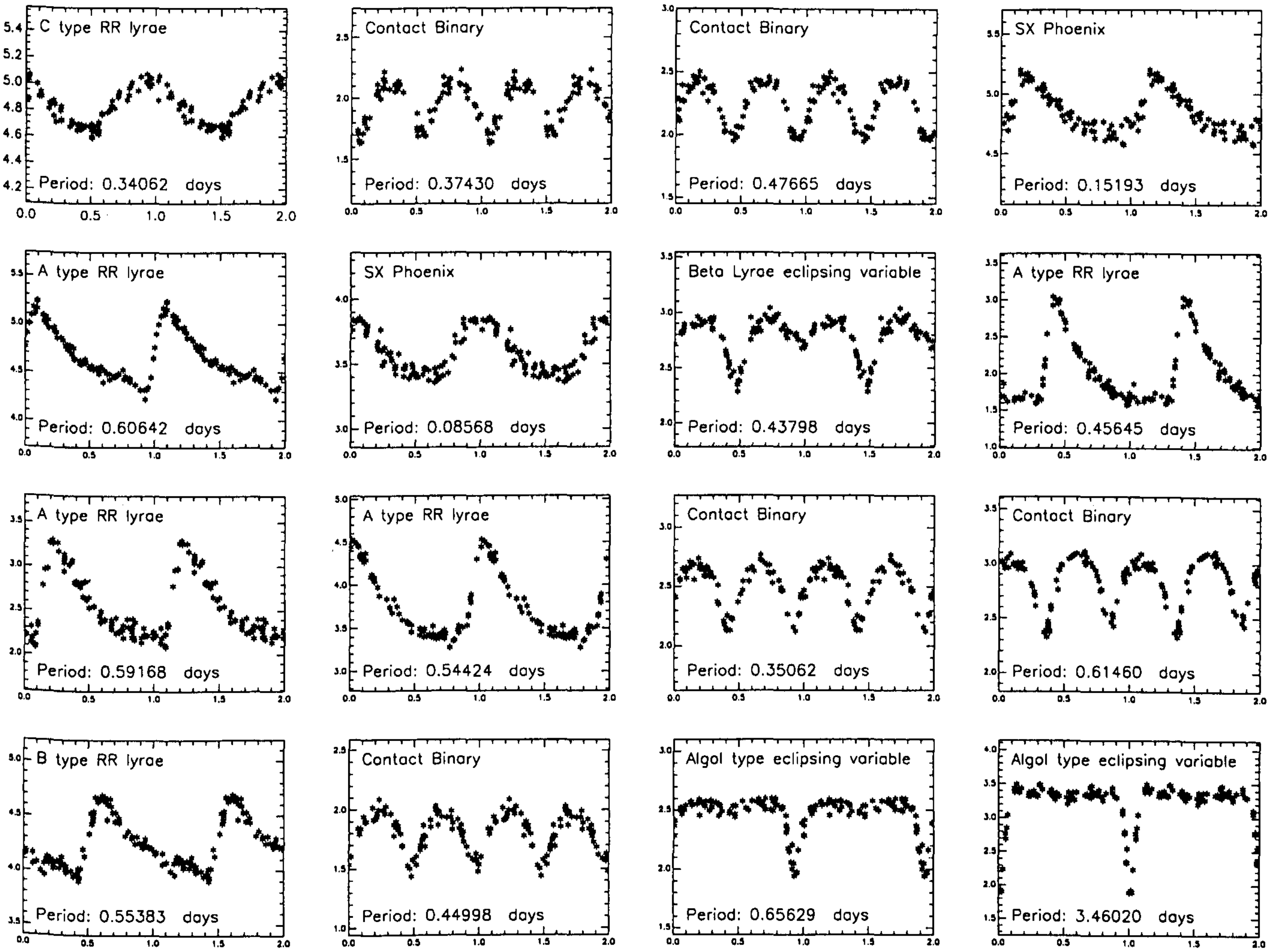

Figure 2: Some examples of the 10,000–15,000 new short-period variables expected from the DUO project. The variability type, derived from the shape and characteristics of the light curve, is indicated at the top of each box. The phase appears in abscissa, and the amplitude (in mag.) in ordinate. The light curve is repeated once for clarity.

(e.g.: Udalski et al., 1994a, Grison et al., 1995, Beaulieu et al.,1995).

2. Observations and Scanning

The plate material for the 1994 campaign is composed of about 200 plates, mainly IIIaJ and IIIaF, taken with the classical GG385 and RG630 filters, respectively, thus giving access to the blue and red parts of the spectrum. A few plates have also been obtained in other bands, namely with the combinations IIIaJ/UG1, IIIaF/GG495, IVN/RG715, for more detailed characterisation of the stars.

The plates were taken over a six-month period around June 1994, most often two IIIaJ and one IIIaF plates per dark night, all three with 20 minutes exposure.

The limiting magnitude is close to 21 and 19 in the blue and red colours, respectively. In view of the time sampling obtained in the blue band, microlensing events of short durations as well as short-period variables, known to be numerous in this region, are within the reach of the project.

The digitisation of one ESO Schmidt plate, performed with a 10 μm (0.67 arcsec) step, yields a series of FITS images requiring a total storage space of 1.6 Gbyte.

3. Reduction and Preliminary Results

In the DUO field, the stellar density, as detectable on Schmidt plates, turns out to range from 200 (in the north-west corner), to 100 (south-east corner) stars per square millimetre – i.e. per square arcmin. As a result, a total number of about 12 million stars can be monitored.

A special software has been designed and developed by one of us (Alard, 1995b) for optimal detection and photometry of this huge number of objects in a rather crowded field. The resolution achieved is better than 0.1 mag. for most of the monitored stars, and often better than 0.05 mag. For the magnitude calibration, CCD frames have been obtained at La Silla with the ESO/Danish 1.54-m telescope.

At the time of writing (April, 1995), half of the field has been entirely reduced, resulting in 8 million light curves. For each star, the stored information comprises the coordinates of the object on the reference plate, and, for the other plates, three bytes describing the magnitude and a confidence indicator. Therefore, for this zone, the requested storage space is 6 Gbytes.

From this significant amount of data, a first set of microlensing candidates, among them an object with a light curve suggesting a binary lens, has already been detected.

A high number of periodic variable objects has also been discovered, essentially eclipsing binaries and RR-Lyrae stars of various types. A total number of 10,000–15,000 such objects is expected for the whole DUO field. Long-period variables, for instance Miras, and irregular red variables, are also numerous in the region.

These first results are hereafter presented in some detail.

4. Microlensing Candidates

The theoretical microlensing magnitude variation has been fitted to the observed light curves after a preselection made among the time series, on the basis of consecutive three-σ deviations with respect to the minimum. The achromatism of the amplifications can be checked only for stars which, when not amplified, are sufficiently above the limiting magnitude of the red plates. The resolution is also better for the IIIaJ plates.

From the reduction of the first half of the field so far performed, some ten events appear to be reliable candidates for microlensing amplifications. Two examples, chosen among these, are shown in Figure 1.

Among the candidates, an object with an unusual light curve has been detected with three consecutive peaks within 7 days. This behaviour is quite surprising for an intrinsically variable object, and the most likely explanation seems to be an amplification by a double lens (Alard et al., 1995). The possibility of observing microlensing by multiple lens, anticipated by Mao and Paczynski (1991), has already been put forward by the OGLE group (Udalski et al., 1994b) on candidate OGLE #7, and later confirmed independently by the MACHO collaboration (Alcock et al., 1995b).

The confirmation of the suspected candidates, with characteristic durations ranging from 3 to more than 60 days, will require scanning and reducing the whole stack of plates, including those taken in the U band, in particular to eliminate the possibility that these events are produced by dwarf novae (Della Valle 1994).

5. Variable Stars

Figure 2 displays a set of short-period variables which are representative of the variety of the new interesting objects detected in the DUO field.

Eclipsing binaries represent the dominant population among the variable stars discovered in the course of our survey. The most numerous are contact binaries with periods smaller than one day, followed by Algol-type objects and Beta-Lyr systems, this ranking being consistent with the results obtained by the OGLE group (Udalski et al., 1994a) on 116 eclipsing binaries discovered in the centre of the Baade's Window. The large number of eclipsing objects which will be produced by the DUO survey is expected to make possible statistical investigations of this population which has been only poorly studied up to the present time.

RR-Lyrae stars represent about 20% of the variable objects so far detected in the DUO field. These can be used to map the interstellar reddening, and are also good distance indicators. They are therefore invaluable in investigations of the structure of the Galactic bulge. The latter issue is of prime importance, in particular, for the study of the Bar. Although the existence of the Bar appears to be well established by now, its orientation and axis ratio are still poorly known.

This component of the galactic structure is receiving special attention from the groups involved in microlensing projects (see, e.g. Kiraga, 1994 and references therein, Stanek, 1995 , Zhao et al., 1995, and references therein). The optical depth to gravitational microlensing in the direction of the Galactic bulge appears to be in excess by a factor of 5–10 with respect to the previously expected values (see, e.g. Evans 1994 and references therein). This could be due to bulge-bulge gravitational amplifications, the Bar playing a major role in this process if oriented towards the Sun as proposed by several authors.

6. The Near Future

The reduction of the second half of the field is in progress. Additional observations will be necessary, especially to improve the time base line, as well as to increase the statistics of microlensing events, and for the study of the long-period variables. This is the reason why we have applied for a second run at the ESO Schmidt: IIIa plates and Kodak 4415 Tech Pan films will be taken on La Silla from May to August 1995.

Acknowledgements

It is a great pleasure to thank B. Paczynski for fruitful discussions and valuable suggestions. We also thank G. and O. Pizarro for the set of excellent Schmidt plates taken at the ESO Schmidt telescope on La Silla, and the MAMA team for support during the scanning of this photographic material.

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The Variation of Atmospheric Extinction at La Silla

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1. Introduction

A total of 248,000 stellar photometric measurements have been obtained from the Swiss station at La Silla from July 1977 to August 1994, during about 4400 nights of photometric quality. These seven-colour photometric measurements in the Geneva System (Golay, 1980; Rufener, 1988) have been obtained by using successively two telescopes (40 cm and 70 cm), two photo-electric photometers and one CCD camera, from two different locations on the site of La Silla.

A very homogeneous set of photometric data, and, in consequence, of data on Earth atmospheric extinction in the optical domain has been collected. A first analysis of the atmospheric extinction variations was published by Rufener (1986, hereafter Paper I) for the period from November 1975 to March 1985. The annual and long-term variations were described as well as the effect of the

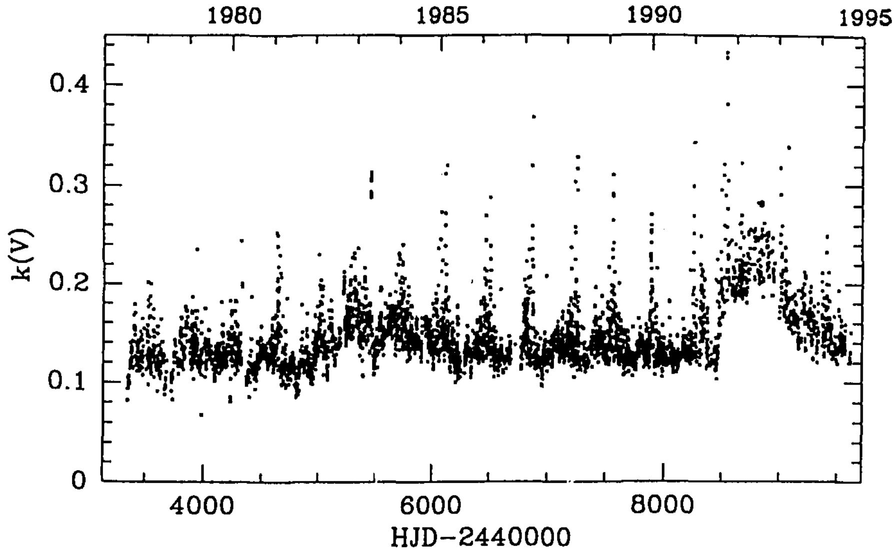

Figure 1: *Variations of the extinction coefficient in the V filter.*

volcanic aerosols injected in the Earth atmosphere by the eruption of the El Chichon volcano.

This problem has been revisited on the basis of the new photometric data (Burki et al., 1995, hereafter Paper II) because of: (i) the time period covered by the observations, which is now 17 years; (ii) the atmospheric extinction which has now been evaluated for all the photometric nights (and not only for the so-called MD nights (see Paper I) representing about only 20% of the photometric nights); (iii) the effect of another volcano eruption, that of the Pinatubo, which can be analysed.

2. The Variations of the Extinction

The general characteristics of the variations of the mean atmospheric extinction during the photometric nights of the past 17 years at La Silla are presented in Figure 1 for the filter *V*. The extinction variations can be decomposed into: long-term variations due to volcano aerosols, a mean annual variation and short-term variations due to meteorological aerosols.

2.1 Long-term extinction variations due to volcanoes

Two volcanoes are well known to have affected the Earth atmosphere's transparency, in particular at La Silla, during the past years:

El Chichon in Mexico (latitude +17°) had two eruptions, in March 23 and April 4, 1982 (HJD 2445051 and 2445064). The stratospheric loads due to El Chichon is estimated to reach about 8 megatons of sulphur dioxide SO_2, a radiatively very efficient absorbant when transformed into sulphuric acid by photochemical effect in the presence of water vapour (Mroz et al., 1983; McCormick & Swissler, 1983).

The Pinatubo in the Philippines (latitude +15°) had also two main eruptions: the first of four pre-paroxysmal vertical eruptions took place on June 12, 1991 (HJD 2448420), and the main eruption on June 15, 1991 (HJD 2448423). The estimation of the amount of SO_2 emitted to the atmosphere is about 20 megatons (Bluth et al., 1992; Pallister et al., 1992).

As shown by Figure 1: (i) these two volcanoes can be considered as the cause for the long-term variations of the extinction at La Silla during the past 17 years; (ii) the increase of the extinction at La Silla was very sudden, roughly 150 days (El Chichon) and 100 days (the Pinatubo) after the eruptions; (iii) the effect from the Pinatubo was much stronger than the one from El Chichon; (iv) the decantation of the volcanic aerosols in the atmosphere is very slow, lasting at least 1000 days, perhaps even 1300 days.

Our data permit to follow the evolution of the extinction law due to the volcano aerosols, during some hundreds of days following the eruptions. Adopting a law of the standard form $k(\lambda) \sim \lambda^{\alpha_p}$, we obtain that: (i) the aerosols from the two volcanoes were very different at their origin (or, more precisely, when they were detected from La Silla), the aerosols from the Pinatubo having produced a flater, or gray, extinction law; (ii) the "volcanic aerosols" produce very different extinction laws than the "meteorological aerosols" (see Section 2.2); (iii) the evolution towards an increase of α_p with time, observed in the cases of the two volcanoes, could mean that the volcano

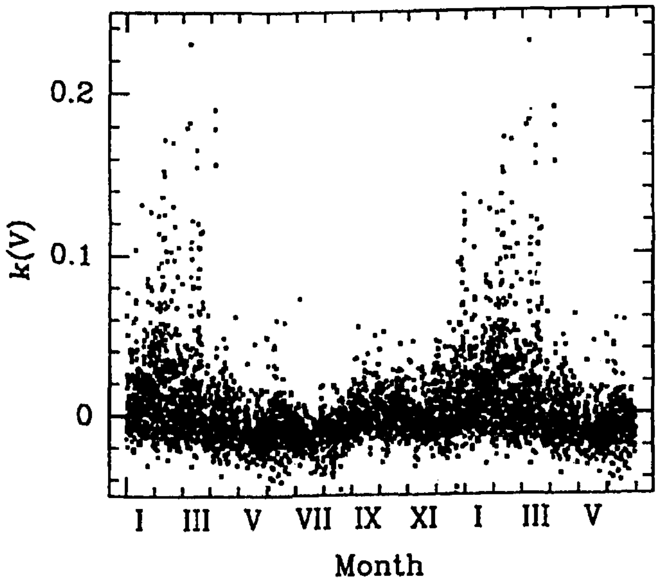

Figure 2: *The annual variation of the extinction coefficient in the V filter.*

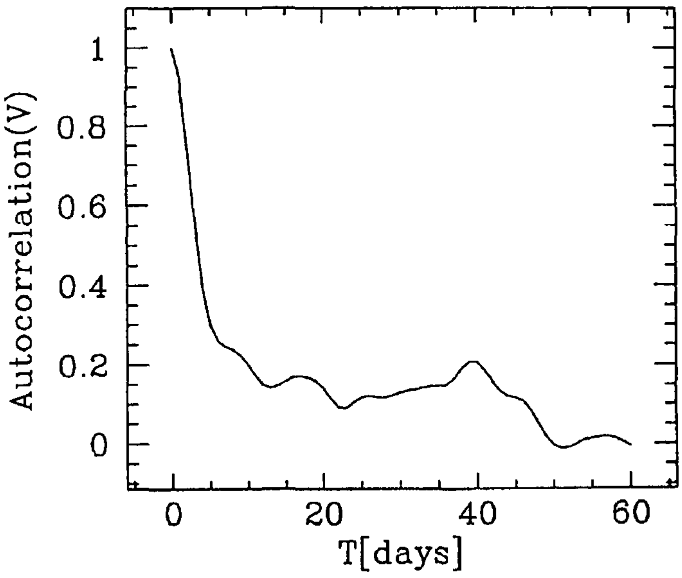

Figure 3: *Analysis of the series of the extinction coefficient determinations in the V filter by autocorrelation.*

aerosols have a size increasing with time, until they fall on the ground.

From the theoretical calculations of the extinction law (van der Hulst, 1952), we derive an increase of the typical aerosol radius from 0.4 to 0.7 μm from HJD 2445170 to 2446030 (El Chichon), and from 0.5 to 0.8 μm from HJD 2448670 to 2449260 (the Pinatubo). Thus, the typical radius was a little larger for the Pinatubo aerosols, and, in the case of both volcanoes, we note *an increase of the typical aerosol radius with time.* These conclusions are in agreement with the results obtained by Hofmann & Rosen (1983, 1987), Knollenberg & Huffman (1983), Oberbeck et al. (1983) in the case of El Chichon and Valero & Pilewskie (1952) in the case of the Pinatubo.

2.2 The annual variation of the extinction

The annual variation of the extinction is mainly due to the variation of the meteorological aerosol content in the atmosphere above the observing site. This variation can be examined by removing the minimum mean extinction values and the extinction due to volcanic aerosols (Section 2.1) to the global data. In addition, for the purpose of this Section, the data from the periods of two years following the eruptions of the two volcanoes have been excluded. The resulting extinction values in *V* have been plotted in Figure 2 versus the date in the year. We see that: (i) the minimum value of the extinction is relatively stable throughout the year; (ii) the maximum values are reached during the first part of the year, i.e. during the southern summer.

The extinction law for these meteorological aerosols has been determined in Paper II (the effect from the volcanoes having been removed): $k_p(\lambda) = b_p \lambda^{-1.39}$. The value $\alpha_p = -1.39$ (the Ångström factor) is remarkably stable and well defined at La Silla. It is known (e.g. Wempe, 1947; Ångström, 1961) that α_p varies within a small range and that, under global, average conditions, at a large variety of locations on the Earth, it has a value close to -1.3 ± 0.2, being seldom above -0.5 or below -1.6. The values of α_p larger than -0.5 are encountered under conditions when the atmosphere is, for instance, polluted by volcanic outbreaks or forest fires. When estimations concern specifically the meteorological haze, the values for α_p are less dispersed, between -1.25 and -1.45, and are independent of the haze density.

The component of the extinction analysed in this Section is related only to the haze present during the nights of very good and stable, *photometric*, atmospheric transparency. This is an indication that the distribution of the radii of the particles forming the haze (mainly constituted of water droplets) is quite stable during these nights and has its mode near the value 0.3 μm.

2.3 Short-term variations of the extinction

Is there any typical period of several days, or weeks, during which the extinction does not vary considerably? Or, in other words, is the extinction in a given night correlated to the extinction of the previous and/or the following night(s)?

Based on our large material, it is possible to give a clear answer to this question, for the La Silla site, since the extinction has been determined during almost all the photometric nights during a period of about 17 years. The best mathematical method to analyse these data is to use an autocorrelation technique. The results, presented on Figure 3, are based on the k(V) values obtained during the years 1985 to 1990 only (HJD 2446066–2448257), in order not to be affected by the effects from the volcanoes. An important autocorrelation appears for a time $T \leq 5$ days, shown up by a decrease of the function from 0 to 5 days: the autocorrelation is very high (0.90) for $T = 1$ day, and decreases until $T \simeq 5$ days. Consequently, *the global tendency is to have series of a few* ($n \leq 5$) nights with similar extinction values.

3. Conclusion

The variation of the atmospheric extinction is essentially due to the meteorological and/or volcanic aerosols. The characteristic time for these variations, *restricted to the nights of photometric quality*, varies from 2–3 hours to several years. The amplitude of these variations is large: during the 4400 nights of our photometric activity, the proportion of the light diffused or absorbed by the Earth atmosphere has varied, in the *V* band, from 9% (minimum extinction) to 33% (beginning of the period affected by the aerosols from the Pinatubo).

In the case of ground-based measurements, the correct estimation of the fluxes "outside the atmosphere" must absolutely be done by using the atmospheric extinction value for the site and at the time the measure has been performed. In the cases of stable photometric nights, the mean value for the night can be used. An estimation based on the extinction values of other nights will give correct results only by chance.

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FITLYMAN: A Midas Tool for the Analysis of Absorption Spectra

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Introduction

The introduction of echelle spectrographs on 4-m telescopes has allowed the observation of faint objects ($m < 18$) with high resolution ($R = \lambda / \Delta\lambda > 20{,}000$). In the study of the interstellar and intergalactic medium, where the absorption lines from tenuous and relatively cold ($T \leq 5 \times 10^4$ K) clouds are sought in the spectrum of bright background sources, this resolution allows the observation of narrow lines with an instrumental FWHM lower than their intrinsic width. This makes it possible to independently derive the column density N and the Doppler width b from line profile fitting, rather than from the curve of growth analysis. Typical applications of these techniques are the study of the Galactic clouds, which trace the gas content and the metallicity inside the Galaxy, and of the absorption systems found in the spectra of high redshift quasars, which trace the evolution of primordial structures.

The fit of heavy element systems may require the simultaneous fit of different lines spread all over the spectrum. For these lines, it is often necessary to test different configurations (i.e. number of components and constraints on them) before a satisfying fit is achieved. In the analysis of the Lyman-α forest, on the contrary, hundreds of independent lines are fitted, which must be identified by the user himself. In any case, a significant fraction of the time required for this analysis is spent in user interaction rather than in computing time.

Three different approaches to this problem are known: (a) interactive construction of a Voigt profile until a

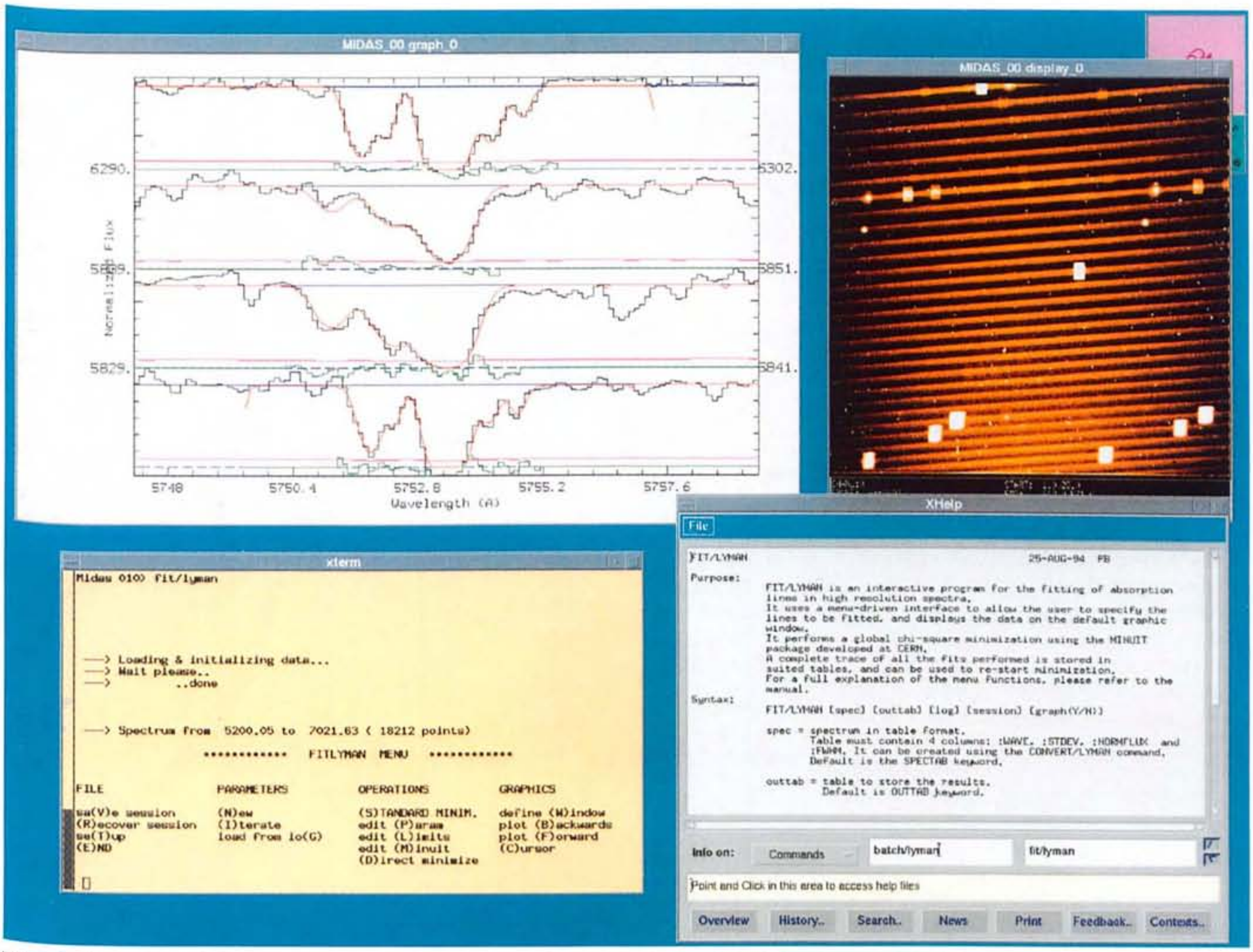

Figure 1: *Example of a FITLYMAN session. The Main Menu is shown in the bottom left window. The graphic window over it displays a fit performed on a complex metal system at z = 2.768. Lines fitted are, from the top, Al1670, CIV1550, CIV1548, SiII1526. The CIV doublet has been fitted with three components, lower ionisation elements with five. Data from Giallongo et al., 1993, and J. Wampler.*

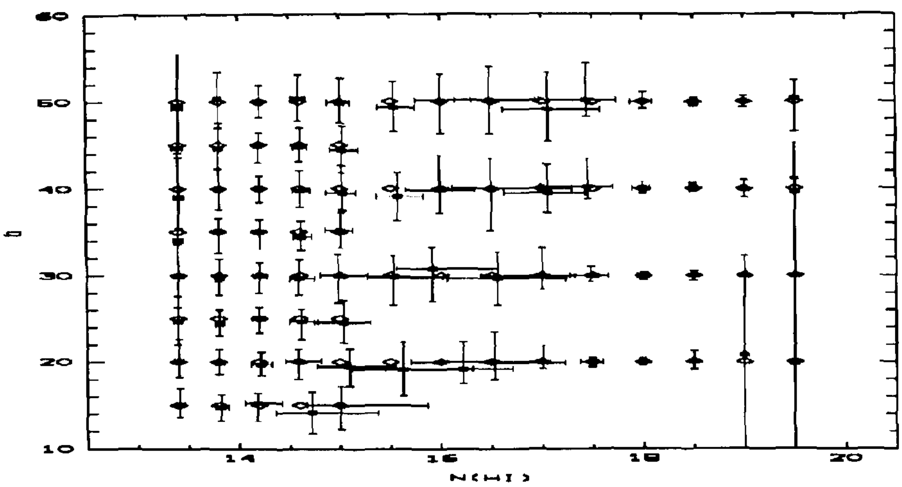

Figure 2: Results of a set of simulated fits. Squares represent the mode value (i.e. the most probable value) of the median value of the b, N values obtained by the fitting procedure, and the error bars show the region where 68% of the points are found, representing an estimate of the observed scatter. Lozenges are the "true" parameters of the line.

satisfactory solution has been achieved (Mar & Bailey, 1995) ; (b) construction of a photo-ionisation model, from which the relevant absorption lines are computed (e.g. using the Midas context Cloud) and finally compared with the data (Wampler et al., 1995); (c) fit of a Voigt profile by numerical minimisation of χ^2 (Carswell et al., 1991, Giallongo et al., 1993).

Even though the two former methods have the advantage of being more intuitive and easier to implement, the latter approach is usually preferred, since it is more objective, testable through numerical simulations, provides an accurate estimate of the errors, and is usually faster.

While the reduction of echelle spectra to 1D calibrated spectra may be accomplished with several standard astronomical packages (such as the MIDAS Echelle context), no similar tool exists for the fit of their absorption features. The lack of a software tool properly tailored for all the different aspects of this problem has moved us to the realisation of FITLYMAN, a new package available in the Lyman context of the Midas 94NOV release, that we present in this paper.

This code is the evolution of a former version, developed at the Osservatorio Astronomico di Roma (Giallongo et al., 1993). It allows the fit of Voigt profiles to a large number of absorption lines in a normalised spectrum through the numerical minimisation of χ^2. Its main features are flexibility in specifying the line configuration, a fast user interface, and full documentation on the fit as performed.

Special care has been taken to maximise the efficiency of the user operations: FITLYMAN provides recursivity and allows recovery of previous configurations.

Main Features

We describe here the most important features of FITLYMAN: for a more complete description of the commands and algorithms please refer to the ESO Midas User's Manual.

• Each absorption line is modelled by a Voigt profile, whose parameters are the central wavelength λ_c, the column density N and the Doppler broadening b. The line profile $I(\lambda)$ for a spectrum $I_0(\lambda)$ is $I(\lambda) = I_0(\lambda) e^{-\tau(\lambda)}$ where the optical depth is $\tau(\lambda) = \frac{N r_0 f \sqrt{\pi} c \lambda_c 10^{-8}}{b \sqrt{2 \ln 2}} H(a, u)$. $H(a,u)$ is the Voigt function, defined as:

$$H(a, u) = \int_{-\infty}^{\infty} \frac{e^{-y^2} dy}{a^2 + (u-y)^2}$$

whose parameters a and u are given by:

$$a = \frac{\Gamma \lambda_c}{4 \pi b 10^{13}}; \quad u = \frac{(\lambda_c - \lambda) c}{b \lambda_c \sqrt{2 \ln 2}}$$

Here, r_0 is the classical radius of the electron, c is the speed of light, λ_c, f and Γ are the three parameters associated with the observed transition (i.e. rest frame central wavelength, oscillator strength and damping coefficient, respectively).

In general, the Doppler broadening of a line is due either to the intrinsic thermal broadening $b_K = (2kT/m)^{0.5}$ or to a turbulent motion of the gas $b_T = \sqrt{2}\sigma_T$, where σ_T is the inner velocity dispersion. When transitions from different ions are observed, it is possible to constrain the two cases: for the thermal component of the broadening, indeed, the b-values of different atoms scale with the masses as $b_{ion1}/b_{ion2} = (m_{ion2}/m_{ion1})^{0.5}$, while in the turbulent case they remain essentially equal. To allow for a complete analysis of the physical conditions of the absorbing clouds, both types of b-values can be accounted for in computing the line profile: each line is thus parameterised by *four* different parameters (λ_c, N, b_K, b_T), and the Voigt profile is computed using a b-value $b = (b_K^2 + b_T^2)^{0.5}$. This unique feature, combined with the possibility of constraining the different parameters in a flexible way (see below), allows for the simultaneous fitting of different ionic transitions to yield meaningful values for both the turbulent and thermal broadening.

• An extensive set of atomic parameters is supplied: it allows for the fitting of several ionic transitions found in absorption spectra, and can be easily expanded by the user him/herself.

• It is possible to simultaneously fit lines from different ions, or from different transitions of the same ion, specifying several links (relations) among them which reflect the physical condition in the cloud responsible for the absorption. The lines can be forced to share the same

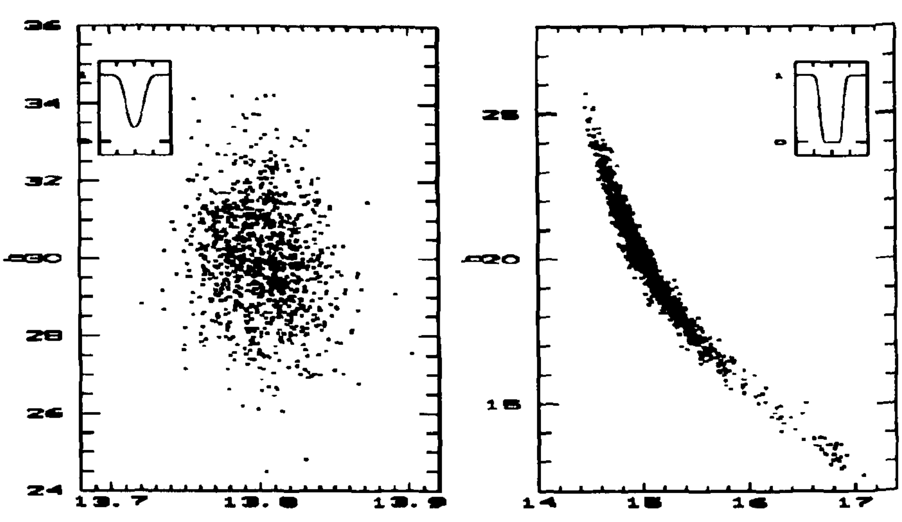

Figure 3: Values of Doppler parameter b and column density N obtained by the fitting procedure for 1000 lines of b = 30 and log N = 13.8 (left) and for 1000 lines of b = 20 and log N = 15 (right). Small boxes show the respective line profile

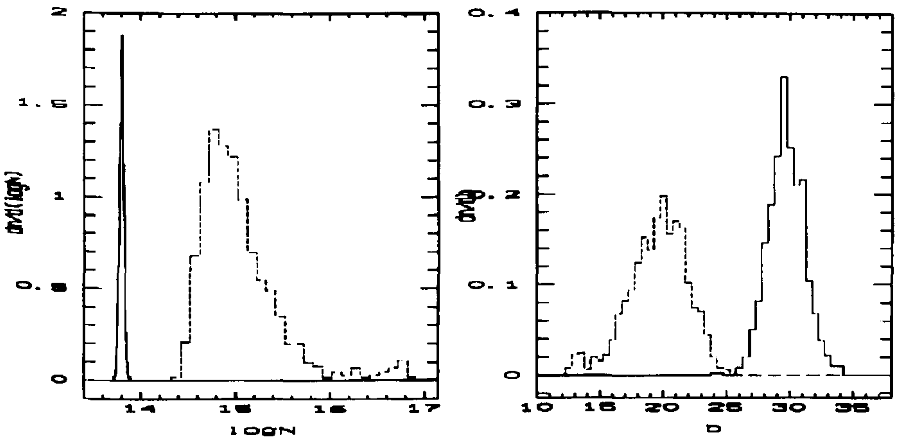

Figure 4: Distribution of Doppler parameter b (right) and column density N (left) obtained by the fitting procedure for 1000 lines with S/N = 10. Solid line is for lines of b = 30 and log N = 13.8, and dashed line is for b = 20 and log N = 15. Solid line on the left panel has been divided by 10 for illustrative purposes.

velocity relative to the earth (redshift), and/or the same column density N, and/or the same b value, and/or the same temperature T by properly scaling (b_K) with the ion masses. Any combination of lines and links is allowed, the only limit being the maximum number of independent parameters which the programme can handle (currently 100). In general, the number of free parameters depends on the kind and number of links imposed: for instance, when the lines are forced to have the same absorption redshift, there is only one actual free parameter (i.e. the redshift), not one for any individual central wavelength.

The absolute freedom in specifying links with these rules is a powerful tool when the ionisation and metallicity of a system is investigated, and also to correct for possible systematic errors: for instance, two lines far away in the spectrum (e.g. Si II1260 and Si II1526) might be forced to have the same b and N but different redshifts, to allow for some wavelength calibration uncertainties.

• The input data have to be stored into a Midas table, containing wavelength, normalised flux, standard deviation and instrumental FWHM for each pixel. A tool for the conversion of the usual image data to this format is supplied. Both pixel size and resolution can vary along the spectrum. Gaps may exist in the spectrum, provided that they do not fall in fitted regions.

• The numerical minimisation is performed using the MINUIT package, developed at CERN. It allows for the simultaneous minimisation of up to 100 free parameters (equivalent to at least 33 independent absorption lines). The user can choose among different minimisation algorithms or strategies. For instance, some parameters may be fixed at the first iteration, to find a reasonable "first guess" solution, and then released to achieve the final result. This procedure is particularly useful to find meaningful solutions in complex situations. The original MINUIT package can also be used in interactive mode: since this option is not compatible with the Midas command language, it has been disabled in FITLYMAN. Nevertheless, all its relevant functions can be invoked from the User Interface: this solution also eliminates the necessity of learning the MINUIT command language.

MINUIT may perform an accurate error analysis, by computing either the covariance matrix and/or more detailed statistics, as non parabolic errors or scans and contour levels in the χ^2 space.

• In principle, the results of each minimisation depend on several parameters, which specify: (a) the line configuration, (b) the spectrum regions where the χ^2 is computed and (c) the MINUIT commands used. To keep track of these parameters, each minimisation is associated with a unique identifier, whose value is stored in the output table. At the same time, the full initial configuration, together with the same identifier, is stored in three "log" tables. Later, these tables can be either consulted for the interpretation of the results, or used to re-start the minimisation. Furthermore, a batch procedure (BATCH/LYMAN) allows for the automatic, non-interactive fit of a whole spectrum using the configurations stored in the "log" tables.

• The FITLYMAN User Interface has been designed to satisfy two different – and almost opposite – requirements: it must allow the user to handle and modify all the parameters needed for the minimisation, reducing the requested time as much as possible. To fulfill the Midas requirements about compatibility with any kind of terminal and environment, we have designed a menu-driven User Interface which uses both the standard I/O devices (keyboard + screen) and the standard Midas graphics window.

A Main Menu introduces the user to all the functions available in the programme, such as modifying the input parameters, loading/saving previous configurations, modifying the set-up options of the programme, or accessing the graphics device. The parameters which specify a line configuration may be entered or modified either by answering a sequence of questions that guide the user to the correct sequence of operations (to be preferred when new lines are defined), or by directly accessing their values (to modify a few parameters).

The input spectrum and the fitted profile are plotted on the active graphics window. Optionally, the standard deviation and/or the residuals may be plotted as well. The cursor in the graphics window may be used to enter the wavelengths needed to specify some parameters (e.g. "first guess" central wavelength or the intervals over which the χ^2 is computed).

An example of a working session with FITLYMAN is shown in Figure 1.

Performance and Examples

To investigate the accuracy and stability of the results obtained with

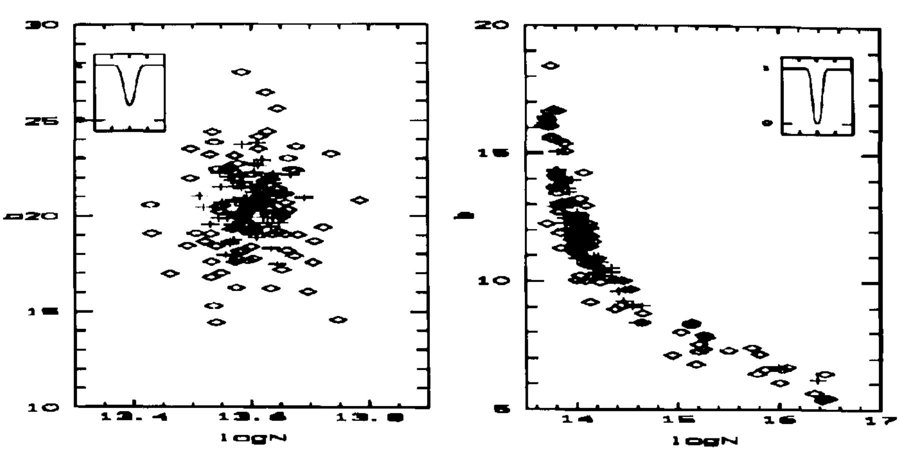

Figure 5: Values of Doppler parameter b and column density N obtained by the fitting procedure for 100 lines at different S/N ratio. Lozenges are for S/N = 5, crosses for S/N = 10. Left: an unsaturated line of b = 21 and log N = 13.6; right: a saturated line of b = 12 and log N = 13.8. Small boxes show the respective line profile.

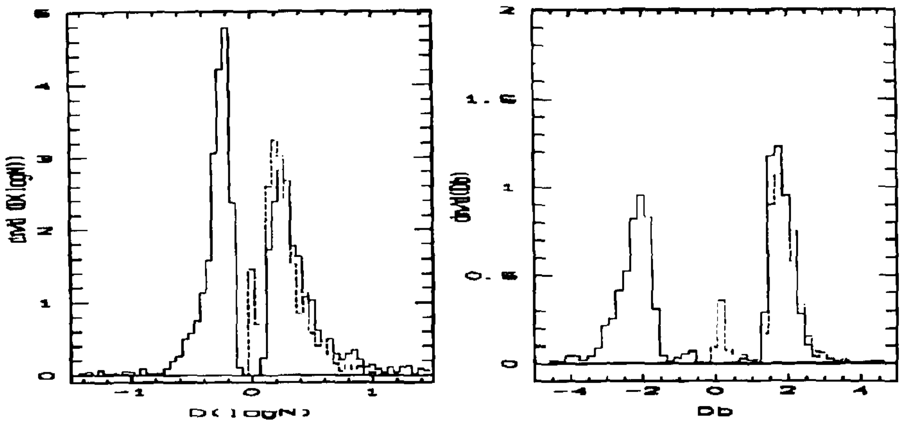

Figure 6: Distribution of statistical errors computed by MINUIT. Left: errors on column density; right: errors on Doppler parameter. Solid line is from the MINOS procedure, dashed line from the HESSE procedure. Note that a fraction of errors estimated with HESSE are implausibly small. Data are for 1000 saturated lines of b = 20 and log N = 15.

FITLYMAN, we have performed extensive tests on simulated data. Clearly, these tests cannot span the whole range of resolution and signal-to-noise ratio available: anyway, since the test data were entirely generated and analysed with the programmes available in the LYMAN context, we strongly invite every user to perform similar tests to evaluate the possible systematic effects on his/her data.

Stability

Concerning the stability of the algorithm we found that, when single lines have been fitted, the results have proven to be remarkably insensitive to the "first guess" values used in the minimisation. Even implausible initial values usually converge to the correct values, the only cost being extra computing time. When more complex situations – i.e. severe blends of many lines – are to be fitted, it may be necessary to provide reasonable initial values to obtain the correct answer.

This behaviour is due to the complex shape of the χ^2 hyper-surface in the parameter space, that may present local minima for unphysical solutions.

Noise effects

To explore the influence of noise on the fitted values we have defined a grid of N and b values, and for each pair we have computed and fitted 100 HI lines with central wavelength 5000 Å (i.e. with $z \simeq 3.11$) and S/N = 10. Figure 2 shows the results obtained for b and N (the central wavelength has always been found with great accuracy). Four regions can be identified. For unsaturated lines (leftmost points) the mode value is quite close to the "true" value, with a small and symmetric scatter around it. As the central flux of the line reaches zero, the spread around the "true" value becomes larger and usually asymmetric: in some cases there is a measurable shift of the mode value, even if it is always well within the observed 68% spread. At higher column densities, however, the line shape becomes unambiguously defined by the appearance of the Lorentzian wings, and the fit becomes much more precise. Finally, for the highest column densities the line width becomes too large for the Doppler broadening to be effective, and b becomes practically undetermined. Clearly, the values of column density and Doppler parameter for which the lines saturate or the damping wings appear, depend on the considered ionic transition.

We have investigated in more detail two cases, which may represent most of the typical situations: an unsaturated Lyman-α line (b = 30, log N_{HI} = 13.8) and a moderately saturated one (b = 20, log N_{HI} = 15.0). In Figure 3 the results of 1000 simulated fits for each line are reported in the $N - b$ plane, while in Figure 4 their b and N distributions are shown. For the unsaturated line the b and N values are essentially uncorrelated (see Figure 3, left panel), and the fitted values are distributed around the "true" values according to Gaussian statistics (Fig. 4). For saturated lines the $b - N$ correlation is quite strong, and the uncertainties on N are much greater. The fitted values are thus distributed along the curve of constant equivalent width, as shown in Figure 3 (right panel). The observed b and N distributions are rather asymmetric, with a tail extending far away from the mode value (Figs. 4a, b). In any case, most of the fitted values are still confined in a region close to the "true" values.

Different levels of S/N ratio do not seem to change the results outlined here qualitatively. As an example, in Figure 5 we report (in the $N - b$ plane) the results of 100 simulated fits with S/N = 10 (crosses) and S/N = 5 (lozenges) for two different lines. At lower S/N the spread of the fitted values obviously increases, but this is entirely consistent with the increased uncertainties on the equivalent width. No systematic effect seems to arise as a pure effect of lower S/N.

Summarising, the effect of noise on the fitting of isolated lines is mainly a spread of the fitted values, without any severe systematic effect. For saturated, but not damped, lines the spread is wider, and occurs along the curves of constant equivalent width, which is an integral quantity poorly affected by noise fluctuations. This gives a characteristic anticorrelation in the b and N plane. We stress that these simulations do not take into account other processes that may alter the fit (Rauch et al., 1993), such as selection effects in the identification of the lines, line blending and a wrong choice of the limits of minimisation (see below).

Error estimate

We have hence tested the MINUIT ability in giving realistic estimates on the statistical errors on fitted values. Errors

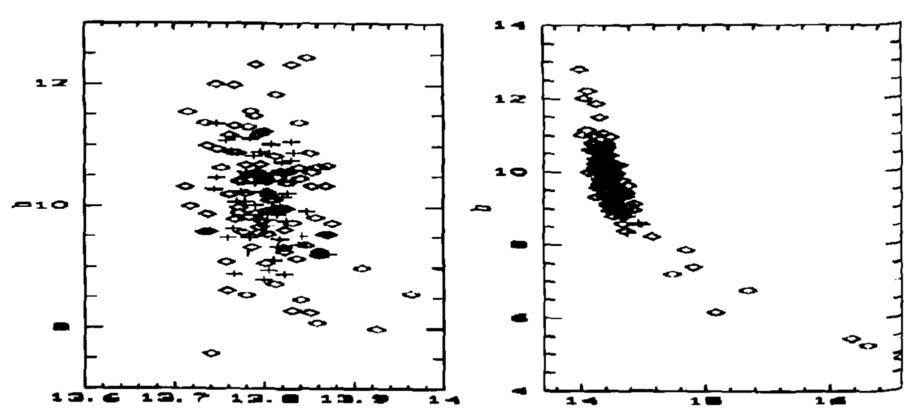

Figure 7: Values of Doppler parameter b and column density N obtained by the fitting procedure on CIV doublets. Lozenges are for individually fitted lines, crosses are for the same lines when the fit is on the two lines simultaneously. Left: b = 10 and log N_{CIV} = 13.8 ; right: b = 10 and log N_{CIV} 14.2.

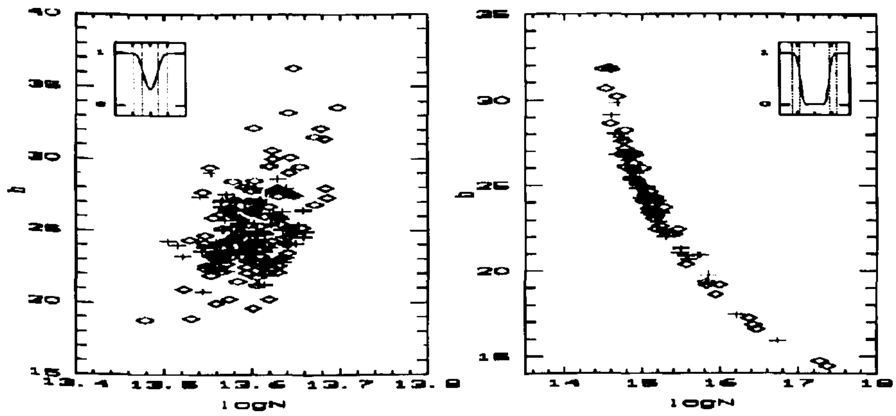

Figure 8: Values of Doppler parameter b and column density N obtained by the fitting procedure on Lyα lines with different fit intervals. Lozenges are for limits set at half intensity of the line, crosses are for the same lines when the fit is over the whole line width. Left: b = 25 and log N_{HI} = 13.6 ; right: b = 25 and log N_{HI} = 15. For clarity, on the right only 50 representative points are plotted. Small boxes show the respective line profile, with the different intervals considered.

may be computed by MINUIT either by inverting the covariance matrix (*HESSE* command) or by scanning the χ^2 hypersurface around the minimum (*MINOS* command) until a 1 σ offset has been reached. In Figure 6 we plot the observed distributions of the errors obtained with both methods for 1000 simulated lines of *b* = 20 and log *N* = 15. The peak value of the distributions is in good agreement with the observed dispersion in fitted values (see Fig. 4). Clearly *HESSE*, due to its symmetric nature, cannot account for the asymmetric distributions such as those shown in Figure 4. This is better accomplished by *MINOS*, as is shown in Figure 6, where the two error distributions are compared: as can be seen, the peaks and the shapes of the *MINOS* errors are not symmetric. We have also found out that both of them are sometimes inaccurate: the first one, for inexplicable reasons, provides implausibly small values in a significant fraction (~ 15 %) of the lines (see Fig. 6, dotted line), while the second is not computed in a small fraction of cases (~ 5 %). Thus, we suggest the performance of both computations, to check for consistency of the results.

Fit of metal systems

We have also verified that the simultaneous fit of different metal lines does significantly increase the precision attainable in the fit. We have performed a set of fits on simulated CIV doublet spectra, again for different values of *b* and *N*, at S/N = 10. A self-explanatory example for two of them is reported in Figure 7. The results of our simulation clearly indicate that the simultaneous fit of different ionic transitions should be exploited whenever possible.

Limits of the fit region

As has been pointed out by Rauch et al. (1993), great care must be taken when choosing the limits on which the χ^2 is computed.

Following Rauch, we quantified the systematic effects by fitting the same set of lines with different limits, repeating this test for different *b* and *N* values. When the limits are chosen inside the line (i.e. before the line has reached the continuum) two effects arise. The first is an increase in the noise on the equivalent width, due to the reduced number of pixels: this reflects into a larger dispersion of the fitted values. Furthermore, severe systematic effects may appear, in particular in the fits of saturated lines, which depend strongly on the line profile close to the continuum level. Thus, *the limits must always be chosen as wide as possible*, in order to follow the line profile up to the continuum. Two examples of the simulated fits are shown in Figure 8.

Improvements

The Lyman context is still an evolving tool. Some improvements are already being implemented, and will be released with the future versions of Midas. Among these, the possibility of drawing plots in the velocity space, and more commands for the research of metallic systems. The convenience of a GUI version is currently being evaluated.

We are grateful to D. Trevese and L. Camurani for having supplied the first version of the code, and E. Giallongo and P. Petitjean for useful suggestions and discussion.

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Astronomers in Chile Meet at ESO in Vitacura

BO REIPURTH, ESO-Chile

During September 1994 the Astronomy Support Department of ESO-Chile moved its offices and facilities from the La Silla observatory to ESO's Vitacura premises in Santiago. Here a new institute of astronomy has emerged and is now successfully operating. For the past two decades ESO astronomers have had their work place at La Silla and have consequently been fairly isolated. With our move to Santiago this situation has significantly improved, and ESO is now able to a much larger degree to be a partner in the wider astronomical activities in Chile.

To celebrate ESO's new presence in Santiago and to further the possibilities for increased scientific ties between the various astronomical institutions in Chile, a three-day workshop *Astronomy in Chile* was held 18–20 April in Vitacura. All astronomers working in Chile were invited, and the workshop gave the about 50 attendees an opportunity to learn about the wide range of astronomical interests currently pursued within Chile. Except the staff working those days at La Silla, Cerro Tololo and Las Campanas, and those travelling abroad, virtually all astronomers in Chile were present. The accompanying list gives an alphabetical list of the speakers and the titles of their talks, which were held in either English or Spanish. Chilean astronomy is principally concentrated in Santiago, but recently efforts from several universities in other cities have been made to develop astronomy, and new groups are emerging in Antofagasta, La Serena and Concepción, led by Luis Barrera, Sergio Char and Ronald Mennickent, respectively.

On the third day of the workshop, a special session was chaired by Mark Phillips of CTIO, who gave an introduction to the growing problem of light pollution that threatens all observatories in the world. He enumerated a number of actions that must be undertaken to safeguard the darkness of the night sky in Chile. During the discussion that followed it was clear that here is a problem that will require joint efforts from all the groups affected.

The workshop happened to coincide with the signing in Bonn of the supplementary agreement between ESO and Chile, and Daniel Hofstadt was able to break the good news to the audience. The workshop unfolded in a positive and collaborative spirit, and we all enjoyed the opportunity to share with each other our scientific results. Even the weather collaborated, and several warm and sunny autumn days allowed the conference lunches to be held in the gardens around the institute. The workshop ended with universal agreement that more such pan-Chilean astronomy meetings would be welcome.

Talks Presented at the Astronomy in Chile Workshop 18–20 April 1995

Thomas Augusteijn (ESO): V485 Cen: A Dwarf Nova with a 59 Min Orbital Period

Luis Barrera (U. Católica del Norte): Fe II, Fe III and Mg II lines in the Spectra of Be Stars

Patrice Bouchet (ESO): What's new about SN 1987A? (and Future Studies of Dust around SNe)

Leonardo Bronfman (U. de Chile): Molecular Clouds and Massive Star Formation in the Galactic Disk

Luis Campusano (U. de Chile): Large Quasar Groups

Eleazar Carrasco (U. Católica): CCD-Photometry of the Brightest Galaxies in Abell Clusters

Sergio Char (U. de La Serena): Studies of Ca II emission in Fast Rotating Stars

Pascal Fouqué (ESO): The DENIS 2 mm Sky Survey: Introduction and Present Status

Guido Garay (U. de Chile): Recently Formed Massive Stars: Molecular and Ionized Environs

Wolfgang Gieren (U. Católica): Studies of Cepheid Variables in the Magellanic Clouds

Roland Gredel (ESO): Molecular Hydrogen in Herbig-Haro Objects

Adelina Gutierrez/Hugo Moreno(U. de Chile): A Diagnostic Diagram for Planetary Nebulae and Symbiotic Stars

Eduardo Hardy (U. de Chile): The Stellar Populations of Fornax

Steve Heathcote(CTIO): The Herbig-Haro 47 Jet

Leopoldo Infante (U. Católica): A Survey of Faint Pairs of Galaxies

William Liller (Inst. I. Newton): Observations of Novae, Dwarf Novae and False Novae

Gautier Mathys (ESO): Magnetic Field Diagnosis in Ap and Bp Stars

Jorge May (U. de Chile): Molecular Clouds in the Outer Galaxy

José Maza (U. de Chile): Calan-Tololo Survey: Quasars and Seyfert Galaxies

Duilia de Mello (CTIO): Mixed Pairs of Galaxies

Jorge Melnick(ESO): Star Formation in Cooling Flows

Jorge Melnick (ESO): Progress at La Silla and Paranal

Ronald Mennickent (U. de Concepción): Understanding Strongly Eruptive Dwarf Novae

Fernando Noel (U. de Chile): Sun Semidiameter Survey with a Danjon Astrolabe

Lars-Aake Nyman (ESO): The Kinematics of the Bipolar Reflection Nebula IC 2220

Patricio Ortiz (U. de Chile): Search of Quasars using CCD's and Objective Prism Techniques in Widefield Telescopes

Luca Pasquini(ESO): Lithium Abundances in the Globular Cluster NGC 6397

Mark Phillips (CTIO): First Results from the High-Z Supernova Search

Hernan Quintana (U. Católica): Cluster and Galaxy Group Mergers

Bo Reipurth(ESO): Herbig-Haro Jets and Molecular Outflows

Miguel Roth (Las Campanas Observatory): The Magellan Project

Monica Rubio (U. de Chile): Molecular Gas in the Magellanic Clouds

Maria Teresa Ruiz (U. de Chile): Cool White Dwarfs

Ricardo Schmidt (CTIO): Present Instrumentation Projects at CTIO

Robert Schommer (CTIO): The Motion of the Local Group with Respect to Distant Supernovae

Hugo Schwarz (ESO): M2–9: Dusty Mirrors in the Sky!

Malcolm Smith (CTIO): The Gemini Project

Roger Smith (CTIO): CCD's and Controllers at CTIO

Amateur Astronomers and Dwarf Novae

L. T. JENSEN (Denmark); G. POYNER (United Kingdom); P. VAN CAUTEREN (Belgium); T. VANMUNSTER (Belgium)

1. Introduction

On December 15, 1855 the English astronomer John Russell Hind (1823–1895) was searching for new minor planets in the constellation of Gemini. During this search he found a new star at approximately 9th magnitude. A new asteroid? He observed the star for several days and found that it didn't move – thus not an asteroid! The next few days the star became fainter and fainter and it was soon invisible in Hinds telescope. He thus classified the star as a faint nova. But a few months later in March 1856 the star was seen again, this time by another English astronomer Norman Robert Pogson (1829–1891). From this moment the star was monitored more systematically and more outbursts were observed. The period between the outbursts was calculated at approximately 100 days. A nova with numerous outbursts was a new phenomenon, so the first member, U Geminorum, of a new class of variable stars, dwarf novae, was discovered! 40 years passed before the next member of this class, SS Cygni, was discovered in 1896. Since then a few hundred dwarf novae or possible dwarf novae ([Downes and Shara, 1993] list 349) have been discovered. Most of these are faint and have only been observed very infrequently. In several cases the classification of dwarf novae is based on very few observations.

The observation of dwarf novae (and other cataclysmic variables) is one of the few fields of astronomy in which amateur astronomers still can deliver substantial contributions to the work of professional astronomers. The unpredictable behaviour of most cataclysmic variables makes it very difficult for professional astronomers to monitor these variables systematically. Our current knowledge and understanding of the physical processes, that form the basis of the dwarf novae outburst mechanism, are still subject to a lot of controversy. In this article the work of a world-wide network of amateur dwarf novae observers is described. We present some examples of the important results achieved by these observers. Moreover we describe the instruments, the charts and the observational methods used.

2. Dwarf Novae

Dwarf novae are associated with a special type of interacting binary stars – the cataclysmic binaries. In a cataclysmic binary a mass-losing secondary (often a late main-sequence dwarf) is in close orbit with a white dwarf primary. The orbit is so close that the secondary star fills its Roche-volume and hence it loses material through the inner Lagrange point L1. The lost gas is accumulated in an accretion disk around the white dwarf. This material then accretes onto the surface of the white dwarf from the disk. At the point where the stream of gas from the secondary impacts the disk, a shock front is formed which results in a hot spot. The luminosity of the disk and the hot spot accounts for most of the luminosity of the entire system. The orbital periods of cataclysmic binaries are very short, a little over 1 hour to about 15 hours. As the orbital periods indicate, cataclysmic binaries are very small systems, and often the dimensions are comparable with solar diameter. Dwarf novae are cataclysmic binaries exhibiting quasi-periodic eruptions of several magnitudes (2–8). Most of the time they stay in a minimum state, but now and again this state is interrupted by abrupt outbursts. The outbursts last from a few days to about 14 days. The time between the outbursts, the recurrence time, ranges from 10 days to months, and in some cases several years. The recurrence time for an individual dwarf nova is not at all constant. It is only possible to indicate an average recurrence time, e.g. the recurrence time for SS Cyg ranges from 15 to 95 days with 50 being the average. The same unpredictability holds for other dwarf nova characteristics as outburst amplitude and outburst duration.

Dwarf novae are divided into 4 subclasses according to their specific behaviour.

SS Cyg type (UGSS): This class contains the classical dwarf novae, i.e., stars like U Gem and SS Cyg.

Z Cam type (UGZ): In addition to the behaviour shown by the SS Cyg subtype, stars of the Z Cam type are characterised by standstills in their light curves. The eruption light curve is occasionally interrupted by periods of standstill lasting from days to several years. During the standstills the star remains at a brightness between the normal maximum and minimum magnitudes.

SU UMa type (UGSU): This subtype is characterised by frequent narrow outbursts, but in addition super-outbursts occasionally occur. During a super-outburst, short-period light variations, superhumps, are observed in most SUUMa stars. The superhumps have a period of a few per cent longer than the orbital period. Thus the detection of these superhumps is very important in order to determine the orbital period of systems where this is otherwise very difficult to obtain.

WZ Sge type (UGWZ): This special type of dwarf nova has outbursts very seldom. The typical recurrence time is several decades. Clearly, the detection of all outbursts of these rare objects is extremely important.

The origin of dwarf nova outbursts is due to a brightening of the accretion disk. The mass-transfer burst model proposed in the early 1970's by Geoffrey Bath explains the outbursts by semi-periodic enhancements of the mass transfer from the secondary.

The disk-instability model proposed independently by Jozef Smak and Yoji Osaki in the mid-1970's is nowadays the most favoured model of an outburst mechanism. This model explains the dwarf nova outbursts as follows: The accretion disk can accumulate a certain amount of gas before it gets unstable. When instability is reached, the accretion of matter to the white dwarf increases dramatically. We see this as an increase in luminosity – an outburst. When the accretion disk has lost enough mass, it becomes stable again, the increased accretion stops and the system returns to minimum magnitude. The disk is now ready for a new fill-up and a new outburst cycle can begin.

The classical novae (N) and the recurrent novae (RN) are also cataclysmic variables. The outburst of classical novae as well as some recurrent novae are generated by thermonuclear runaway reactions at the surface of the white dwarf, following long periods of accretion from the secondary. The outburst of classical novae are always accompanied by an expulsion of a shell of material, whereas for the recurrent ones this seems not to be the case. A more thorough and comprehensive review of dwarf novae and other cataclysmic variables can be found in [Patterson 1984] and the references therein.

3. The Observers, Their Instruments and Techniques

The major part of the visual dwarf novae observations are made by a few very active and enthusiastic observers.

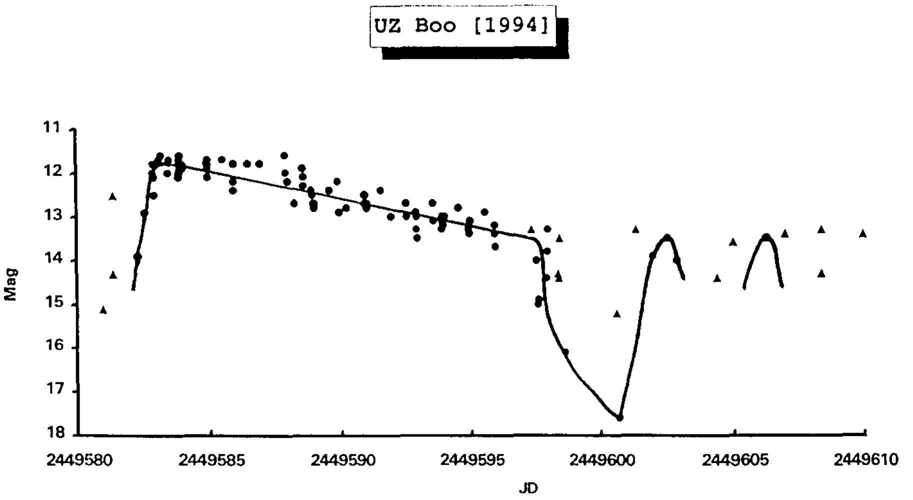

Figure 1.

Most of them are very experienced variable star observers, with proven skills in 'traditional' variable star work. Lot of practice and perseverance has turned them into well-trained amateurs, that are capable of memorising tens of star fields. On every clear night, they visually check these fields, hunting for 'new' stars. No sophisticated instruments are required: an alt-azimuth dobsonian type of reflector is quite common, with apertures in the range from 20 cm to 50 cm and more. Using this technique, some amateurs are capable of visually inspecting between 50 and 100 star fields in one single night! On such nights typically 3–10 dwarf novae are seen in outburst.

Often the magnitude of a dwarf nova in minimum is in the range magnitude 17–21. Most dwarf novae are hence only observed in maximum and naturally the observers get a lot of negative (fainter than) observations. Negative observations are often as important as the positive ones to get a continuous light curve. What makes dwarf novae hunting so challenging to amateur astronomers? There is no single answer to this question. Most amateurs are driven by the unpredictable nature of the dwarf novae: no one can anticipate the outcome of a nightly observation session. Others are attracted by the 'scientific' contribution of their observations. Variable star charts and sequences come from various organisations, such as the AAVSO (American Association of Variable Star Observers), The Astronomer and the BAAVSS (UK), RASNZ (Royal Astronomical Society of New Zealand), BVVS (Belgium Vereniging voor Sterrenkunde), and from reprints of articles in professional journals [Vogt and Bateson, 1982], [Bruch et al., 1987] and [Downes and Shara, 1993].

Monthly tables, listing all dwarf novae outburst activities are generated and distributed by organisations like the AAVSO (The AAVSO Circular). Approximately 40–50 more or less active observers contribute to the dwarf nova section of the AAVSO Circular. Often an outburst is only observed by a few observers. Nearly 400 variables are currently classified as UG stars. For many possible UG stars nearly no characteristics are known, because they are very faint even in outburst or they have very long recurrence times. Some of them have only been observed on very few occasions, for some the identification is unknown, or the subclass classification is very tentative. The task of monitoring such stars is largely taken over by amateurs, who join their efforts in worldwide networks, that in total cover over 100 peculiar objects. All over the world, only a few dozens of amateurs participate in these dwarf novae alert networks.

3. Interest from Professional Astronomers

The Astronomer organisation (UK) has set up a programme specifically to monitor poorly studied-long period dwarf novae. The Recurrent Objects Programme contains approximately 75 objects of various types, ranging from dwarf novae, recurrent and old novae, to suspected UG, UGSU and UGWZ stars. Gary Poyner has been coordinator of the programme since 1991. The main criteria in the object selection were the following:

1. The star must have an outburst period (or suspected period) of at least one year.
2. Little (if any) information on the precise cycle length or amplitude is available.

Gradually more stars were added to the list, as research uncovered many more of these long-period objects where just one or perhaps two outbursts had been recorded. Among recent successes we note the first ever visual observations of the following stars (discoverers' names following).

EF Peg: October 1991 (Schmeer, Ger)
SS UMi: August 1991 (Mitchell, UK)
HV Vir: April 1992 (Schmeer, Ger)
AK Cnc: January 1992 (Kato, Japan)
V1113 Cyg: August 1993 (Szentasko, Hungary)
V493 Lyr: October 1993 (Bortle, USA/Van Cauteren, B)
LL And: December 1 (Vanmunster, B)

Also many stars which have been monitored by observers have been reclassified after observations had shown that outburst activity wasn't quite as predicted. If a programme star is found to go in outburst frequently, it is dropped from the programme, but only after monitoring it intensely through several outbursts. This has recently happened with the UGSU star SS UMi.

Figure 1 shows an example of a light curve obtained for a programme star: UGWZ type dwarf nova UZ Bootis. The light curve documents a recent superoutburst (August 1994). The last observed outburst of UZ Boo was in 1978.

Occasionally stars which are not eruptive in nature, but were originally thought to be are revealed. Four of these rogue stars have recently been identified and dropped from the programme. Three, HN Cyg, UY Vul and UZ Vul, were in fact semi-regular type variables catalogued as possible cataclysmic stars. However, observations from the programme's observers have revealed their real nature. When activity of a suspected star is noticed, other members of the network are informed (over telephone) in order to obtain immediate confirmation. Positive identifications of outbursts result in alert calls (telegrams and electronic circulars), that are issued to amateurs all over the world and to interested professional astronomers.

Examples of such services are The Astronomer Electronic Circulars (UK) and the Cataclysmic Variables Circular (B). Photometric observations, that cover the outburst activity, are passed between professional and amateur astronomers by electronic mail, mainly through Internet and CompuServe. The availability of e-mail to many amateurs has meant that professional astronomers can be alerted to an outburst very quickly, thus making possible extremely valuable observations early in the outburst phase and in various wavelengths.This can provide valuable information into the mechanisms behind these cataclysmic events. Summarising results, complemented with contributions from professional astronomers, are published in various magazines.

4.1. HV Virginis

The HV Vir outburst deserves special mention here, as it proves just how valuable amateur observations can be. HV Vir was photographed by Schneller in 1929 in outburst at magnitude 11.5. Following a series of observations of it at maximum light and in decline, it was classified as a classical nova. The object was added to the recurrent objects programme in 1988 primarily because of it's high galactic latitude, and the possibility that it may be a rare type WZ Sge dwarf nova, although no other outbursts had been detected. On April 20, 1992, a German amateur, Patrick Schmeer, made his usual check of the field with his 20-cm telescope and saw HV Vir in outburst at magnitude 12. At first Schmeer thought it might be a minor planet, but following a search of minor planet positions it soon became evident that HV Vir was indeed in outburst. Observations of spectra and high-speed photometry have shown that HV Vir is indeed a dwarf nova. It shares many characteristics of WZ Sge itself, and displays superhumps typical of UGSU stars.

4.2. LL Andromedae

Another major success of the TA dwarf nova network was the detection of an outburst of LL And by Belgian amateur Tonny Vanmunster on the evening of December 7, 1993 using a 35-cm dobsonian reflector. The outburst was confirmed within minutes by UK and Belgian observers. LL And was discovered photographically by astronomer Paul Wild (Bern Observatory) in September 1979 [Wild 1979], when it reached V~13th. Since then, the dwarf nova had never been seen again. Due to an alert, the December 1993 (super)outburst could also be monitored by several professional astronomers. Spectroscopic observations of the star at maximum light were obtained, as well as a photometric outburst light curve based mainly on observations contributed by amateurs. The outburst amplitude was ~ 6 magnitudes. Dr. Kato (Kyoto University, Japan) conducted CCD photometry during four nights, and detected superhumps, hence classifying the star as a UGSU dwarf nova, possibly belonging to the WZ Sge subclass.

5. Belgian Cataclysmic Variables Alert Programme

The Belgian Cataclysmic Variables Alert Programme (CVAP) was initiated in May 1994 as a dwarf nova observation programme, complementary to the TA programme. It mainly consists of poorly observed objects, for which professional astronomers have shown interest and have requested continuous monitoring. The CVAP currently includes about 13 objects, of which the identification and/or the subclass is uncertain or unknown. These objects are now monitored on a very regular basis by European variable star amateur observers. Due to the unavailability of professional search charts and sequences for these objects, the CVAP members currently are using charts based on the Guide Star Catalogue (GSC). Example CVAP objects include: AS Psc (last seen in outburst in 1963), V358 Lyr (seen in 1965) and SS LMi (seen in 1980, and classified as either N or UG).

Although the CVAP started only recently, a first result has already been obtained. The programme star IR Lyr, classified as a possible UG star, has been observed during activity in recent months. A first interpretation of photometric observations indicates that the star does probably not belong to the UG variables. Paul Van Cauteren and Tonny Vanmunster are currently the coordinators of the Belgian programme.

6. Future Perspectives

As CCD cameras become more widely available to amateur astronomers, we would like to point out the important role that these instruments can play in the observation of dwarf novae, even if they are mounted on a small telescope.

(1) Monitoring of dwarf novae at quiescence

Most amateur astronomers, even with larger instruments, obtain only limiting magnitudes around magnitude 14.5–15.5. But the majority of dwarf novae are much fainter when at quiescence. With the use of a CCD camera, however, many of these objects are within reach. This means that daily monitoring may result in observing the start of the outbursts, and early warning of interested observers is possible.

(2) Confirmation of outburst discovered by visual observers

When an outburst is reported by a visual observer, it is common practice to obtain confirmation from a second observer, before the astronomical world is informed. Confirmation via a CCD image is much more 'safe' than a second visual sighting. Having something on file/paper also makes it possible to analyse and re-check the result later on.

(3) Astrometry/photometric sequence

With CCD images an accurate position measurement may be obtained. At present, too many inaccurate charts are used, resulting in 'false' outburst-alerts or large scatter in magnitude estimates. Preparing charts with reliable comparison stars is of utmost importance.

(4) Photometry

By taking regular images of the variable star, reliable photometry may be performed. The accuracy is much higher than the visual estimates. Detecting superhumps in suspected UGSU stars is an example of useful work that can be done.

It is our impression that most astronomers do not know about the important work some amateurs do in the field of cataclysmic variables. It is our hope that this article will inspire more professional astronomers to make use of the results and observations obtained by the amateur astronomers. The different recurrent object programmes are always open for new interesting cataclysmic variables to be monitored. Naturally, it is also inspiring for the amateurs to see that their efforts can be and are used by professional researchers to gain more knowledge about the behaviour of cataclysmic binaries.

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Wild 1979: IAU Circular No. 3412.

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Telescope Software Scientist (CTR 118)

08.06.1995
Grade 8

La Silla Observatory, Chile.

This post is open to suitably qualified men and women.

Education: University degree or equivalent in computer science or related field.

Experience and knowledge: Experience in UNIX systems and software. A knowledge of C and Fortran is essential, and the candidate should have some experience with workstations, PCs and Macintosh computers. Some knowledge of VME or equivalent data bus systems would be an advantage. Fluency in English is required.

Assignment: The successful candidate will be part of the team of ten scientists and engineers responsible for the day-to-day operation and continuing development of the Swedish-ESO (Sub) Millimetre Telescope (SEST) and its operating system at the La Silla Observatory in Chile. The schedule of work requires that he/she be capable of working both independently and in a group.

Duty station: La Silla, Chile.

Starting date: As soon as possible.

Remuneration: The remuneration for this post will be commensurate with the background, experience and family status. The basic monthly salary (tax-free) will not be less than DM 6.072,–. Furthermore, an expatriation allowance of either 30–35% (single) or 40–45% (head of family) of the basic salary as well as some other allowances may be added.

Applications should be submitted **before July 20, 1995.**

Application forms may be obtained from ESO, Personnel Services, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany.

ESO Fellowships in Chile 1996/97

The European Southern Observatory (ESO) intends to award one or more postdoctoral fellowships tenable at ESO's Astronomy Centre in Santiago, Chile.

The main areas of activity of ESO in Chile are:

- Research in observational and theoretical astrophysics;
- Operating the La Silla Observatory;
- Building the VLT, consisting of four 8-m telescopes, at Paranal.

Fellows will spend most of their time at ESO's centre in Santiago, but will regularly visit the La Silla Observatory, where they will take part in supporting visiting astronomers and maintaining the instrumentation. Fellows will normally spend up to 50% of their time in support work, and the remainder doing their personal research. The fellowship programme in Chile offers a unique opportunity to learn and to participate in the process of observational astronomy while pursuing a research programme with state-of-the-art facilities.

The La Silla Observatory has eight telescopes in the range 0.9 m to 3.6 m, as well as the 1-m Schmidt, the 15-m SEST millimetre radio telescope and smaller instruments. ESO's Institute of Astronomy in Santiago offers computational facilities, a library, as well as the stimulation of colleagues from ESO and the local Chilean astronomy community.

Applicants should have a recent doctorate. The basic monthly salary will be not less than DM 5526 to which is added an expatriation allowance of up to 40%. The fellowships are granted for one year with the expectation of a renewal for a second year and exceptionally a third year. Fellowships begin between April and October of the year in which they are awarded. Applications should be submitted to ESO **not later than October 15, 1995**. Applicants will be notified in December 1995. The ESO Fellowship Application Form should be used. The applicant should arrange for three letters of recommendation from persons familiar with the scientific work of the applicant to be sent directly to ESO. These letters should reach ESO **not later than October 15, 1995**.

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

European Southern Observatory, Fellowship Programme, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany

ESO Fellowships in Garching 1996/97

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

The main areas of activity at the Garching Headquarters are:

- Research in observational and theoretical astrophysics;
- Managing and building the Very Large Telescope (VLT);
- Development of instruments for current ESO telescopes and for the VLT;
- Management, calibration, analysis and archival of astronomical data for the current ESO telescopes and the VLT;
- Fostering co-operation in astronomy and astrophysics within Europe.

Fellows normally participate in one or more of the above activities. There is also the possibility of participating in the activities of the Space Telescope European Coordinating Facility (ST-ECF), which is located in the ESO Headquarters building.

In addition to personal research, Fellows will spend up to 25 % of their time in support or development activities related to the main areas of activity at the ESO Headquarters. This functional work will normally include a few short-term visits per year to Chile (La Silla and Vitacura).

ESO facilities include the La Silla Observatory in Chile with its eight telescopes in the range 0.9 m to 3.6 m, as well as the 15-m SEST millimetre radio telescope, and smaller instruments. In Garching, extensive measuring, image processing and computing facilities are available. There are several Max-Planck Institutes and the University Observatory in the Munich area with major programmes in astronomy and astrophysics and with which joint programmes can be conducted.

Applicants should have a recent doctorate. The basic monthly salary will be not less than DM 5526 to which is added an expatriation allowance of 9–12% if applicable. The fellowships are granted for one year with the expectation of a renewal for a second year. Applications should be submitted to ESO **not later than October 15, 1995**. Fellowships begin between April and October of the year in which they are awarded. Applicants will be notified in December 1995 or soon thereafter. The ESO Fellowship Application form should be used. The applicant should arrange for three letters of recommendation from persons familiar with the scientific work of the applicant, to be sent directly to ESO. These letters should reach ESO **not later than October 15, 1995**.

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

European Southern Observatory, Fellowship Programme, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany

Postdoctoral Fellowship on La Silla – NTT Upgrade Project

In the framework of the Very Large Telescope Programme, ESO has undertaken a project to upgrade the 3.5-m New Technology Telescope (NTT) in order to test operational concepts and software for the VLT. As part of this development, ESO is offering a fellowship to a qualified optical astronomer who would like to participate in this programme. In addition to carrying out an independent research programme (50%), specific duties (50%) would include support of Visiting Astronomers and calibration and performance control of the instrumentation on the NTT. This position is intended to offer the recipient the opportunities both to develop an independent research programme with the facilities of a major observatory and to contribute to the realisation of the NTT Upgrade Project.

The successful candidate will be expected to work in close collaboration with the scientists and engineers of the NTT Team to ensure the success of the NTT upgrade project. Scientifically, collaboration with the Astronomy Support Department (ASD) of ESO-Chile is encouraged. Current research interests within the ASD are: active galactic nuclei, star formation, supernovae, RR Lyrae stars, chemical abundances, the interstellar medium, the activity of cool, and magnetic stars. Knowledge of modern software utilities is a requirement. Candidates acquainted with (surface-) photometric techniques are especially encouraged to apply.

The ESO fellowships are granted for a period of one year, renewable for a second year and exceptionally for a third year.

The monthly basic salary will not be less than DM 5279, to which are added an expatriation allowance of 30–45% as well as a mountain allowance of 5–10%.

Starting date: As soon as possible.

Applications should be submitted to ESO **not later than July 20, 1995**. Applicants will be notified by October 31, 1995. Application forms are available from

ESO Personnel and General Services (PGS), Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany.

Applicants should arrange for 3 letters of reference to be sent by the same date directly to PGS.

For further information: contact the NTT upgrade project scientist (Internet: dbaade@eso.org).

Staff Astronomer (ESD 208)

08.06.1995
Grade 9/10

Science Division at the ESO Headquarters in Garching near Munich, Germany.

This post is open to suitably qualified men and women.

Education: *PhD in Astronomy, Astrophysics or Physics.*

Experience and knowledge: Candidates must have several years of postdoctoral research experience, and have contributed significantly to at least one area of modern astrophysics. They must also have substantial experience in the use of large ground-based telescopes. Evidence of an interest and a demonstrated skill in exploiting telescopes and their instruments to their limits will be looked for.

Assignment: The successful candidate will be expected to carry out a significant programme of personal research for up to 50% of the time. The appointee will also work in the Science Division with the Associate Director for Science (J. Bergeron) in strengthening interactions between the Science Division and the VLT and Instrumentation Divisions. The appointee will provide scientific input for VLT instrumentation in particular for pipe-line calibrations and archiving of the optical spectrographs FORS and FUEGOS. The appointee will also supervise the VLT instrumentation-related functional work carried out by ESO Fellows.

Three letters of recommendation from persons familiar with the scientific work and observational experience of the applicant should be sent to ESO, Personnel Services, directly.

Duty station: Garching near Munich, Germany.

Starting date: As soon as possible.

Contract: This position is a three-year, renewable contract and may lead to a tenure staff appointment. Serious consideration will be given to outstanding candidates willing to be seconded at ESO on extended leaves from their home institutions.

Remuneration: The remuneration for this post will be commensurate with the background, experience and family status. The basic monthly salary (tax-free) will be in the range of DM 6.845,– to DM 9.583,–. Furthermore, an expatriation allowance as well as some other allowances may be added.

Application forms may be obtained from ESO, Personnel Services, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany.

Applications should be submitted **before 20 July 1995**.

New ESO Publications

(March – May 1995)

Scientific Report No. 16: Fourth Catalogue of Stars Measured in the Long-Term Photometry of Variables Project (1992–1994).

Scientific Preprints

1068. F. Murtagh, J.-L. Starck, A. Bijaoui: Image Restauration with Noise Suppression Using a Multi-Resolution Support. *AA.*
1069. U. Lindner et al.: The Structure of Supervoids – I. Void Hierarchy in the Northern Local Supervoid. *AA.*
1070. S. Cristiani et al.: The ESO Key-Programme "A Homogeneous Bright QSO Survey" – I. *AA.*
1071. J. Rönnback and N. Bergvall: Blue Low Surface-Brightness Galaxies. II. Spectroscopy and Chemical Abundances. *AA.*
1072. J.K. Kotilainen et al.: The Nature of the two Nuclei in the Young Merger NGC 3256: An Obscured AGN? *AA.*
1073. D. Minniti: Spectroscopy and IR Photometry for Giant Stars in Obscured Globular Clusters: NGC 6325, NGC 6401, NGC 6440, NGC 6517, NGC 6642, HP1 and PAL6. *AA.*
1074. D. Minniti: Abundances and Velocities for Open and Globular Giants: The Data. *AA.*
1075. N.N. Chugai, I.J. Danziger, M. Della Valle: Optical Spectrum of SN 1978K: Emission from Shocked Clouds in the Circumstellar Wind. *M.N.R.A.S.*
1076. F. Murtagh, A. Aussem, M. Sarazin: Nowcasting Astronomical Seeing: Towards an Operating Approach. *P.A.S.P.*
1077. P.A. Shaver: High Redshift Quasars. Invited paper presented at the 17th Texas Symposium, 12–16 Dec. 1994; to appear in *17th Texas Symposium on Relativistic Astrophysics and Cosmology* (ed. H. Böhringer et al., Ann. New York Academy of Science).
1078. N.Y. Lu and W. Freudling: Large-Scale Structures in the Zone of Avoidance: The Galactic Anticenter Region. *ApJ.*
1079. G. Carraro and F. Patat: The Stellar Content of the Open Clusters Tombaugh 1 and Rupprecht 46. *M.N.R.A.S.*
1080. P. Frisch et al.: Evolution of the Supercluster-Void Network. *AA.*
1081. M. Bobrowsky et al.: He 3–1475 and its Jets.
1082. H.E. Schwarz, L.-Å. Nyman, E.R. Seaquist, R.J. Ivison: A Search for SiO Maser Emission from Symbiotic Miras. *AA.*
1083. W. Freudling et al.: Determination of Malmquist Bias and Selection Effects from Monte-Carlo Simulations. *A.J.*
1084. G. Meylan, M. Mayor, A. Duquennoy, P. Dubath: Central Vlocity Dispersion in the Globular Cluster ω Centauri. *AA.*
1085. F. Courbin et al.: Photometric Monitoring (1987 to 1994) of the Gravitational Lens Candidate UM 425. *AA.*

Technical Preprints

66. S. D'Odorico: Array Detectors and Instruments for the ESO VLT.
    Highlights of IAU Symposium No. 167.
    Review papers to be published in the Proc. of the IAU Symp. No. 167, "New Developments in Array Technology and Applications".
67. Very Large Telescope – Instrumentation.
    Papers submitted to the International Conference "Scientific and Engineering Frontiers for 8–10m Telescopes". 4–6 October 1994, Tokyo, Japan.

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 organising collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, 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) became operational in 1990, and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. It is being erected on Paranal, a 2,600 m high mountain in northern Chile, approximately 130 km south of Antofagasta. 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, Germany. 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 analyse their data. In Europe ESO employs about 200 international Staff members, Fellows and Associates; at La Silla about 50 and, in addition, 150 local Staff members.

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

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The ESO Messenger:
Editor: Marie-Hélène Ulrich
Technical editor: Kurt Kjär

Printed by Universitäts-Druckerei
Dr. C. Wolf & Sohn
Heidemannstraße 166
D-80939 München 45
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ISSN 0722-6691

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