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Active Optics: the NTT and the Future

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1. Background to the Development of Active Optics at ESO

At a press conference on 13 July at Carl Zeiss, Oberkochen, jointly organized by ESO and Carl Zeiss, the final results of the manufacture (figuring) of the NTT optics were announced. This included a functional test of the basic Active Optics correction of the telescope. The results were so good that they exceeded even the expectations of both Carl Zeiss and ESO in all respects. We consider this to be a milestone not only in the development of the NTT and the history of ESO, but also in the evolution of the astronomical reflecting telescope in general.

To understand the significance of the NTT optics and the quality achieved, we must first review the background of the development and the principles on which it is based.

It is not the purpose of this article to give a full scientific account of the ESO Active Optics system. This is fully documented in the publications "Active Optics I" and "Active Optics II" [1] [2]. Here we wish to give the reader a résumé of the essential features and advantages of the system, and the practical results with the NTT optics.

The first ideas on a general active control system for the optical quality of telescopes go back to the late sixties when the first author was in charge of optical design for astronomical instruments at Carl Zeiss. Here he became conscious of the extreme difficulty of

The finished NTT primary mirror at Carl Zeiss in July 1988. The mirror is mounted here on its final NTT support in its cell for testing in the same set-up as was used for manufacture.

respecting centring tolerances with conventional large telescopes, i.e. maintaining the primary and secondary mirror optical axes sufficiently colinear. Very few telescopes maintain in practical use the centring tolerances required for high image quality and this leads to an ugly, asymmetrical image error known technically as *decentring coma*. Since this is the commonest and most serious optical "illness" of Cassegrain telescopes (the standard modern form because it is effectively a powerful mirror telephoto system giving a tube length much shorter than its focal length), the first author called it "Cassegrainitis". In the early seventies he concluded that it was hopeless to expect to maintain such absolute tolerances in a *passive* system, and some sort of *active correction* was necessary. While still at Carl Zeiss, he also learned from a colleague, Gerhard Schwesinger, the basic principles of the design of mirror supports. These principles were an essential prerequisite for the later development of active optics at ESO.

We have introduced above two fundamental terms, *passive* and *active*, which must now be defined. A normal, conventional telescope is *passive* in the sense that it is set up by some adjustment procedure and can only be maintained or modified by a subsequent *off-line* maintenance operation. Between such operations, the adjustment will degrade and will anyway be influenced by the telescope attitude. A further problem is that off-line access to telescopes is always difficult and in conflict with the observing schedules. The consequence is that telescopes are, in practice, virtually never in an optimum state of optical performance: often they are shockingly bad and nowhere near the quality achieved by the optician.

During the set-up and alignment of the ESO 3.6-m telescope in 1976 [3], the basic scheme for an *active* telescope became clear to the first author, although it was quite impossible to realize it with that telescope. Such an *active* telescope would monitor its own image quality *on-line* and correct any errors (i.e. optimize itself) automatically. The first and most important aspect of an active telescope is therefore *automatic maintenance* of optimum optical quality. Later it became clear that there was a second aspect of active optics which is hardly less important than the first: the relaxation of certain manufacturing tolerances which, with subsequent active correction, leads to an optimum level of quality far surpassing anything achievable with passive telescopes.

To understand this, we must introduce the term *Intrinsic Quality* (the IQ of a telescope!) which was defined in connection with the set-up tests of the (passive) ESO 3.6-m telescope in 1976. Figure 1 shows the results of these (Hartmann) tests for the zenith position and for zenith distances from 45° to 60° at the four azimuths south, west, east, north. In each case, the left-hand point of the histograms gives the actual image quality of the telescope as measured in the conventional way (image diameter in arcsec containing 80 % of the geometrical energy of a star image). Note that there is a significant variation of quality with telescope attitude, the quality being worst in the south and best in the north. The principal reason for this is quite simple: a residual of decentring coma is increased in the south by tube flexure (Serrurier) error, whereas it is compensated in the north. The histograms show the improvement that *would be* achieved *if* the errors shown were removed. Although the histograms must all fall monotonically towards the last point 5 on the right, their form varies significantly. However, within the error of measurement, the right-hand point is a constant for this telescope, independent not only of telescope attitudes but also of time. This is what we call the

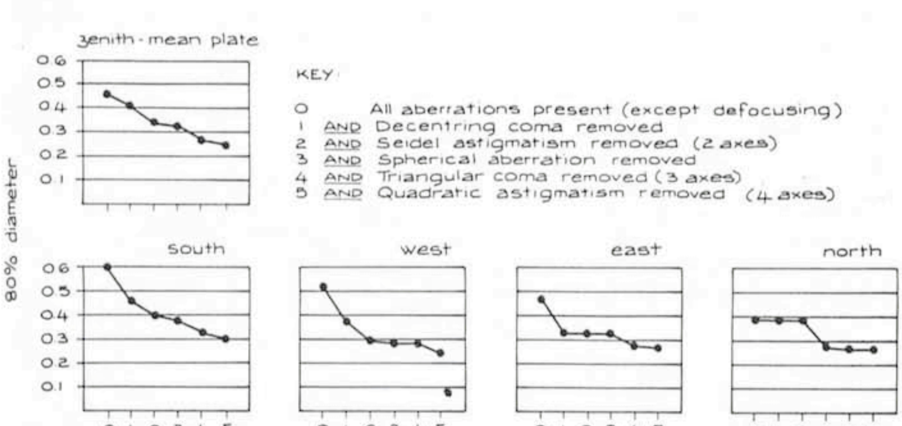


Figure 1: *Results of Hartmann tests of the passive ESO 3.6-m telescope in 1976 [3], showing the theoretical improvement that would be attained by correcting low spatial frequency terms if the telescope were active. The mean right-hand point of the functions gives the* intrinsic quality *(IQ).*

ESO Places Contract For World's Largest Mirror Blanks

After a period of intense negotiation, the European Southern Observatory and Schott Glaswerke, Mainz (F.R. Germany), reached agreement about the delivery of four giant mirror blanks for the ESO Very Large Telescope (VLT). The blanks will be spin-cast of Zerodur, a ceramic material. Each will have a diameter of 8.2 metres, an area of ~ 53 square metres and a thickness of only 17.5 centimetres.

The contract was signed on September 12 at the ESO Headquarters in Garching bei München, by Professor Harry van der Laan (right), Director General of ESO, and Mr. Erich Schuster (left), Member of the Board of Directors of Schott Glaswerke.

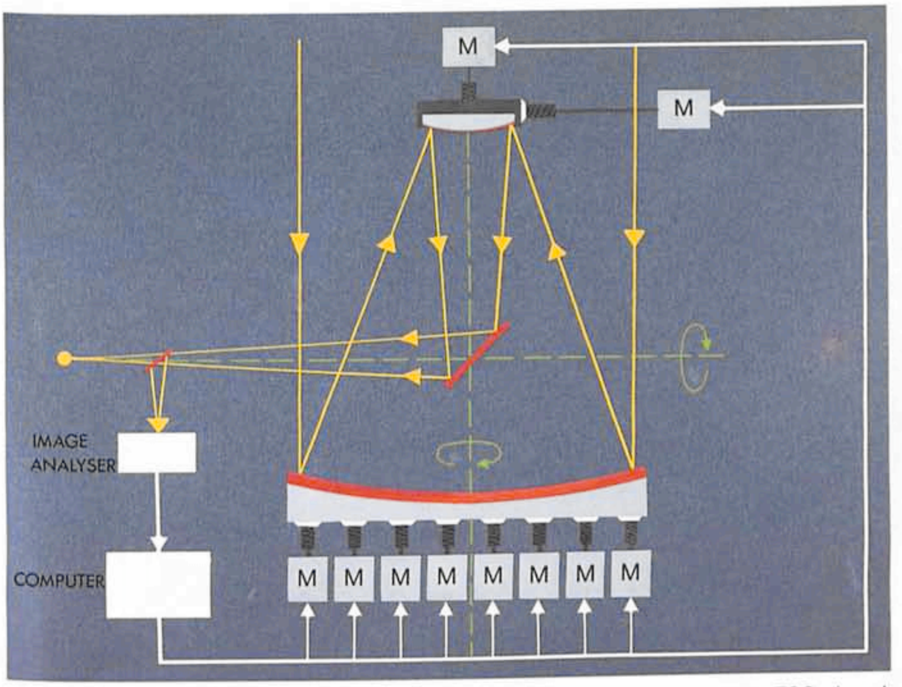


Figure 2: Active optics *for low frequency bandpass correction: principle of the ESO closed-loop control technique for optimizing image qualitiy.*

intrinsic quality of the telescope, the value for the 3.6-m being 80 % geometrical energy in 0.27 arcsec.

It is important to realize that the process shown above for the 3.6-m telescope was a purely mathematical abstraction. In practice, this telescope has no physical means for systematically carrying out the process shown. The same is true of all conventional, passive telescopes. The best one can do is from time to time to try to correct one or more of these errors in a laborious off-line operation. In practice, the left-hand point of the histogram often has a far worse quality than that shown above, because of deterioration of the adjustment.

The difference with the NTT, an *active* telescope, is that the correction process shown in the histograms *can be performed at will on-line so that the IQ can be realized all the time.* The left-hand point of the histograms is then of no importance, so that relaxed manufacturing tolerances for the terms shown are possible. Hence we have the two advantages:

- Relaxation of low spatial frequency (long-wave) manufacturing tolerances.
- Automatic maintenance in respect of all errors which can vary through maladjustments, etc.

2. Practical Application to the NTT

How, then, is this process realized in the NTT? This is shown schematically in Figure 2. The offset guide star image is "borrowed" from time to time for the image analyses whose measurements are processed in the computer. Using prestored information and a simple algorithm, signals are sent to the secondary mirror and to the primary mirror. The secondary is then rotated slightly about its centre of curvature (to correct decentring coma) or shifted along its axis (to correct defocus). The signals to the primary mirror modify the axial support forces and thereby correct all the other errors which are to be controlled. It should be noted that the form of the primary mirror is *not* determined by direct position control since this would require an impossibly stiff supporting cell. The mirror is located by three fixed points and its form determined by the forces exerted by 75 astatic (i.e. floating) supports. Apart from the important difference that the forces can be modified in a controlled way, the support operates essentially in the same way as the astatic lever invented by the English engineer Lassell in 1842 and used in innumerable telescopes since then.

The algorithm for the correction process is based on three laws of physics:

- *The linearity law:* This is simply Hooke's law in elasticity theory which says that the strain (deformation) in a system is linearly proportional to the stress (force).
- *The convergence law:* This arises out of the principle of St. Venant in elasticity theory. The important consequence for active optics is that only relatively few low spatial frequency (i.e. "long-wave") terms need to be corrected to achieve the IQ.
- *The orthogonality law:* This results from the definition of the error terms and states that they can be corrected independently.

The image analyzer requires a minimum of 30 seconds, preferably 60 seconds, to obtain the basic data. This integration time is necessary in order to eliminate the effects of the atmosphere which would otherwise falsify the results. (Correction of disturbances due to the atmosphere requires a system with response to higher time frequencies. This is the field of *adaptive optics* which is enormously more difficult and still represents an unsolved problem at visible wavelengths.) A further 60 seconds is sufficient for the computer analysis and actual correction process. This whole process of detection, analysis and correction does not disturb the observation in any way: indeed, the astronomer will be unaware that it is taking place! The rhythm with which it is desirable to perform corrections will have to be decided by practical experiments but it is unlikely to be more than once per hour or once per change of object. The NTT is designed to track within 0.1 arcsec without guiding for at least 15 minutes, far longer than the 1-minute integration time.

3. Experimental Confirmation from the 1-m Experiment

Our active optics concept is an essentially simple and natural development out of normal passive support systems. Nevertheless, as with all new developments, it was desirable to test it in

Figure 3: *The 1-m test mirror (the thin rim shows the high aspect ratio of 56).*

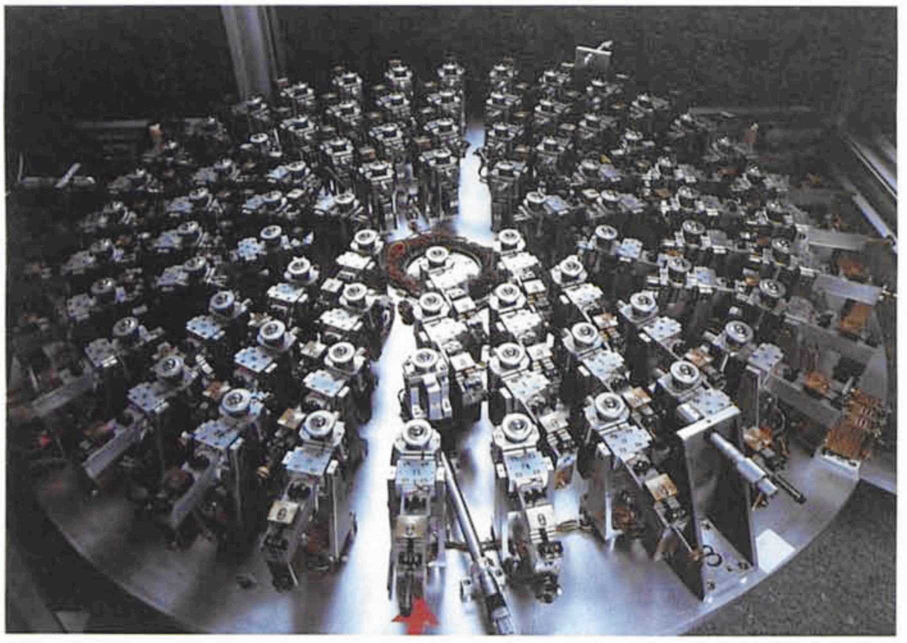


Figure 4: *Photo of the complete 1-m support. There are 78 individual supports of which 75 are active levers and 3 fixed points. The geometry of the support in the 4 rings is identical with that of the NTT primary mirror. Each support has a load cell to measure the force.*

practice before applying it to the NTT itself. This was the purpose of the 1-m test mirror, which had a diameter of 1,050 mm and a thickness of only 18.9 mm. These dimensions were obtained by scaling the NTT primary (diameter 3,580 mm, thickness 240 mm) according to the *gravity flexure law*. The geometry of the support can then be taken over and all forces scaled in the ratio of the weights of the two mirrors.

Figure 3 shows the 1-m mirror and Figure 4 its support. The four support rings are easily recognizable, but the supports themselves are simpler than in the NTT since the 1-m mirror is a fixed installation. Although the 1-m looks very thin – and *is* thin compared with a conventional mirror – it is not particularly so compared with more modern developments. The proposed VLT mirror would have a 1-m equivalent of only about 2½ mm, roughly like window glass! In fact, the thickness of the NTT primary was quite cautiously chosen to be about 40% of that of a conventional blank since an imposed requirement was that it should also work with normal quality in the purely passive mode.

The 1-m experiment had many purposes which are described in detail in ref. [2]. Here we will give only two results which illustrate clearly the power of active optics control.

As was indicated above, an essential feature of the method is modal control, i.e. the independent correction of certain errors or aberrations. The mode most easily generated in telescope mirrors is the *astigmatism mode*. To correct such a mode, we start with a theoretical *calibration* of a force variation pattern intended to generate such a mode in quite pure form. Figure 5 shows the generation of such a mode on the 1-m mirror using the ESO MIDAS image processing system. These colour patterns were produced off-line from data given on-line by the image analyzer. Starting with an arbitrary state of the mirror, a large amount of astigmatism was introduced. Then the same was done with reversed sign. Subtraction of the second result from the first should leave a large amount of pure astigmatism, about 7 wavelengths of *wavefront aberration*. This result is shown at the top left of Figure 5. The astigmatic effect is very obvious: one axis is more curved, the other less curved. The pattern at the top right of Figure 5 is a mathematical construction of the pure effect intended. At the bottom left, the difference of these is shown on the same colour scale and represents the error, or *cross-talk*, in the procedure. On this scale, hardly any error is detectable. At the bottom right, the colour scale has been magnified 24 times to show the residual error in detail. Clearly it is only random noise.

Our second example (Fig. 6) shows a MIDAS representation of the actual active correction of the 1-m mirror, as it was first performed. The top left-hand pattern shows a state of the mirror in which major aberrations left by the manufacturer were still to be corrected (since active correction was intended, quite generous tolerances were given to the manufacturer for the terms concerned). Clearly there is a major amount of astigmatism, as well as other errors. At the top right, a *manual* correction of the support has been performed to get the mirror into the dynamic range of

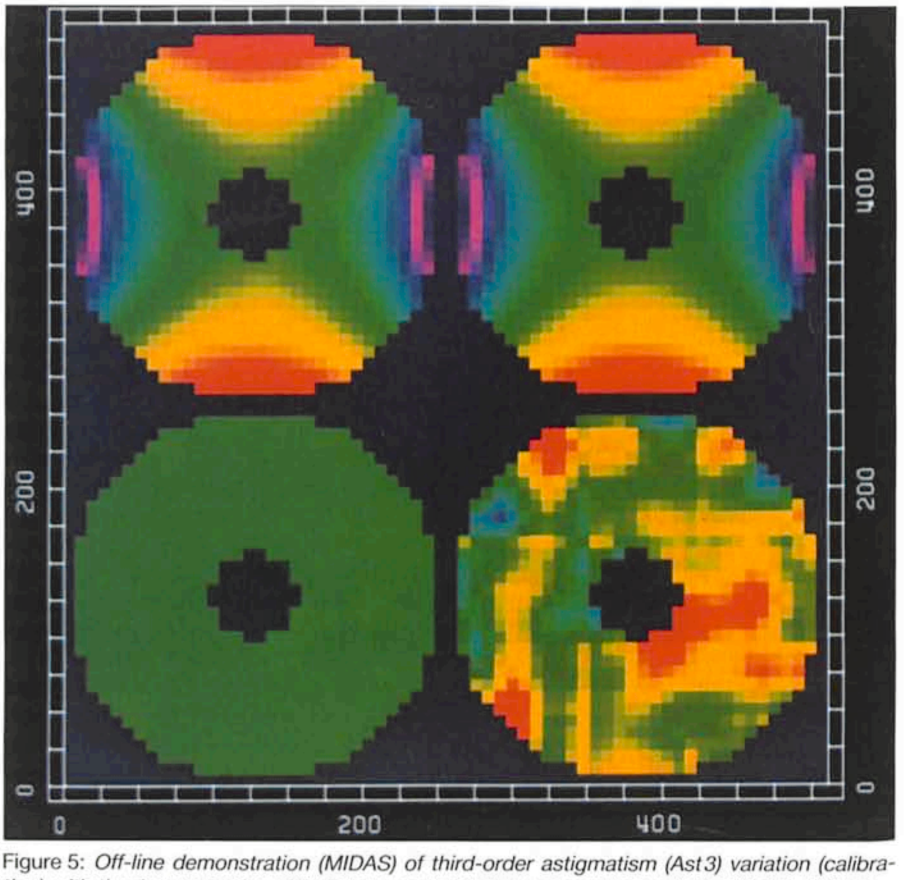


Figure 5: *Off-line demonstration (MIDAS) of third-order astigmatism (Ast3) variation (calibration) with the 1-m test mirror [2]. Colour scale 3650 nm except lower right which is 150 nm.*

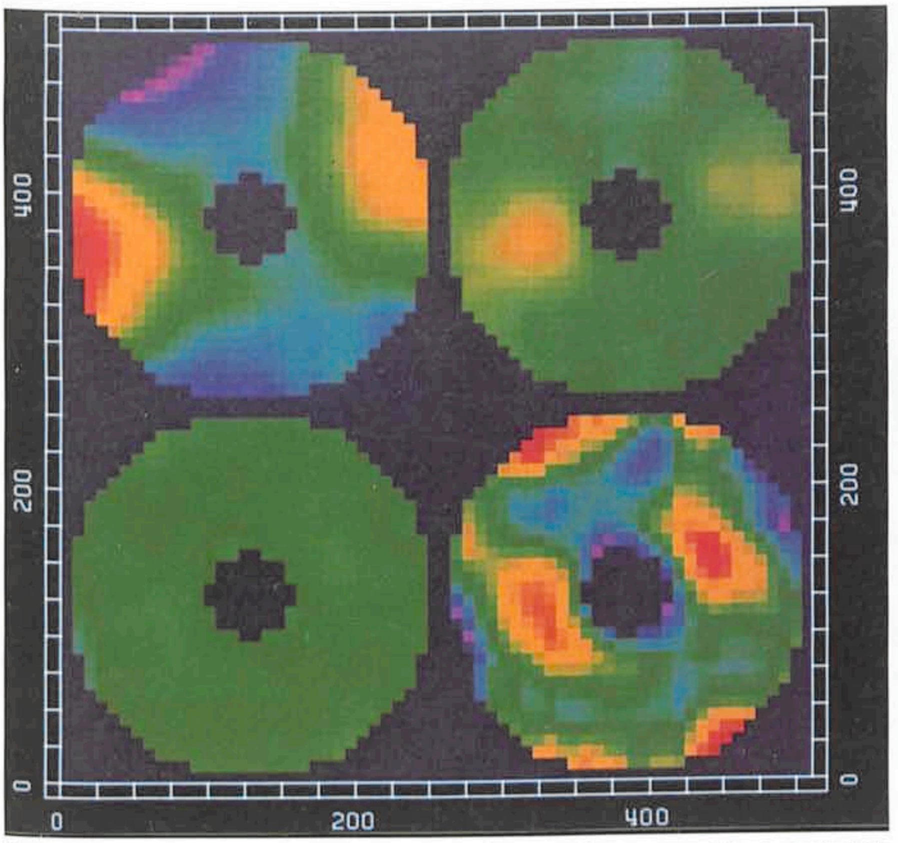


Figure 6: *Off-line demonstration (MIDAS) of the active correction process of the 1-m mirror [2]:*
Upper left: *Initial state. Colour scale 2340 nm.*
Upper right: *After hand correction. Colour scale 2340 nm.*
Lower left: *After automatic correction (1 iteration only). Colour scale 2340 nm.*
Lower right: *After automatic correction (1 iteration only). Colour scale 370 nm. The small residue of Ast5 was subsequently removed in a second iteration.*

automatic correction. At the lower left, the automatic correction has been carried out giving a hardly detectable error on this colour scale. At the bottom right, the colour scale has been increased by 6.3 times. We had expected a purely statistical result, as with Figure 5. But this pattern shows in fact a systematic residual error known technically as fifth-order astigmatism. We had considered controlling this term but expected it to be negligible. It appeared, in fact, as a small but readily detectable harmonic of the astigmatism we had permitted in the tolerance. A theoretical calibration was then performed and the term subsequently removed leaving purely statistical noise. This shows the flexibility of our active optics correction system. One estimates the terms necessary for correction to the quality desired. More terms can always be added if necessary, provided the dynamic range of the system is sufficient.

4. Tests of the Finished Optics of the NTT

We referred at the beginning of this paper to the press conference on 13 July announcing the results of the optical figuring at Carl Zeiss, Oberkochen. The background of these tests was given in the *Messenger* No. 52, which we reproduce here:

"To understand the manufacture of the NTT optics, we must look at its specification for the final Nasmyth image:

(a) 80 % geometrical energy within 0.40 arcsec.
(b) 80 % geometrical energy within 0.15 arcsec if 5 terms, to be controlled actively, are mathematically removed from the combined image forming wavefront (Intrinsic Quality).

The active control gives a relaxation of certain errors (such as astigmatism) which enables the manufacturer to concentrate above all on specification (b) which ensures very smooth surfaces without high frequency errors such as "ripple", zones or local bumps. In function, specification (b) should then operate all the time and will be the working specification of the telescope. This is quite near the "diffraction limit" for such a telescope.

The blank with aspect ratio 1 : 15 (2½× thinner than the blank of the ESO 3.6-m telescope) was delivered from Schott to Carl Zeiss in June 1986. The blank itself represents a great technical achievement by Schott in zero-expansion glass ceramic, Zerodur. Two years of intensive work at Carl Zeiss followed. The NTT specification (b) has required, and resulted in, a remarkable technological development at Carl Zeiss both in figuring techniques and in test technology. With the practical development of 'stabilized phase interferometry', Carl Zeiss is now in possession of an excellent and time-saving technology in the manufacture of large optics.

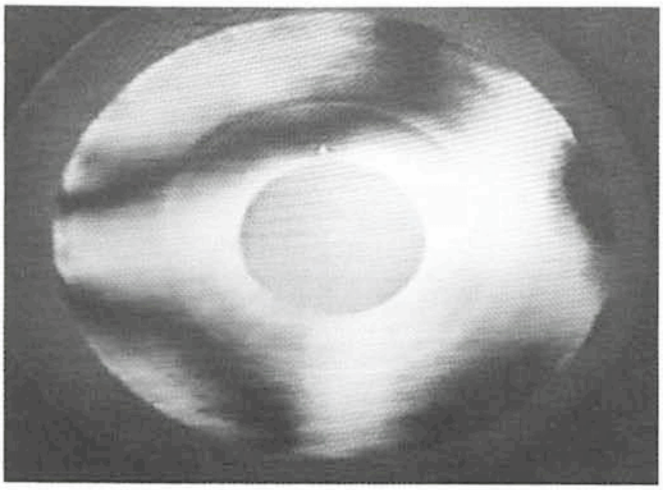
The results of the Carl Zeiss interferometric tests, established in a most rigorous way, are as follows for the whole optical train M1, M2, M3:

(a) 80 % geometrical energy within ca. 0.30 arcsec.
(b) 80 % geometrical energy within ca. 0.125 arcsec for the Intrinsic Quality.

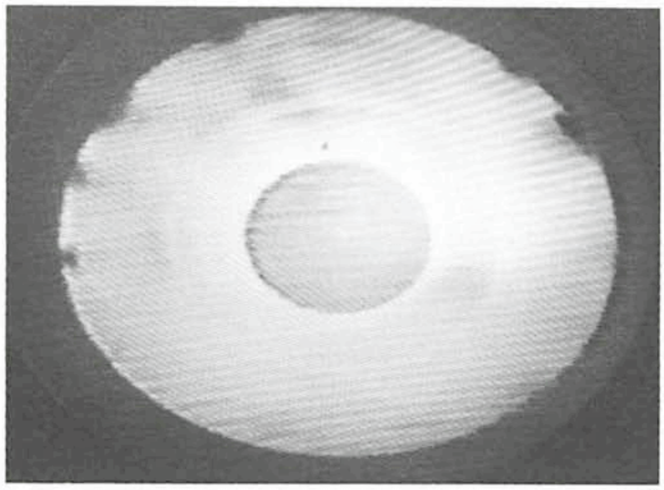
Both values are thus well within the specification."

The above results were obtained on the original manufacturing support. The mirror cell, with the actual supports to be used in the telescope, was then mounted on the manufacturing table and the primary mirror (M1) lowered on to its support system and tested under the same conditions (see photograph on page 1). There was no detectable difference in the image quality according to specification (a) above between the Carl Zeiss and ESO supports: for M1 alone the value was 80 % in *0.25 arcsec,* already a remarkable technical achievement. However, specification (a) does not take account of the improvement achievable by active optics: specification (b) is what should be achieved in the telescope. Carl Zeiss had calculated the result according to the (b) specification for M1 alone as 80 % in *0.096 arcsec!* But this was a *mathematical* calculation and this quality had not been physically realized. So the last stage of the tests was to perform physically the active correction. This was achieved under calm air conditions at night, the controlled error being reduced to the detection level. In this state the mirror showed *physically* no difference from the *mathematically* produced form. Figure 7* (basic material kindly supplied by Mr. Knohl of Carl Zeiss) demonstrates these results. Figure 7 (i) shows the initial *passive* state, corresponding to 80 % in 0.25 arcsec, as an on-line, stabilized interferogram. It is clear that the principal low frequency error is as-

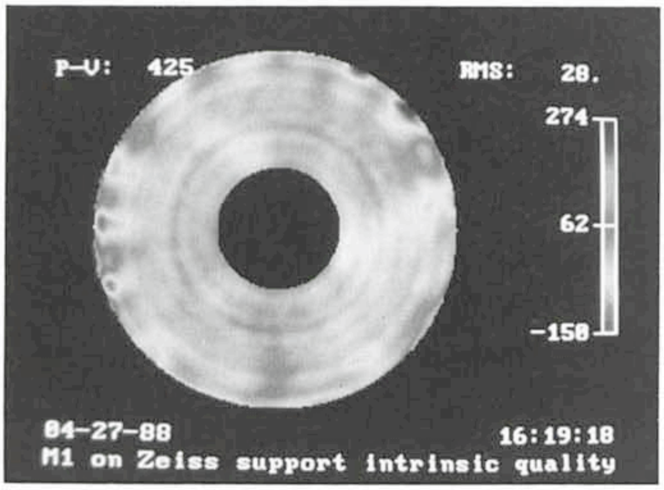
* The wavefronts of Figure 7 show a quite sharp "ring" at about half radius. This ring has nothing to do with the real form of the mirror: it is an artifact introduced by reflexions in the so-called "Null" or "Compensation" system used by Carl Zeiss to remove the huge amount of aberration which would appear in the image due to the correct aspheric form when the primary is tested at its centre of curvature. For technical reasons, Carl Zeiss used the "Offner type" of Null system in which such reflexions cannot be avoided.



(i)



(ii)



(iii)

Figure 7: *Final tests of the NTT primary mirror in its own cell at Carl Zeiss in July, 1988. The figures show the "wavefront" errors (that is, the phase errors of the image forming beam) as variations of intensity for three cases:*
(i) Passive support state without active optics correction.
(ii) The theoretical "Intrinsic Quality" generated mathematically (simulation of perfect active optics correction).
(iii) The physical "Intrinsic Quality" achieved by the final active optics correction in reality.

tigmatism. The averaged rms error of such frames is 175 nm. The elliptical pupil form arose from transfer to a video-recording from which these on-line frames were photographed. Figure 7 (ii) shows the final state, corrected by active optics. This is also an on-line, stabilized interferogram produced under exactly the same conditions. Clearly, the low frequency errors have been corrected, and all that remains is some high frequency azimuthal error at the edge. Figure 7 (iii) shows an *artificial* representation after theoretically perfect correction of the low frequency terms: these terms were mathematically removed from the passive state (equivalent of Fig. 7 (i) above) and the residual errors are represented here as a variation of grey intensity (originally in a colour scale). This grey scale somewhat confuses the direction of the error compared with the colour original, but the high frequency residual errors at the edge are clearly identifiable with those of Figure 7 (ii), taking account of a slight azimuthal rotation. Figure 7 (iii) is averaged for a number of frames and has an rms error of 28 nm, *equivalent to the IQ of 80% in 0.096 arcsec.* Comparison of Figure 7 (ii) and (iii) demonstrates clearly that this IQ has been physically realized.

With the possible exception of the primary of the Space Telescope (2.4 m), this quality for the NTT primary is easily the highest ever achieved in large telescope optics. With active optics the step from Figure 7 (i) to (ii) is a rapid and quite trivial operation. By contrast, it is the considered professional opinion of Carl Zeiss that this quality could not be achieved by conventional *passive* means, not even at ten times the price or more!

5. Final Installation of the NTT

In the autumn of this year, the optics of the NTT will be aligned following our standard procedures – essentially with reference to the altitude axis. After completion of the electronics and optimization of tracking and pointing, the active optics system will be fully tested and its fixed (dc) component installed – the equivalent of the correction just performed at Carl Zeiss. It is expected that this will be completed by March 1989.

We are confident that the NTT will then be working constantly at its Intrinsic Quality, i.e. 80% geometrical energy within 0.125 arcsec. As the first active telescope, it will have easily the best optical quality of all ground-based telescopes. We believe the NTT building and site are well chosen to exploit this inherent quality. But the NTT will still be limited by the seeing. With advances in *adaptive optics* (atmospheric correction), it will be possible in the future to exploit even more fully the quality of the NTT.

6. The Future of Active Optics

We hope we have convinced the reader that the ESO NTT will be a milestone in telescope development. The VLT is based on the same principles but is defined from the start as only functioning in the active mode, since its primaries will be some 40 times more flexible than the NTT primary. The future of active optics with thin monoliths has been discussed in a paper [4] at the ESO conference in March 1988. Perhaps the most exciting possibility is the combination of stress polishing and active optics to avoid completely the aspherizing process for primary mirrors. The VLT blanks are already most of the way towards the necessary flexibility. However, a difficult overlap area, because of time frequencies entering the adaptive optics bandpass, is that of deformations of very thin primaries due to wind buffets. The possibilities and limitations of active optics in this area are still under investigation.

7. Acknowledgements

We wish to acknowledge the advice and help of Gerhard Schwesinger, not only for his invaluable contribution through the theoretical calibrations for the active control of the NTT primary and 1-m mirrors, but also in many other aspects; the firm of REOSC for excellent work on the manufacture of the 1-m mirror; Oberto Citterio and his colleagues in Milan for the design and manufacture of the 1-m supports which have functioned superbly; and, last chronologically but by no means least, the firms of Schott and Carl Zeiss and all their colleagues who contributed to the final excellent test results of the NTT optics and the active optics demonstration. We wish also to thank many ESO colleagues for their contribution.

References

[1] Wilson, R.N., Franza, F., Noethe, L., 1987, "Active Optics I", ESO Preprint No. 484 and *Journal of Modern Optics* **34** (4), 485.

[2] Noethe, L., Franza, F., Giordano, P., Wilson, R.N., Citterio, O., Conti, G., Mattaini, E., 1987, "Active Optics II", ESO Preprint No. 560, accepted for publication in *Journal of Modern Optics.*

[3] Franza, F., Le Luyer, M., Wilson, R.N., 1977, "3.6-m Telescope: The Adjustment and Test on the Sky of the PF Optics with the Gascoigne Plate Correctors", ESO Technical Report No. 8.

[4] Wilson, R.N., Noethe, L., 1988, "Mirrors and Supports", Proc. ESO Conf. on "Very Large Telescopes and their Instrumentation", Garching, March 1988, to appear shortly.

The 3rd ESO/CERN Symposium

G. SETTI, ESO

The 3rd ESO/CERN Symposium on "Astronomy, Cosmology and Fundamental Physics" was held in Bologna (16–20 May, 1988) at the invitation of the University of Bologna celebrating its 900-year anniversary. It was attended by approximately 250 participants, but on many occasions the audience was much larger due to the presence of local scientists and students.

The Symposium was focused on the various subjects important to cosmology and particle physics which were covered by a set of comprehensive review lectures, contributed papers and posters. The reviews included a critical discussion of the value of the Hubble constant (A. Dressler), the large scale distribution of galaxies (M. Geller), a discussion on the distribution and properties of classes of objects at high redshifts (R. Kron), the microwave background (B. Partridge) and the formation of structures in the Universe (N. Vittorio, A. Starobinsky), the evidence and particle constituents of dark matter (D. Lynden-Bell, M. Turner), the status of the standard model of particle physics (R. Peccei), the implications both for the inflationary model of the Universe and of particle physics of going well beyond the standard model (D. Nanopoulos), the fascinating results of ultrarelativistic nuclear collisions (M. Satz) and a review of the underground physics experiments (E. Bellotti). One afternoon was dedicated to the discussion of the Supernova 1987A, this extraordinary event which took place in the Large Magellanic Cloud and for which ESO has accumulated an impressive amount of observational material.

The introductory lecture was given by Prof. A. Salam, Nobel Prize for Physics, who, among other things, emphasized the fundamental importance of studying the Universe for the understanding of the basic laws of physics. As he put it, the extreme conditions to be found in the hot "big-bang" scenario would require man-made particle accelerators having sizes up to the distance to the nearby stars, which is obviously outside of any foreseeable technological development. The main results of the Symposium were beautifully summarized in the Closing Lecture by L. Van Hove.

According to many unsolicited comments the meeting was extremely successful, both scientifically and organizationally, and for this last point a special thanks should be addressed to the local organizers, the Departments of Astronomy and Physics of the University of Bologna. The organization of the meeting greatly benefitted from the generous support provided, among others, by the University of Bologna, the City Authorities of Bologna, the National Research Council of Italy (C.N.R.) and the National Institute of Nuclear Physics (I.N.F.N.).

The Proceedings will be published by Reidel towards the end of this year. Their availability will be announced in the *Messenger.*

At the end of the Symposium, in a ceremony that took place at 12 a.m. on May 20, the Rector of the University of Bologna presented Professor L. Van Hove, former Director General of CERN, and Professor L. Woltjer, former Director General of ESO, with a laurea "honoris causa" respectively in Astronomy and in Physics.

In parallel with the ESO/CERN Symposium, and on the same premises, the Departments of Physics and Astronomy of the Bologna University had organized an exhibition in astronomy and particle physics at which both ESO and CERN participated with their exhibition material. The exhibition was officially opened on May 7 by the Rector of the University and local authorities and was extremely successful, attracting about 30,000 visitors, including many organized school tours.

List of ESO Preprints

June–August 1988

592. P. Bouchet et al.: Infrared Photometry and Spectrophotometry of SN 1987A: March to October 1987 Observations. *Astronomy and Astrophysics.*
593. L. Milano et al.: Search for Contact Systems Among EB-Type Binaries. I: TT Herculis. *Astronomy and Astrophysics.*
594. R. Buonanno et al.: On the Ages of Globular Clusters and the Sandage Period-Shift Effect. *Astronomy and Astrophysics.*
595. J. Melnick et al.: The Galactic Giant H II Region NGC 3603. *Astronomy and Astrophysics.*
596. P.A. Shaver et al.: The Evolution of Structure. Paper presented at a meeting on "Large-Scale Structure and Motions in the Universe", Trieste, April 1988 (to be published by Reidel; eds. G. Giuricin et al.).

597. F. Barone et al.: Gravitational Wave Background from a Sample of 330+4 Pulsars. *Astronomy and Astrophysics.*
598. G. Contopoulos: Short and Long Period Orbits. *Celestial Mechanics.*
599. L. Milano et al.: Search for Contact Systems Among EB-Type Binaries. II: ES Lib and AR Boo. *Astronomy and Astrophysics.*
600. C.N. Tadhunter et al.: Very Extended Ionized Gas in Radio Galaxies: IV. PKS 2152-69. *Monthly Notices of the Royal Astronomical Society.*
601. D. Baade and O. Stahl: Rapid Line Profile Variability of the A-Type Shell- and Possible Pre-Main Sequence Star HD 163296. *Astronomy and Astrophysics.*
602. D. Baade and O. Stahl: New Aspects of the Variability of the Probable Pre-Main Sequence Star HR 5999. *Astronomy and Astrophysics.*
603. S. D'Odorico: Multiple Object Spectroscopy at ESO: Today's Facilities and Future Prospects. Invited paper to a conference.
604. G. Setti: The Extragalactic X-Ray Background. Invited paper to appear in the Proceedings of the YAMADA Conference XX on "Big Bang, Active Galactic Nuclei and Supernovae, Tokyo, March 28–April 1, 1988.
605. S. Cristiani et al.: Quasars in the Field of SA94. III. A Colour Survey. *Astronomy and Astrophysics.*
606. F. Barone et al.: Search for Contact Systems among EB-Type Binaries. III: UU Cnc and VZ Psc, Contact Systems Before the Common Envelope Phase? *Astronomy and Astrophysics.*
607. G. Contopoulos: Nonuniqueness of Families of Periodic Solutions in a Four Dimensional Mapping. *Celestial Mechanics.*

Seeing Measurements with a Differential Image Motion Monitor

H. PEDERSEN, F. RIGAUT, M. SARAZIN, ESO

Concept of the DIMM

Seeing is possibly the most important parameter describing a ground-based astronomical observatory. Under conditions of good seeing, an aberration-free telescope will produce sharp and bright images. The astronomer can then explore the universe to greater depths than otherwise possible.

In recent years, a considerable amount of theoretical and experimental seeing studies have been conducted. The action of the earth's atmosphere on the quality of astronomical observations is now understood in quite some detail, and it has also become possible to measure the prevailing seeing, without the use of large and very expensive telescopes. This is obviously of great interest in the search for new observatory sites.

One particular instrument which can simulate seeing conditions at larger telescopes is called the Differential Image Motion Monitor, or DIMM. Its concept goes back at least to 1960, when it was used for qualitative seeing studies [1]. Later, F. Roddier [2] has shown its potential for quantitative measurements. This prompted ESO to use DIMM in the search for the site for the Very Large Telescope.

The detector unit of DIMM houses an intensified CCD and is attached to an alt-alt mounted, 350-mm aperture Cassegrain telescope. All essential functions are computer controlled, and tracking is assisted by an autoguider. The instrument is placed in open air on a 5 m high tower. Typically, the telescope follows a bright star for a couple of hours, while the star crosses the meridian.

The full aperture of the instrument is used for self-calibration, while, in its regular mode of operation, the entrance is restricted to two circular holes. These are 4 cm diameter, and spaced 20 cm, centre to centre. Under perfect conditions, light arrives as a plane wave, forming two images at fixed positions. The presence of turbulence in the earth's atmosphere causes the arrival direction to differ slightly between the two holes. The two spots on the detector will then shift relative to each other. Their time-averaged motion is proportional to the astronomical seeing. In principle, the scaling factor is defined by the system parameters, and does not depend on any empirically determined value. To demonstrate that this is really the case, we decided to compare the DIMM with standard seeing measurements at big telescopes. Such have been conducted on a regular basis for several years, using imaging CCD cameras [5]. In order to allow a comparison as realistic as possible, it was necessary to mount the DIMM inside a dome. For the presently described tests, May 26 to 28, 1988, it was mounted on the exterior of the 2.2-m telescope's mirror cell.

Measurement in Parallel with the 2.2-m Telescope

In spite of the fact that the instruments were observing in parallel, at least two effects tend to complicate the comparison. A relatively small effect is due to turbulence within the 2.2-m mirror cell. This is not measured by the DIMM, since it used its own optics. The size of the error is difficult to quantify. We believe it is comparable to the measurement accuracy (0.1″), or smaller.

A more severe effect is due to optical aberrations in the 2.2-m. In order to quantify this, we refer to the last optical tests, which were conducted in December 1987. A set of Shack-Hartmann plates show that the main error is due to astigmatism, decentring coma being negligible and spherical aberration absent. At best focus, 80% of the energy is concentrated within a diameter of 0.45″. For seeing ~ 1″, this corresponds to a quadratic contribution of 0.35″ in terms of FWHM. To allow also for the mirror-seeing problem, we have

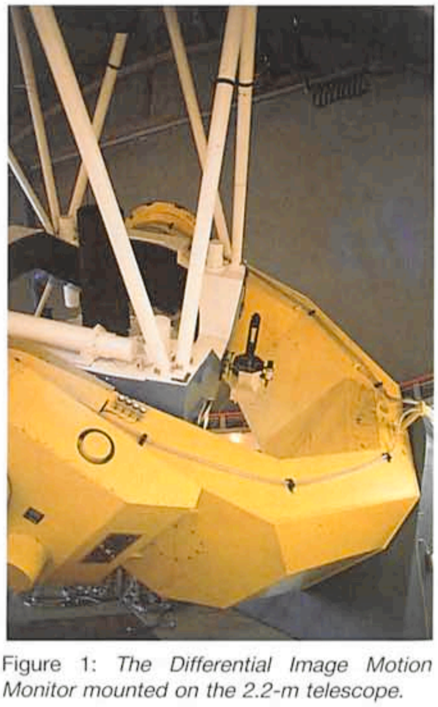


Figure 1: *The Differential Image Motion Monitor mounted on the 2.2-m telescope.*

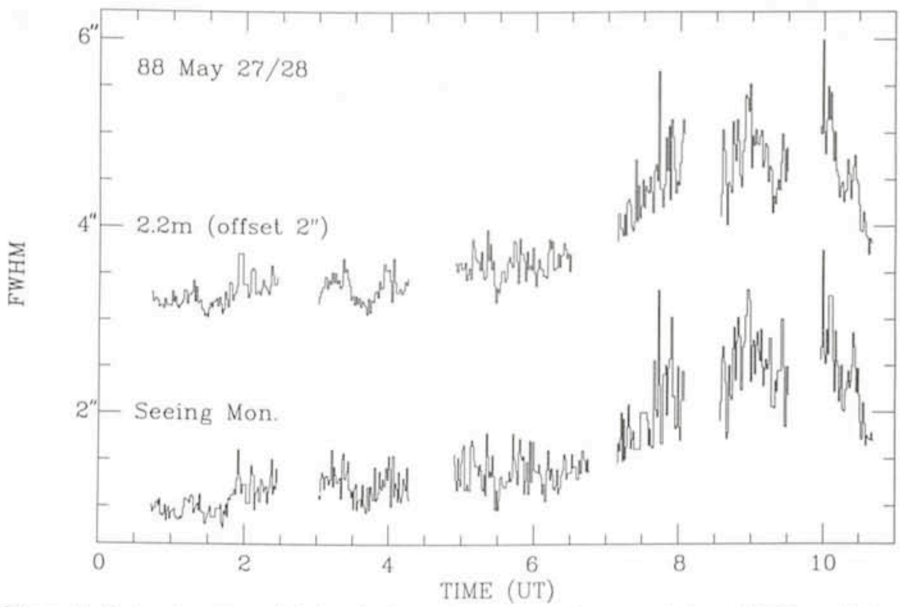


Figure 2: *During the second night of observation, the seeing started around 0.8", and later became worse. In this presentation the 2.2-m data have been rebinned to match the DIMM time slots, and corrected to a standard wavelength 560 nm.*

assigned 0.4" as the intrinsic image quality of the 2.2-m telescope.

During the nights of simultaneous seeing measurements, the 2.2-m CCD camera employed a detector with pixel size 0.365". At this resolution proper sampling is ensured. The optical filter was RG-9 and we have assumed that this corresponds to 800 nm effective wavelength. The integration time was 50 seconds, followed by 15 seconds dead-time. Standard software was used to fit Gaussian profiles to star-images. The seeing at full width, half maximum, was calculated in two orthogonal directions, S_x and S_y, and transformed to 560 nm wavelength. The astigmatism was noticed through slow drifts of the focus, caused by temperature changes of the telescope structure. To minimize the effect, we used the average, S, in the two directions. The rms error of a single determination of S is smaller than 0.1", as shown by an analysis of $S_x - S_y$.

The simultaneously acquired DIMM measurements lasted 1 minute each, and the statistical error was 6%. The conversion from differential image motion to equivalent seeing was also made at 560 nm. Note, however, that the DIMM results are independent of the detector's chromatic characteristics, since image motion is not a function of wavelength [3].

Figure 2 shows the results obtained during one of the test nights. The seeing ranged from 0.8" in the beginning, to more than 3". Periods without data correspond to change of star, combined with a careful refocussing of the 2.2-m. The 2.2-m data have been rebinned in time to correspond to the time-slots of the DIMM.

The direct comparison (using data from both nights) gives a best linear fit: $S_{2.2m} = 1.05 \times S_{DIMM} + 0.14$ arcseconds, with a correlation coefficient of 0.965. Following correction for the known aberrations of the 2.2-m telescope the relation (Figure 3) changes to $S_{2.2m} = 1.02 \times S_{DIMM} + 0.08$ arcseconds.

The difference from a one-to-one relation is more likely due to an undescribed problem in the 2.2-m data than to a systematic underevaluation on part of DIMM. Therefore we believe that the present comparison provides sufficient reassurance for the use of DIMM as a quantitative seeing measurement tool.

DIMM in Operation

The first DIMM unit has been in regular use since April 1987 when it was installed at Cerro Paranal, one of the candidate sites for the VLT. Over 40,000 individual seeing measurements are available from that place. A second system was recently built, and is now mounted at another candidate site, Cerro Vizcachas, a few km south-east of La Silla.

The hardware of both systems is prepared for automatization. This will be completed in the near future, whereafter seeing monitoring can be done on a permanent basis. As a by-product, we obtain quantitative data on the photometric quality of the sky.

We note that seeing monitors are not only of interest in the site-testing phase. Also remote controlled observations, and automated programme selection can benefit much from such information.

References

1. M. Sarazin: "ESO-VLT Instrumentation for site evaluation in Northern Chile", in *Advanced Technology Optical Telescopes III"*, SPIE, Vol. **628,** 138–141 (1986).
2. J. Stock and G. Keller: "Astronomical Seeing", in *Stars and Stellar Systems* Vol. **1,** 138–153 (1960).
3. F. Roddier: "The effect of atmospheric turbulence in optical astronomy", in *Progress in Optics XIX,* editor E. Wolf, 281–376 (1981).
4. M. Sarazin: "Site evaluation for the VLT: a Status Report", *The Messenger* No. **49,** 37–39 (1987).
5. H. Pedersen: "Seeing at La Silla", Internal Report, ESO (1988).

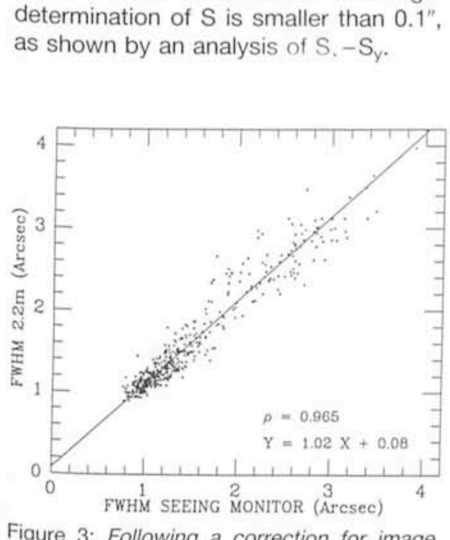


Figure 3: *Following a correction for image aberrations at the 2.2-m, the correlation between the two sets of data is acceptable.*

Visiting Astronomers

(October 1, 1988–April 1, 1989)

Observing time has now been allocated for Period 42 (October 1, 1988–April 1, 1989). As usual, the demand for telescope time was much greater than the time actually available.

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

3.6-m Telescope

October 1988: Wampler, Guzzo/Collins/Heydon-Dumbleton, Soucail/Fort/Tyson/Turner, Mellier/Mathez/Soucail, Maccagni/Gioia/Maccacaro/Vettolani, Iovino/Shaver/Cristiani/Clowes, Danziger/Gilmozzi, Moorwood/Oliva, Danziger/Moorwood/Oliva, Danziger/Fosbury/Lucy/Wampler/Bouchet.

November 1988: Moeller/K. Rasmussen, Danziger/Cristiani/Guzzo, Barbieri/Clowes/

Iovino/Cristiani/La Franca, Surdej/Borgeest/Kayser/Kellermann/Magain/Remy/Refsdal/Swings, Breysacher/Azzopardi/Lequeux/Meyssonnier/Westerlund, Kudritzki/Méndez/Husfeld/Herrero, Zickgraf/Wolf/Gail/Gass, Israel/Koornneef, Danziger/Fosbury/Lucy/Wampler/Bouchet.

December 1988: Renzini/D'Odorico/Greggio/Bragaglia, Madejsky/Bender, Meylan/Shaver/Djorgovski, Marano/Boyle/Zamorani/Zitelli, Kunth/Augarde/Chalabaev/Comte/Lequeux/Machara/Takase, Heydari-Malayeri/Schwarz, Lortet/Testor/Schild, Foing/Collier/Soderblom/Rucinski/Pettersen/Penston/Robinson, Ferlet/Lallement/Vidal-M./Grenier/Andreani, Wampler, Danziger/Fosbury/Lucy/Wampler/Gouiffes.

January 1989: van Paradijs/Augusteijn/van der Klis, Giraud, Röser/Meisenheimer, Weigelt/Baier/Fleischmann, Chalabaev/Perrier/Mariotti, Wolf/Stahl/Davidson/Humphreys, Ardeberg/Lundström/Lindgren, Webb/Carswell/Shaver, Schwarz/Huggins.

February 1989: van der Kruit/Pickles, Bignami/Caraveo/Mereghetti, Capaccioli/Cappellaro/Held, Sparks/Macchetto/Miley, Weidemann/Koester/Jordan, Nissen/Schuster, Kudritzki/Méndez/Husfeld/Herrero, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Möllenhoff/Madejsky.

March 1989: Bertola/Buson/Danziger/Sadler/de Zeeuw, Tadhunter/Fosbury/di Serego Alighieri/Danziger/Morganti, Courvoisier/Danziger, Bergeron/Yee, Hammer/Le Fèvre/Proust, Fosbury/di Serego A./Tadhunter/Hook/Robinson, Jarvis/Dubath/Martinet, Moneti/Moorwood/Tapia, Danziger/Fosbury/Lucy/Wampler/Bouchet.

2.2-m Telescope

October 1988: MPI TIME, Heydari-Malayeri, Danziger/Moorwood/Oliva.

November 1988: Cetty-Véron/Sandage/Véron, Johansson, Surdej/Borgeest/Kayser/Kellermann/Magain/Remy/Refsdal/Swings, Azzopardi/Lequeux/Rebeirot, Westerlund/Azzopardi/Rebeirot/Breysacher, Melnick/Hunt, Westerlund/Azzopardi/Rebeirot/Breysacher, Baade/Krautter, Danziger/Fosbury/Lucy/Wampler/Bouchet, Lundgren.

December 1988: Lindblad/Jörsäter, Wagner/Bender, Bender/Nieto, Meylan/Djorgovski, Brahic/Smith/Grenier/Terrile/Vidal-Madjar, Caplan/Deharveng, Heydari-Malayeri, Falomo/Tanzi/Treves.

January 1989: Franx/Illingworth, Walton/Pottasch/Taylor, Giraud, Paresce/Nota/Clampin/Viotti/Lamers/Burrows, MPI TIME.

February 1989: MPI TIME, Tanzi/Bouchet/Falomo/Treves, Danziger/Fosbury/Lucy/Wampler/Bouchet, Reipurth, Prusti/Wesselius/Assendorp, Gioia/Bouchet/Maccacaro/Vettolani/Maccagni, Piotto/Ortolani.

March 1989: Capaccioli/Ortolani/Piotto, Tosi/Focardi/Greggio, Bertola/Buson/Danziger/Sadler/de Zeeuw, de Jong/van den Broek/van Driel/Lub, Tadhunter/Fosbury/di Serego Alighieri/Danziger/Morganti, Appenzeller/Bender/Wagner, Grosbøl.

1.5-m Spectrographic Telescope

October 1988: Arsenault, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Guzzo/Collins/Heydon-Dumbleton, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Schulz/Rafanelli, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Khan/Duerbeck, Doazan/Sedmak/Barylak/Bourdonneau, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Böhnhardt/Vanysek/Grün/Massonne/Beißer.

November 1988: Böhnhardt/Vanysek/Grün/Massone/Beißer, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Balkowski/Proust/Maurogordato, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Johansson/Bergvall, Danziger/Fosbury/Lucy/Wampler/Gouiffes, de Boer/Heber/Möhler, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Buzzoni/Mantegazza/Malagnini/Castelli/Morossi.

December 1988: Lundgren, Pakull/Motch, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Lortet/Testor, Spinoglio/Malkan, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Boffin/Jorissen/Arnould, de Ruiter/Lub, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Greve/McKeith.

January 1989: Greve/McKeith, Pottasch/Pecker/Karoji/Sahu, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Courvoisier/Bouchet, Mathys/Maeder, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Faraggiana/Gerbaldi/Ramella/Böhm, Pallavicini/Giampapa/Cutispoto, Baade/Simon.

February 1989: Danziger/Fosbury/Lucy/Wampler/Gouiffes, Johansson/Bergvall, Bässgen M./Bässgen G./Grewing/Cerrato/Diesch, Pettersson, Tanzi/Bouchet/Falomo/Treves, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Weiss/Schneider, van Paradijs/van Kerkwijk/Zuiderwijk, Sterken, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Waelkens/Lamers/Trams/Waters.

March 1989: Waelkens/Lamers/Trams/Waters, Gosset/Surdej/Swings/ Woltjer, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Vettolani/Chincarini/Fairall/da Costa/Willmer, van Genderen/v. d. Hucht/Schwarz/de Loore, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Friedjung/Bianchini/Sabbadin, Danziger/Fosbury/Lucy/Wampler/Gouiffes, Courvoisier/Bouchet, de Jong/Hu/Slijkhuis, Thé/Hu.

1.4-m CAT

October 1988: Gerbaldi/Faraggiana, Crane/Palazzi, Schwarz/Bode/Duerbeck/Meaburn/Seitter/Taylor.

November 1988: Lèbre/Mennessier, Pasquini/Restaino/Falciani, Martin N./Maurice, Maurice/Martin N., Cayrel de Strobel, Lagrange/Ferlet/Vidal-Madjar, Ferlet/Andreani/Dennefeld/Vidal-Madjar.

December 1988: Ferlet/Andreani/Dennefeld/Vidal/Madjar, Thimm/Hanuschik/Schmidt-Kaler, Danks/Crane/Massa, Schwarz/Bode/Duerbeck/Meaburn/Seitter/Taylor, Lagrange/Vidal-Madjar/Ferlet, Ferlet/Lallement/Grenier/Vidal-Madjar/Andreani, da Silva/de La Reza.

January 1989: da Silva/de La Reza, Pottasch/Pecker/Sahu K.C./Sahu M., Barbuy, Grenon/Barbuy, Pottasch/Sahu K.C., Gredel/v. Dishoeck/Black, Mathys/Solanki, Westerlund, Reimers/Toussaint/Schröder, Pallavicini/Giampapa/Cutispoto.

February 1989: Baade/Kürster/Schmitt, Gustafsson/Gray/Norberg, Baade/Kürster/Schmitt, Pettersson/Westerlund, Waelkens/Lamers/Trams/Waters, de Vries/v. Dishoek/Habing, Reimers/Toussaint/Schröder.

March 1989: Thimm/Hanuschik/Schmidt-Kaler, Clausen, Gillet, Foing/Jankov/Char/Butler/Rodono/Catalano, Gratton/Gustafsson/Eriksson.

1-m Photographic Telescope

October 1988: Hesselbjerg Christensen, Alcaino/Liller, Di Martino/Zappalà/Cellino/Farinella, Jockers/Rauer/Wagner/Barteldrees/Dettmar/Hoffmann/Geyer, Encrenaz T./Bouchet/Combes M., Danziger/Fosbury/Lucy/Wampler/Bouchet, Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff.

November 1988: Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff, Gouiffes/Cristiani, Johansson/Bergvall, de Boer/Heber/Möhler, Johansson/Bergvall, Danziger/Fosbury/Lucy/Wampler/Bouchet, Encrenaz T./Bouchet/Combes M., Gouiffes/Cristiani.

December 1988: Gouiffes/Cristiani, Mattila/Schnur, Sterken, Spinoglio/Malkan, Danziger/Fosbury/Lucy/Wampler/Bouchet, Encrenaz T./Bouchet/Combes M., Courvoisier/Bouchet, Le Bertre, Schneider/Jenkner/Maitzen.

January 1989: Schneider/Jenkner/Maitzen, Gouiffes/Cristiani, Barucci/Fulchignoni/Harris/Binzel/Di Martino/De Angelis/Burchi/Di Paolantonio, Danziger/Fosbury/Lucy/Wampler/Bouchet, Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff, Courvoisier/Bouchet, Le Bertre, Balkowski/Arimoto/Durret/Proust, Wolf/Stahl/Davidson/Humphreys, Balkowski/Arimoto/Durret/Proust.

February 1989: Trefzger/Labhardt/Spaenhauer, Pettersson, Caraveo/Bignami/Mereghetti, Gerbaldi/Faraggiana, Heske, Danziger/Fosbury/Lucy/Wampler/Bouchet, Waelkens/Lamers/Trams/Waters, Le Bertre.

March 1989: Courvoisier/Bouchet, Gouiffes/Cristiani, Manfroid/Vreux/Gosset, de Jong/Hu/Slijkhuis, Thé/Hu, Danziger/Fosbury/Lucy/Wampler/Bouchet, Le Bertre, Courvoisier/Bouchet, Brocato/Di Giorgio/Richichi.

50-cm ESO Photometric Telescope

October 1988: Group for Long Term Photometry of Variables, Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff.

November 1988: Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff, Group for Long Term Photometry of Variables, Carrasco/Loyola, Morell/Gustafsson, Vidal-Madjar/Sevre/Ferlet/Lagrange.

December 1988: Mattila/Schnur, Bernacca/Massone/Lattanzi, Foing/Collier/Soderblom/Rucinski/Pettersen/Penston/Robinson.

January 1989: Kohoutek, Bouvier/Basri/Bertout/Bastien/Bouchet/Imhoff, Wolf/Stahl/Davidson/Humphreys, Pallavicini/Giampapa/Cutispoto.

February 1989: Carrasco/Loyola, Trefzger/Labhardt/Spaenhauer, Gustafsson/Gray/Norberg, Cutispoto/Rodono/Ventura/Giampapa, Debehogne/Di Martino/Zappala/Lagerkvist/Hahn/Magnusson/De Campos.

March 1989: Cutispoto/Rodono/Ventura/Giampapa, Foing/Jankov/Char/Houdebine/Butler/Rodono/Catalano S., Thé/Hu.

GPO 40-cm Astrograph

November 1988: Böhnhardt/Vanyek/Grün/Massonne/Beißer, Böhnhardt/Geffert.

December 1988: Madsen/West, Bernacca/Massone/Lattanzi.
January 1989: Aniol/Seitter/Duerbeck/Tsvetkov, Scardia.
February 1989: Scardia, Debehogne/Machado/Mourao/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Protitch-B./Javanshir/Woszczyk.

1.5-m Danish Telescope

October 1988: Olsen, Gyldenkerne, Hansen, Møller/Kjaergaard Rasmussen/Møller, Olsen, Magain/Remy/Surdej/Swings.
November 1988: Johansson/Bergvall, de Boer/Richtler/Sagar, Bergvall/Jörsäter/Olofsson, Balkowski/Arimoto/Durret/Proust, Liller/Alcaino, Baade/Krautter, Storm/Andersen.
December 1988: Storm/Anderson, Reiz/Piirola, Reipurth, Ardeberg/Lindgren/Lundström, Häfner/Schoembs.
January 1989: Naylor/Charles/Smale/Callanan, West, Duerbeck/Vogt/Leibowitz, Augusteijn/Schwarz/van Paradijs, Andersen/Nordström, Reipurth, Knude.
February 1989: Knude, Hansen, Knude, Andersen/Nordström/Mayor/Olsen, Nordström/Andersen, Griffin R.F./Griffin R.E.M./Mayor/Clube, Mayor/Duquennoy/Andersen/Nordström.
March 1989: Meylan/Mayor, Fusi Pecci/Buonanno/Ortolani/Renzini/Ferraro, de Jong/van den Broek/van Driel/Lub, de Jong/Hu/Slijkhuis, Andersen/Nordström, Gammelgaard/Kristensen.

50-cm Danish Telescope

October 1988: Olsen, Rodriguez/Lopez/Rolland.
November 1988: Rodriguez/Lopez/Rolland, Group for Long Term Photometry of Variables.
December 1988: Lampens, Lampens/Dommanget.
January 1989: Lampens, Lampens/Dommanget, Ardeberg/Lindgren/Lundström, Lodén K.
February 1989: Clausen.
March 1989: Clausen, Group for Long Term Photometry of Variables.

90-cm Dutch Telescope

October 1988: Van Genderen/Hadiyanto.
November 1988: van Genderen/Hadiyanto, van Paradijs/Winget/Warner/Augusteijn, v. Amerongen/v. Paradijs.
December 1988: de Loore/Hensberge/Verschueren/David/Blaauw.
January 1989: Greve/van Genderen/Laval, v. Amerongen/v. Paradijs.
February 1989: Schneider/Weiss.
March 1989: Schneider/Weiss, van Genderen/v. d. Hucht/Schwarz/de Loore, Thé/Hu.

61-cm Bochum Telescope

October 1988: Seggewiss/Moffat.
January 1989: Schneider/Jenkner/Maitzen.

SEST

November 1988: Tacconi, Mebold, Gredel, Brand, Reipurth.
January 1989: Israel, Dupraz, Radford, Huchtmeier, Becker, Israel, Cernicharo, Pottasch, Reipurth.
March 1989: Bajaja, Dahlem, Israel, Armstrong, Le Bertre, Boulanger, Bel, Cerin, Gredel, Bronfman, Omont, Tapia, Haikala, Loup.

The First ESO-OHP School in Astrophysical Observations Blessed by Clear Skies!

A. CHALABAEV, Observatoire de Haute-Provence, C. N. R. S., France, and
S. D'ODORICO, ESO

In the last decades, the search for better conditions for astronomical observations as well as the need to cover the southern sky led many countries to develop observatories at relatively remote sites. Among many positive consequences, this move also has a negative one. Because of the cost of travelling, the training of European students in astronomy is too often limited to data reduction or, if the students are sent overseas, they lack the guidance of a senior astronomer during their first observing run. As a consequence, sophisticated and expensive facilities are often not used in the most efficient way, since the gathering of accurate and reliable data in a minimum of telescope time – while not an impossible art to learn quickly – greatly benefits from experience.

The aim of the Summer School in Astrophysical Observations, organized jointly by ESO and the Observatoire de Haute-Provence (OHP) with the support of the C. N. R. S. of France, was to fill this gap in the professional preparation of young European astronomers. The OHP has a number of characteristics which makes it a unique place in Europe to fill this role. It is placed at a relatively central location with good observing weather during summer and autumn. Besides classical instrumentation, still using photographic plates, the observatory is equipped with CCD-based modern spectrographs. The data-aquisition sys-

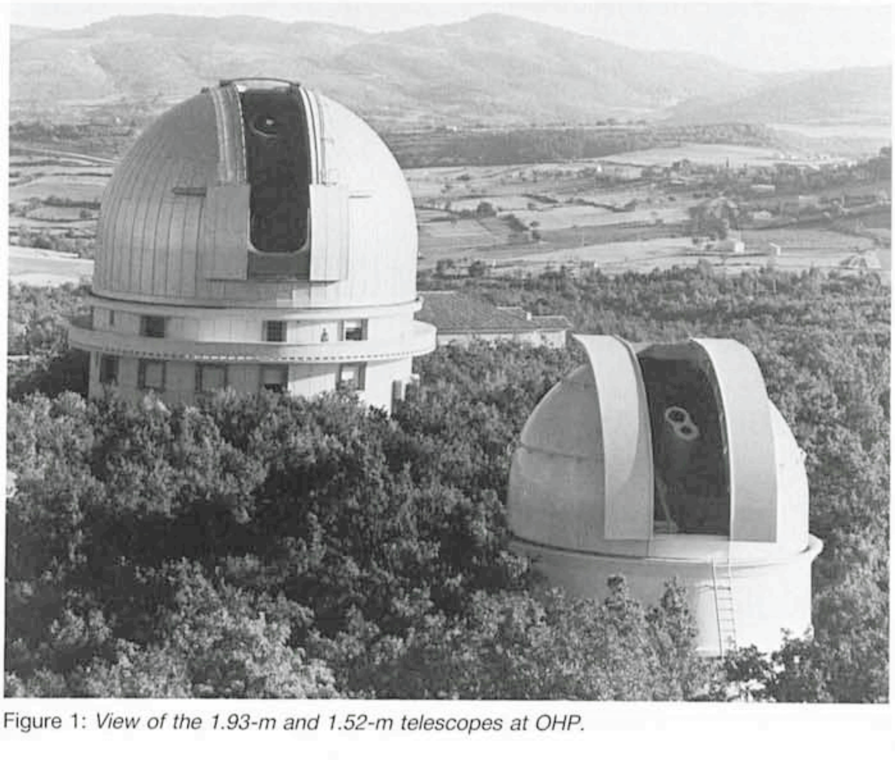


Figure 1: *View of the 1.93-m and 1.52-m telescopes at OHP.*

tem and the data reduction software (IHAP and MIDAS) are identical to those used at ESO. Autoguider and the remote controlled spectrograph functions are also very similar to the ones astronomers face in the observatories overseas.

The school offered a number of courses on different subjects of observational astronomy. The courses, given by scientists with sound observational experience, dealt with the scientific background, the theory and the practice of observations. The emphasis was on the preparation of an observing programme, on the evaluation of parameters which determine the signal-to-noise ratios of the final data and on the practical problems to be faced at the telescope. Finally, an introduction was given to the IHAP and MIDAS data reduction systems. The speakers made an effort to cover all those points that you hardly ever find in textbooks or that are hidden between the lines of user's manuals (anyway, did you ever meet an astronomer who carefully reads user's manuals?).

List of courses

Modern and future telescopes	M. Tarenghi (ESO)
Optical and imaging instrumentation	S. D'Odorico (ESO)
Detectors in astronomy	M. Dennefeld (Paris)
Photometry in the visible	F. Rufener (Geneva)
Photometry with CCD's	S. Ilovaisky (OHP)
Photometry in the infrared	P. Bouchet (ESO)
Low resolution spectroscopy	S. Cristiani (Padova)
High resolution spectroscopy	D. Gillet (OHP)
Polarimetry	H. Schwarz (ESO)
Interferometric observations	J.M. Mariotti (Meudon)
Observations at the 120-cm telescope	E. Maurice (Marseille)
Observations at the Schmidt telescope	R. Burnage (OHP)
IHAP	M.-P. Véron-Cetty (OHP)
MIDAS	A. Richichi (ESO)

Tutoring astronomers: A. Chalabaev, C. Chevalier, D. Gillet, S. Ilovaisky, Ph. Véron, M.-P. Véron-Cetty (all OHP), M. Dennefeld (IAP, Paris), and S. D'Odorico (ESO)

Students: H. Boffin (Bruxelles, Belgium), A. Cappi (Bologna, Italy), Ph. Chantry (Meudon, France), J.-G. Cuby (Meudon, France), B. Cunow (Münster, FRG), M. Deleuil (Marseille, France), P. Dubath (Genève, Switzerland), J. Egonsson (Lund, Sweden), M. Jensen (Copenhagen, Denmark), M. Franchini (Trieste, Italy), A. Fruscione (Paris, France), A. Lèbre (Montpellier, France), F. Leone (Catania, Italy), P. Petitjean (Paris, France), R. Plötzel (Heidelberg, FRG), H. Röttgering (Leiden, the Netherlands), Thou Xu (OHP, France).

Besides the theoretical courses, and this is the particularity of the School, four nights were reserved at the 1.93-m, the 1.2-m and at the Schmidt telescopes in order to offer the students a chance to obtain astrophysical data "in real time". While the work at the smaller telescopes was limited to obtaining photographic plates under the guidance of an astronomer (a spectrum at the 1.2-m and an objective prism plate at the Schmidt), the spectroscopy at the 1.93-m with the CARELEC spectrograph and a CCD detector had a more ambitious character. The students were divided in groups of two or three, each with a tutoring astronomer. The latter proposed a programme of spectroscopic observations, guided the students through data reduction with IHAP or MIDAS software and helped with the presentation of the results on the last day of the School. Measuring redshifts of a number of extragalactic sources and classifying them, monitoring the spectroscopic variation of an X-ray source are examples of the work done by students.

The perfect observing weather greatly contributed to the smooth and successful progress of the school. The atmosphere of the Observatory, with its peculiar working schedules, and the excitement of collecting real and interesting astronomical data, made the contacts among the participants easy and stimulated the initiative of the students, who played an active role in conducting their mini research programmes. Sure, an OHP staff astronomer was always present in a corner of the control room, ready to provide help or advice, but we can say, without exaggeration, that after the 10 days of intensive training we would feel confident to leave our ex-students to perform an observing run fully on their own. Well, at least most of them. The school was hard work, too. Towards the end, the pleasures and the frustrations of reducing and analysing the CCD data on a crowded computer overlapped with the observing, leaving little time for regular sleep. The students passed this familiar "astronomer stress" test as well and on the final day gave remarkable final presentations of their work.

We feel that the school fully accomplished its task. This was due to the motivated and active cooperation of several persons at OHP and ESO. We would like, in particular, to address a special word of thanks to our colleagues who gave the spoken and practical courses and/or played the role of the tutors.

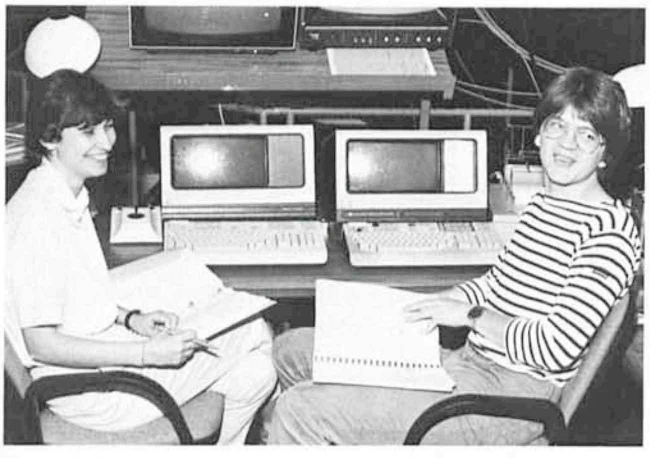
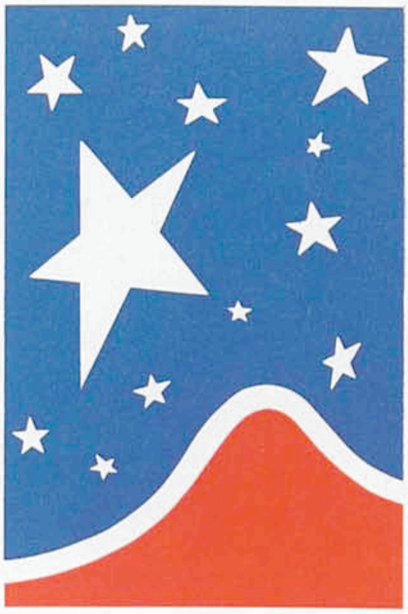


Figure 2: *Students M.G. Franchini and H. Boffin enjoying a moment of relax during a long CCD integration at the 1.93-m telescope.*

Figure 3: *Students A. Lèbre, F. Leone and H. Röttgering working on the reduction of a CCD spectrum at a MIDAS station.*

20th General Assembly of the International Astronomical Union



UAI 20 IAU
UNION ASTRONOMIQUE INTERNATIONALE
ASSEMBLÉE GÉNÉRALE
BALTIMORE MARYLAND USA

Following the earlier IAU General Assemblies in Montreal (1979), Patras (1982) and Delhi (1985), the XXth IAU GA was held in Baltimore, Maryland, USA, from 2–11 August 1988. This was the first time in the United States since 1961. About 2,000 participants listened to more than 1,000 talks during more than 250 sessions, organized by 40 IAU Commissions. In addition, there were three Invited Discourses and seven one-day Joint Discussions.

A full report will appear in the IAU *Transactions* and *Highlights*. In the meantime, and for the benefit of those *Messenger* readers who were not present, here is a small selection of items from the GA. They were mostly written by participating ESO astronomers at the editor's request and should only be regarded as personal reflections, culled from the enormous information flow. Others are adapted from the excellent daily newspaper, *IAU Today* and unsigned notes are by the editor.

The Inauguration

The General Assembly was formally opened on 2 August by the President of the IAU, Professor J. Sahade from Argentina. During the Inaugural Ceremony, speeches were given by the hosts, Drs. A.F. Davidsen and R. Giacconi and the chairman of the National Organizing Committee, Prof. F. Drake. They were followed by the President of the Johns Hopkins University (Dr. S. Muller), the Mayor of Baltimore (The Honourable Kurt L. Schmoke), the Lieutenant Governor of the State of Maryland (M.E. Steinberg) and representatives of the funding organizations, NSF and NASA. Finally, the Science Advisor to President Reagan, Dr. William R. Graham, brought a message from the President.

All of the speakers stressed the importance of astronomy and astrophysics and although some of them hinted at some current funding shortages in the United States, most were optimistic about future discoveries and the realization of future, large facilities. Professor Sahade, in his speech of thanks, mentioned the importance of conserving optimal observing conditions and the need to avoid sky pollution. He explicitly mentioned the Celestis project as a potential major offender.

Astronomy is for Everybody

Have you ever been asked the question (perhaps by yourself) why developing countries should engage in astronomical research? If posed with an "If" at the front end, everyone engaged in astronomy will readily answer with "Yes". But the "Why" requires more thought and care. All the more remarkable is the convincing simplicity of the answer given by Mazlan Othman from Malaysia at a press conference. The following quotations of her statements are taken from the daily newspaper *IAU Today:*

Mayor Schmoke said (in the inauguration ceremony) astronomy is "the stuff of dreams and youthful fascination". This is true in the United States and it is also clearly true for us in developing countries. . . . Our youth are interested in astronomy and space just as much as young people in developed countries. And when you do achieve your dreams, we hope not to be too far behind you. . . . For excitement in science, there's nothing better than astronomy.

Fun, improved national self-reliance, gateway to scientific literacy, and technology transfer – maybe also in the developed countries we should pay more attention to these potentials of astronomy in other regions of the world.

D. Baade

Optical Sensors

The world of optical sensors moves forward more slowly than many astronomers would wish, but it moves forward none the less. Even though we may not yet have the long promised Tektronix 2048 × 2048 CCD in our hands, definite evidence is now available to show that the charge-trap problem, which has plagued these devices in the past, has been brought under control. Meanwhile, other new devices with impressive performance figures have recently appeared on the scene. The 1200 × 400 Reticon CCD offers a very generous surface area for spectroscopic applications, and the new Ford-Aerospace CCDs show outstanding noise and CTE characteristics. Although neither of these chips has yet been thinned, both the major European CCD manufacturers, EEV and Thomson, have already produced examples of thinned devices in the last six months, as well as prototypes of their own large area imagers.

Altogether, the CCD landscape has taken on a decidedly more rosey hue than in recent years. Maybe by the next IAU General Assembly we will really be using the sensors of which we have long dreamt. Let us hope that our horizons have not expanded too much in the meantime.

M. Cullum

Photography

The Working Group on Photographic Problems (under Commission 9) held two well-attended sessions with talks ranging from recent developments in image processing to technical and astronomical aspects of the various projects in which the world's large Schmidt telescopes and other photographic instruments are now engaged. Of particular interest was a talk by D.F. Malin (AAT) on the combination of large numbers of plates showing clusters of galaxies. This enables photographic detection of objects down to 26th–27th magnitude. There was also a very detailed presentation by J. Burdsall from Eastman Kodak which offered a rare insight into the plate manufacturing process. He also discussed the possibilities of minimizing the batch-to-batch differences for the IIIa-emulsions and how to double the effective speed of these emulsions by changes in the manufacturing process. There was also a discussion about the new tablet-grain emulsion (Kodak T-max) which holds great promise in astronomy.

ESO was represented by a paper on the detection of low-mass star formation regions by means of very deep Schmidt plates (by Reipurth and Madsen) and also a paper on elliptical galaxies with dust lanes (by Bertola et al.).

C. Madsen

Interferometry Progresses at All Wavelengths

Interferometry in the centimetre wavelength range has become an established tool in astronomy. This has been beautifully demonstrated by high resolution images from the VLA, Westerbork and other radio observatories. Now multi-aperture imaging is pushing towards full coverage of the metre to visible wavelength range, as is already the state of the art in single-aperture imaging. Among the many current projects are the metre wavelength array in India and also the IRAM submillimetre telescopes which will soon become operational in the combined mode on the Plateau-de-Bures.

The ultimate technological challenge now lies in the infrared and visible wavelength regions, as exemplified by the ESO Very Large Telescope. The first results with smaller arrays have shown that the complex problems of phasing are well understood; this was pointed out by Pierre Léna. Several projects with individual telescope sizes up to 1.5 m are planned or under construction; they have fancy names like SUSI, IOTA, COAST, INT, CHARA, etc. There were no less than four sessions about interferometry at the General Assembly – a crowded auditorium testified to the high expectations in this new, exciting field.

F. Merkle

Astronomy in Space

Inexperienced GA participants attending one of the various Joint Discussions run the risk of being disappointed in the sense that these events often are neither joint nor discussions. An interesting exception to this rule was the fourth session of JD VII *The Hubble Space Telescope – Status and Perspectives* which was devoted to long-term prospects. Not surprisingly, the nature of the discussions there was not purely astronomical.

A vision of an 8–16-m telescope as the successor of HST was commented upon as being too little innovative by a high-ranking ESA representative who felt that merely increasing the light collecting power was not in itself a sufficient goal. He also demanded that the costs must be kept within reasonable limits – nevertheless, twice the financial envelope of HST would not scare away too many interested parties, at least not on the astronomical side.

In the second presentation, a speaker from the USSR impressed the audience with this nation's ambitious plans for future space research, the most important point being that the heavy-lift rocket *Energija* has already been tested successfully. Proposals for collaborations were strongly encouraged, and the complementarity of the current situation of East and West was immediately realized by everybody and addressed by several participants in the discussion: availability of reliable launchers on the one side and still grounded high-tech equipment on the other one. The dependency of the rate of scientific progress on the advances achieved in the field of general politics was strongly felt. But the expectations aired during the following discussion were definitely more optimistic than pessimistic.

The last speaker, from the Royal Observatory in Scotland, suggested in an enjoyable and eloquent outline of his personal view of the next three decades of astronomy from space that in future more attention should be paid to possibilities to economize by not observing all kinds of object at all frequencies but rather being more selective. Not unexpectedly, this caused several astronomers rather vividly to express their personal reservations about what they perceived as doubts concerning the principal competence of their favourite frequency domain to solve the fundamental problems of astronomy.

D. Baade

Adaptive Optics Matures

Adaptive Optics is knocking at the front door in observational astronomy. For instance, an adaptive system has been developed by B. Smithson and has delivered the first results in solar work at Sacramento Peak Observatory towards the end of July 1988. The exciting seeing improvement was shown on video. Another system for stellar astronomy is nearing completion at NOAO in Tucson and is expected to give the first results in some weeks. Our own ESO system will join the club shortly. There are indications that other observatories plan to follow the pioneers; the interest in this new observational tool is great, and the two sessions and one tutorial on this subject in Baltimore was attended by many participants.

F. Merkle

Multi-Wavelength and Multi-Facility Astrophysics

Multi-wavelength and multi-facility astrophysics took an important step forward during the IAU General Assembly. A corresponding Working Group was created under the auspices of Commission 44 (Astronomy from Space); the first Chairman is Thierry Courvoisier who was formerly with ESO, and is now at the Geneva Observatory. The WG includes members from several European countries, and also from the USA, USSR, South Africa, China and Japan.

The WG held its first meeting following the day of its creation. Many specific ideas were brought forward about how to increase collaboration and to improve exchange of information between ground- and space-based observatories, and also between individuals and committees responsible for the scheduling of observing time at these facilities. The very first measure, which will now be implemented by the WG, is to compile and regularly update a list of the key persons at the various observatories. The WG will also help to exchange information about observing schedules. But there are many more complex issues concerning the organization of multi-facility observing campaigns and the archiving of the results, cross-calibration issues, dedicated ground-based support for space programmes. Moreover, this may influence the future design of instruments, and the extensive discussions in Baltimore resulted in a long list of action items which will be looked into during the coming years.

A striking aspect was the match between the need for facilities to be used in collaborative projects and long-term monitoring (for example with medium-sized optical and radio telescopes) and the resources actually available in many countries. It was also felt that multi-facility and multi-wavelength astrophysics may considerably improve the efficient use of many facilities for top-quality science. This approach is likely to have a positive impact on many astronomical programmes.

Th. Courvoisier and C. Sterken

Documentation

The Joint Discussion on "Documentation, Data Services and Astronomers" was attended by many astronomers, and also by quite a few librarians, who came from IAU Colloquium 110 ("Library and Information Services in Astronomy"), held during the preceding week in Washington D.C. The key words for these GA sessions were computers and networks: use of computers for libraries, for the preparation and submission of scientific papers (a subject presently being looked into by the editors of the main astronomical journals), for communications between astronomers (e-mail), for information retrieval (data bases) and for archiving of observational data.

The new programmes for observational data archiving (e.g. RGO at La

Palma; for the Space Telescope; at ESO in Garching) all make use of the FITS standard format to describe the material. The use and maintenance of the future, large-capacity storage media, like optical disks and video-casettes, was also discussed. In order to locate and retrieve the observational data, online data bases are being built up. The astronomical designation for the observed objects is one of the key parameters for the location of the objects; the ESO archive, for instance, will provide several synonyms for each object. The adopted ESO archiving policy was described in the June 1988 issue of the *Messenger* (**52,** page 3). *F. Ochsenbein*

News about Pluto and Charon

During one of the sessions in Commission 16 (Physical Study of Planets and Satellites), D. Tholen gave a summary of our current knowledge about the outermost, known planet in the solar system. With improved speckle techniques, and in particular from observations of the eclipses in the Pluto/Charon system, which started in late 1984, it has now become possible to measure the radii as 1,142 $\pm$ 9 km and 596 $\pm$ 17 km, respectively. The occultation of a 12-magnitude star by Pluto on June 9, 1988, was observed in several places and unambiguously showed that Pluto has an atmosphere that reaches at least 3,200 km above the surface. From spectroscopy it is known to consist of methane, and the surface pressure is about 10 microbar. The lightcurve has a period near 6.4 days and an analysis of the light variation, also during the eclipses, indicates that Pluto has at least one polar "ice"-cap and one or two dark and light areas on the surface. The colour of Pluto is reddish, while Charon is grey. Pluto is thought to have a silicate core with radius $\sim$ 800 km and there is methane ice on the surface. The density is in the 1.8–2.1 g/cm^3 range.

R. M. West

Lithium Abundances

Duncan reported on new results which permit to recover the initial Lithium abundances in Population II stars, taking into account possible stellar depletion. As Reeves pointed out in his review to Commission 47, if this Lithium abundance is primordial, then it is possible to exclude that the density parameter $\Omega_{\text{barion}} = 1$, even in the case of the inhomogeneous models which have recently been proposed. *G. Setti*

The Companion of HD 114762

A team of astronomers from the Harvard-Smithsonian Center for Astrophysics announced the determination of a spectroscopic orbit for the IAU radial velocity standard star HD 114762, a seventh-magnitude solar-type star, about 90 light-years from the Sun. With a period of 84 days, the companion of HD 114762 is at about the same orbital distance as Mercury is from the Sun. The rather low velocity amplitude of 600 m/sec implies a mass of about ten times that of Jupiter, if the orbit is being viewed edge-on. Unless the orbit happens to be oriented nearly in the plane of the sky, the companion is a brown dwarf, and it may even be a massive planet. More than one hundred observations, spread over ten years, are now available, so more than 30 orbital periods have been covered. Because HD 114762 was recommended for intensive observation as a candidate for inclusion on a new list of IAU radial velocity standards, a beautiful series of CORAVEL observations is also available, and the CfA orbital solution has been independently confirmed by Michel Mayor of the Geneva observatory and his collaborators. This result is a small step towards understanding how frequently stars have planetary companions. *D. Latham*

Mass Loss from Early-Type Stars

On the fringe of the GA, a small two-day workshop – but with intensive participation by all attendees – was held at the STScI on variable mass loss from early-type stars. The undisputed highlight was the report by Stan Owocki on his numerical explorations of the dramatic instabilities in both the sub- and the supersonic zones of line-driven winds. The inclusion of time-dependent hydrodynamics by him and his collaborators for the first time offers an explanation *and* quantitative description of the discrete components in the extremely broad profiles of non-saturated UV resonance lines. About 15 years after their discovery and thousands of observations in hundreds of stars, this would be a major theoretical advance if borne out by future work. According to Owocki, the phenomenon is due to shocks and associated density enhancements in the flow at certain velocities (i.e. distances from the star). *D. Baade*

Radio Galaxy at Redshift 3.8

It was announced by Ken Chambers and George Miley that a record redshift of z = 3.8 has been measured for the radio galaxy 4C41.17. It is one of fifty radio sources, mostly in the "ultra-steep spectrum" class which have been studied during the past ten years. Seven of these were found to have redshifts above 2. The lines and continuum in 4C41.17 both extend over several arcseconds, proving the nature of the object beyond doubt. Such objects may possibly be detected to z = 7 and may become our best probes of the very distant universe during the next years. In any case, the observation of 4C41.17 now definitely shows that galaxies formed already within a few billion years after the Big Bang. *P. Shaver*

Standard Candles

The nature of the brightest galaxies in rich clusters, which have been used extensively as standard candles in observational cosmology, has been the subject of a long standing debate. Some authors have supported the hypothesis that these galaxies belong to a special class of objects, others think that they are simply the tail end of a statistical luminosity function. According to Bahvsar, both hypotheses may be correct. During a meeting of Commission 47 (Cosmology), he said that the magnitude distribution of these galaxies can best be explained if they are drawn from two populations, one of "special" objects which is normally distributed and another population of extremes from a statistical distribution. *G. Setti*

Quasar Absorption Systems

Quasar absorption systems in which the Lyman-α profile shows damping wings have been interpreted as the intervening H I disks of young galaxies. Hunstead has now reported about studies of heavy element enrichment in one such system towards the quasar PHL 957 with z_{abs} = 2.309, which indicate an abundance of only 5% of the solar abundance with very little evidence of dust. In another system towards the quasar 0836 + 113 (z_{abs} = 2.465), narrow Lyman-α emission is seen in the base of the damped Lyman-α line. The star formation rate inferred from the Lyman-α luminosity may be as low as 1 solar mass per year. *G. Setti*

Gravitational Lenses

Recent observations of the quasar 2237 + 030 show four images with identical spectra which can be interpreted as a gravitational lens system with the lensing galaxy unusually close (z = 0.039). Refsdal said that for this system the expected effects of micro-lensing are larger and can be more accurately estimated than for any other system presently known. He predicts that a typical change of 0.05 magnitudes per year for each of the four images due to microlensing can be expected. Since the time delay between the images is only about one day or less, micro-lensing will produce a change in the luminosity ratios which, if detected, will be a proof of the micro-lensing effect, since variability intrinsic to the quasar would show up "simultaneously" in all images. *G. Setti*

The ESO Exhibition

The ESO booth in the cavernous exhibition hall was visited by hundreds and hundreds of conference participants, enquiring about ESO in general and – not surprisingly – about the Very Large Telescope in particular. The Milky Way Panorama also drew much attention and many visitors tried to locate their particular object of interest. Several ESO staff members took turns at the booth, answering questions and handing out information material, including copies of the most recent issues of the *Messenger*. In fact, the ESO booth soon developed into a sort of small communication centre for ESO staff where messages were passed and many discussions were held. And finally, on 10 August, four strong staff members dismantled the entire exhibition and packed it in less than three hours, most probably breaking some of the local "union rules"! *C. Madsen*

IAU Travelling Telescope Almost Ready to Go

The IAU's new travelling telescope should be ready for its first assignment later this year. Its purpose is to provide astronomers in countries where astronomy is still in the developing phase with practical training in observational astronomy. A grant from the Canadian International Commission for UNESCO and the Canadian International Development Agency has enabled the purchase of an 8-inch Celestron telescope, an OPTEC solid state photometer, Optomechanics slit spectrograph, camera, power supply and other accessories. Other instrumentation such as a microcomputer and a Reticon or CCD detector can be added.

All interested parties should contact John R. Percy, Department of Astronomy, University of Toronto, Ontario, Canada M5S 1A1. From *IAU Today*

Six More Countries Join the IAU

Six countries have requested to join the IAU since the last GA in Delhi. Following IAU tradition, representatives from Algeria, Iceland, Malaysia, Morocco, Peru and Saudi Arabia reviewed the situation of astronomy in their countries during short speeches at the second session of the General Assembly on 11 August 1988. The Assembly welcomed the new members with acclamation, bringing the number of member countries to 57.

The General Assembly also admitted more than 800 new individual members.

Resolutions

The IAU General Assembly passed 8 resolutions of which the full texts will appear in the IAU Bulletin. It is indicative that four of these are directly concerned with adverse influences on observational astronomy. The titles:

- Amateur-Professional Cooperation in Astronomy
- Adverse Environmental Impacts on Astronomy
- Improvement of Publications
- International Space Year 1992
- Cooperation to Save Hydroxyl Bands
- Sharing Hydroxyl Band With Land Mobile Satellite Services
- Revision Frequency Bands for Astrophysically Significant Lines
- Endorsement of Commission Resolutions

New IAU Executive Committee

Following the formal election procedures during the second GA session on 11 August, the new Executive Committee (1988–1991) now consists of: President Y. Kozai (Japan); President-elect A.A. Boyarchuk (USSR); Vice-presidents A. Batten (Canada), R. Kippenhahn (F.R. Germany), P.O. Lindblad (Sweden), V. Radhakrishnan (India), M. Roberts (USA), Ye Shu-hua (P.R. China); General Secretary D. McNally (UK); Assistant General Secretary J. Bergeron (France); Advisors J. Sahade (Argentina); J.-P. Swings (Belgium).

Next IAU General Assembly

The 21st General Assembly will take place in Buenos Aires, Argentina, supposedly from 23 July–2 August 1991. In response to various discussions which took place in Baltimore, partly because of the somewhat smaller number of participants than expected (the organizers had hoped for 3,000), the new Executive Committee has announced that it will study ways to make the format and content more attractive, possibly by incorporation of one or more symposia/colloquia into the next Assembly.

Comparison of Astronomical Journals

S. R. POTTASCH and F. PRADERIE, Editors of "Astronomy and Astrophysics"

At the request of the Board of Directors of *Astronomy and Astrophysics (AA)*, we have undertaken a comparison of the more important astronomical journals. The original reports covered the amount of material published, financial aspects, time delays in publication, aspects of refereeing and rejection of articles and the very difficult question of the overall scientific quality. Because of the general interest among astronomers in publishing and publications we have prepared this summary of the reports. Some of the information used has been supplied by Dr. H. Abt, editor of the *Astrophysical Journal (ApJ)* and Prof. R.J. Tayler, editor of the *Monthly Notices of the Royal Astron. Soc. (MNRAS)*. We have limited our comparison mainly to the three journals mentioned, plus the *Astronomical Journal (AJ)*.

1. Amount of Material Published

This comparison can most easily be made on the basis of the total number of pages published each year. This is somewhat misleading because the average number of words published per page varies significantly from journal to journal. Therefore, a better comparison can be made by using the average number of words on a printed page in each journal to convert to a common "equivalent page". There is a considerable uncertainty involved in this "conversion factor" however, because the different journals have somewhat different policies concerning the relative sizes of figures and tables. Such a comparison is shown for 1987 in Table 1. The first four columns show the actual number of pages published. In these columns, the Letters section is listed

TABLE I

Journal	Number of published pages (1987)			Factor to compare to *AA* pages	Total equiv. pages
	MJ	Lett.	Total		
ApJ	11,178	1,542	12,720	0.88	11,200
AJ	3,297	–	3,297	0.88	2,900
AA	7,457	341	7,798	1.0	7,798
MNRAS	5,920	570	6,490	0.56	3,600

TABLE II

Journal	Income ($) (1988)			Income ($) per equivalent page
	Page charges	Subscription	Total	
ApJ	8.7×10^5	6.4×10^5	1.51×10^6	135
AJ	3.3×10^5	2.0×10^5	5.3×10^5	181
AA	2.5×10^{5}*	8.3×10^5	1.08×10^6	139
MNRAS	–	7.46×10^5	7.46×10^5	203

* Including the contribution of the participating countries.

TABLE III: *Subscription costs (1987)*

Journal	Number of subscribers		Price per year*		Cost to Subscriber**	
	Institute	Personal	Institute	Personal	Institute	Personal
ApJ	1,176	1,507	$ 375	95	3.4	0.85
AJ	850	950	$ 155	40	5.3	1.4
AA	776	576	DM 1,870	65	13.3	0.46
MNRAS	651	611	£ 500	78	24.4	3.8

* excluding postage. ** 10^{-2}\$ per equivalent page.

separately (the pink pages in *MNRAS* are listed as Letters). The comparison factor, normalized to *AA*, is given in column 5 and the total equivalent number of pages published is given in the last column. It is clear that *ApJ* publishes substantially more than the other journals although *AA* now publishes only about 30 % less. Taken together, the two predominantly "European" journals, *AA* and *MNRAS*, publish about 20 % less than the two "American" journals, *ApJ* and *AJ*. This may be compared to the situation 10 years ago when the "European" journals published 35 % less.

A comparison of the total number of pages (Main Journal plus Letters) published over the past 10 years, is given in Figure 1, for the four journals. "Equivalent" pages are used in the comparison using the 1987 conversion factor for the whole period. This is only an approximation because the page format (or type size) of all the journals has changed in somewhat varying degrees, all of them increasing the number of words published per page. It is clear from the figure that *ApJ* has had a slower but steadier increase than the other journals. *AA* is experiencing a rather large increase in the number of pages published, which have increased by a factor of 2 in the past 5 years. The somewhat larger fluctuations of *AA* are caused to some extent by financial policies which limit the number of pages published per year. This may continue for several years whilst a back-log increases. Major changes in the editorial policy of *AA* occurred in 1984.

2. Financial Aspects

The financial considerations are dominated by the fact that about 60 % of the total income of the "American" journals, *ApJ* and *AJ*, are from page charges, which are charged to virtually all authors. *AA* also has page charges for most non-European articles (with no European co-authors). Twelve sponsoring countries contribute to the expenses and the page charges amount to only slightly more than 20 % of the total income. *MNRAS* has no page charges at all. A detailed comparison is given in Table 2, the last column of which lists the total income per equivalent page published. The variations appear to be substantial, *AA* appearing to produce a page for 70 % of what *MNRAS* charges. But one should remember that currency conversion (1.8 DM = 1 $; 0.56 £ = 1 $) is necessary to produce this table and the conversion factors are not constant over a long time.

3. Subscriptions

The number of subscribers to each of the journals is shown in columns 2 and 3 of Table 3. The number of institute and personal subscribers are listed separately. The "American" journals have substantially more subscribers than the "European" journals. The reason for this is not so clear. Probably many more (American?) university physics departments subscribe to American journals. The large number of personal subscribers to the "American" journals may be a remnant from the time when all members of the American Astronomical Society were required to subscribe to at least one of the journals.

The number of subscribers to *AA*, both institute and personal, has remained constant over the past ten years. This number had decreased substantially for the other journals. For example, there were 1,450 institute subscribers and 1,742 personal subscriptions to *ApJ* in 1979, which is 20 % higher than at present. The same decrease is shown for *MNRAS* which had 776 institute and 802 personal subscribers in 1979. This decrease may partly be explained by the very unfavourable dollar exchange rate several years ago and the general cuts in university funding almost everywhere. *AA* has managed to resist these factors.

The cost per equivalent page to the subscriber is shown in the last two columns of Table 3. The "American" journals are clearly the "best buy" for institutes, mainly because the page charges account for a large fraction of the income for these journals. The substantial factor in cost for institutes between *ApJ* and *AA* may be decisive for some smaller physics institutes to sub-

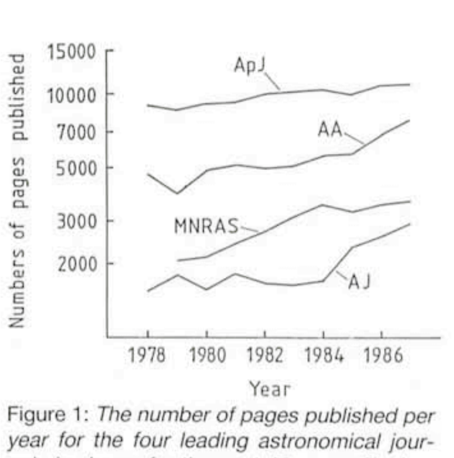


Figure 1: *The number of pages published per year for the four leading astronomical journals is shown for the past 10 years. Equivalent pages are used which contain the same number of words as an AA page.*

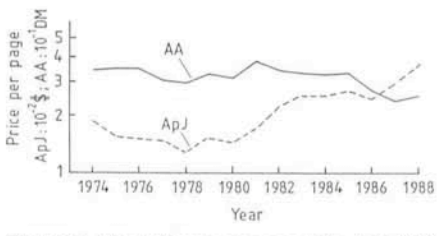


Figure 2: *The prices per page of* ApJ *and* AA *are shown for the past 15 years. Note that the units on the ordinate are different for the two journals. The actual number of pages (and not equivalent pages) was used.*

scribe to *ApJ* instead of *AA* when funds are limited.

The cost to personal subscribers is different. Here *AA* is the cheapest per page due to the policy of the journal to supply the journal at approximately the cost of the paper and binding. The low cost is not reflected in the number of personal subscribers, however.

MNRAS is the most expensive journal both to institutes and to personal subscribers.

Finally, a comparison has been made of the changes in the price per page for institutes for *ApJ* and *AA* over the past 15 years. The results are shown in Figure 2. No attempt has been made to put the price in a common unit because of the large exchange fluctuations in the course of the past 15 years. The general trends are clear. *AA* has remained roughly constant for most of this period and has decreased in the past 3 years. *ApJ* remained roughly constant until 1981 and has increased substantially since then. It should be recalled, however, that the absolute cost per page of *AA* to institute subscribers is still four times higher than *ApJ*.

4. Time Delays in Publication

A more detailed analysis will be given for *AA* because we know it better. Furthermore, the Main Journal and the Letters are discussed separately.

The time delay can be divided into two periods. The time between receipt and acceptance will be called "processing time at the Editors" and the time between acceptance and publication will be called "processing time at the publisher".

For the *AA* Main Journal the average processing time at the Editors was 3.1 months in 1987, slightly higher than the average over the past 6 years (2.7 months). A mean value is given because there is a long tail to the distribution, primarily due to the time it takes for authors to revise their articles before acceptance. The processing time at the publisher was 5.6 months in 1987, somewhat higher than the 4.8 months average of the last 6 years. Due to the fact that the total amount to be published in a given year in *AA* is fixed several months before the year begins, a "backlog" can occur if the number has been too low for several years in a row. This is the case at present. In a more "normal" situation the processing time at the Publisher should be 2 months shorter.

For comparison – the processing time at the Publisher in *ApJ* was about 6.5 months in 1987, and 5.5 months for *MNRAS*. Thus it appears that there are no large differences in publication time in the various journals.

In contrast to the approximate 8½ months median delay for the Main Journal, the *AA* Letters are published considerably faster. Here the mean processing time at the Editor is 3 weeks and the mean time at the publisher is 5 weeks. The total time is higher than the sum of these two times because preparation of the camera-ready manuscript takes the average author a few weeks and time spent in the mail becomes important. Thus a median time of almost 3 months is required. This time is faster than the 4½ to 5 months required for the *ApJ* Letters. The *MNRAS* pink pages are usually published within 4 months of receipt.

5. Refereeing

All major journals have a refereeing system, the purpose of which is twofold. Firstly, it allows the rejection of papers which are either wrong or do not contain sufficient new material to warrant publication. Secondly, it points out the weak arguments in the paper and permits publication only after these weaknesses are removed or more strongly defended. This latter sometimes requires additional observations to be made.

In *AA* Main Journal, 65% of the articles received are accepted by the referee on the first reading with only minor revisions required. About 23%, while foreseeing eventual publication, have much more serious criticism, and a major revision is recommended. Further refereeing then takes place before the paper is accepted. About 12% of the papers received are recommended for rejection. Of these 12% not all are finally rejected, for many reasons. Sometimes very considerable revision can save the paper. The final rejection rate is about 9%.

This rejection rate is very similar to that of *ApJ* and *AJ*. Abt (1988, *Pub. Astron. Soc. Pac.* **100,** 506) reports a combined rejection rate for these two journals of 9.4%. In investigating the further fate of the rejected papers, he reports that ⅔ are never published and ⅓ is published elsewhere. No information is available concerning the fate of the rejected articles in the other journals. The rejection rate in *MNRAS* is not available directly. By comparing the number of papers submitted and published, a 13% rejection rate is found.

The rejection rate for *AA* Letters is

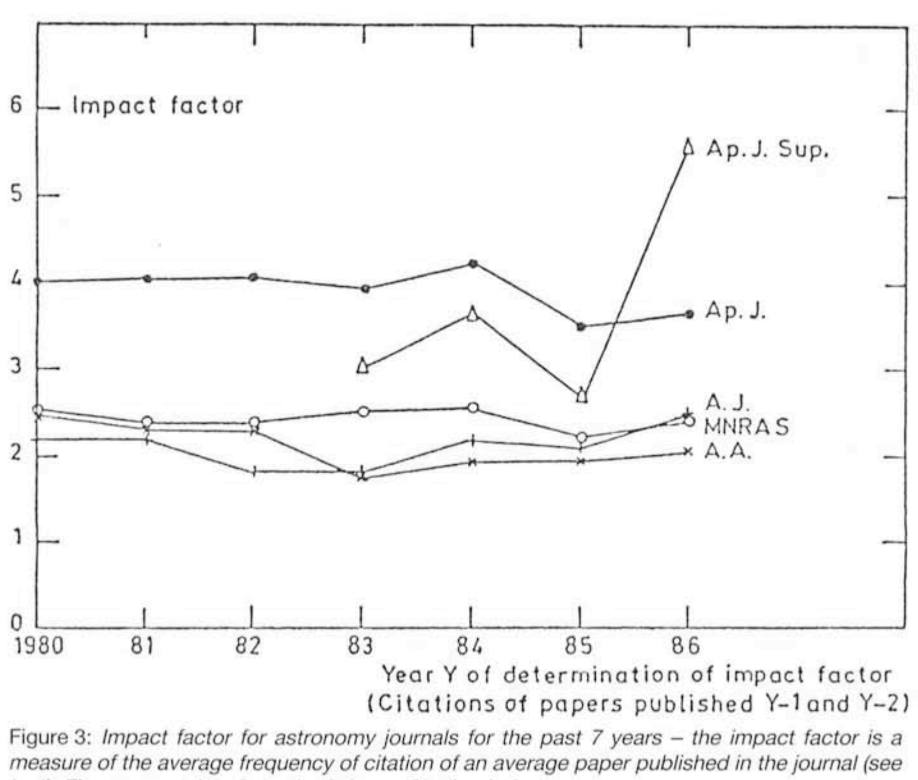


Figure 3: *Impact factor for astronomy journals for the past 7 years – the impact factor is a measure of the average frequency of citation of an average paper published in the journal (see text). Figures are taken from the* Science Citation Index.

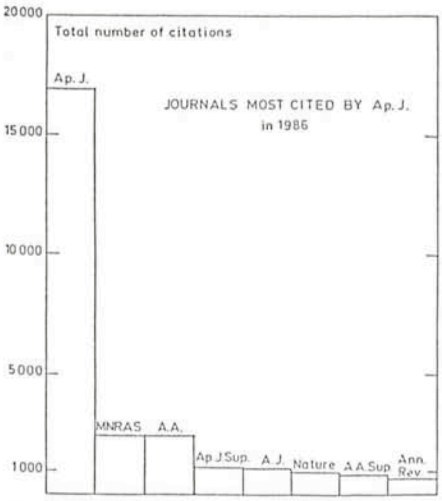


Figure 4: *Total number of citations by* ApJ. *of papers from different astronomy journals.*

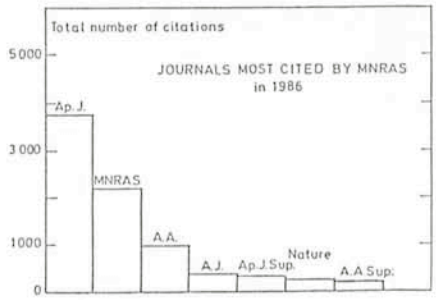


Figure 5: *Idem for* MNRAS.

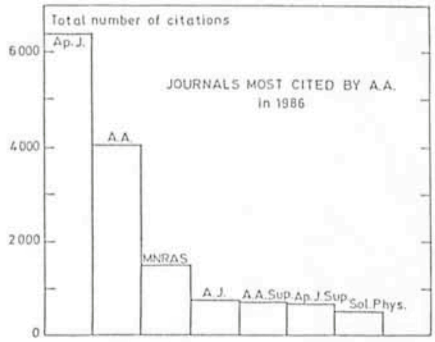


Figure 6: *Idem for* AA.

much higher. In 1987 36% were rejected. This is somewhat less than 5–10 years ago when about 50% of the articles were rejected. Some of the rejected "Letters" are eventually published as normal articles in the Main Journal. In 1987 this number was about 10%.

It appears that, with the exception of *AA* Letters, astronomy journals have a higher acceptance rate than physics journals. Although recent figures are not available, Batchelor (1981, *J. Fluid. Mech.* **106,** p. 1) finds a rejection rate of between 14% and 33% for ⅔ of 44 leading physics journals. It is not clear why the rejection rate is lower in astronomy.

6. Influence of the Journal

The scientific quality of the journals is difficult to define and compare. The one factor which can be compared is the number of citations which is compiled and published, by the Science Citation Index. Complete figures are now available for 1986. In particular we compare the "impact factor", which is defined as the ratio of the total citations (to a particular journal) to the total number of citable items in that journal.

Figure 3 gives the impact factor for the various journals since 1980. As can be seen, the *ApJ* has a higher impact factor than the other journals, which are closely ranked. This may be interpreted as a higher scientific quality of the *ApJ* but a careful examination indicates that another interpretation is possible. This can be seen in Figures 4 to 6 which show the total number of citations to *ApJ, MNRAS* and *AA* separately. It is obvious from these figures that there is a tendency in all the journals to cite themselves more often than might be expected from the total number of articles published, a kind of "astronomical provincialism". This appears to be especially bad in the *ApJ.* Some of this may be understood because different fields (or sub-fields) are more prominent in one journal or the other. This cannot be the complete answer, however, because then the various diagrams, after correction for the total number of articles published in each journal, should be symmetric.

It seems clear that *ApJ* authors are influenced much more by what is published in *ApJ* than in the other journals. Especially *AA* and *AJ* have comparatively little influence. It is impossible to determine how much of this is due to a lower scientific quality of the latter journals and how much is due to "provincialism" in the former.

On the Nature of the Bars of SB0 Galaxies: First Results

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1. Introduction

Bars are a common feature of disk galaxies: approximately 60 to 70 per cent of all galaxies between Hubble types S0 to Sc, including the SAB's, are barred. Their structure and evolution represents one of the most puzzling problems in galactic dynamics. Much attention has been focused during recent years on the theoretical aspects of the dynamics of barred galaxies. Essentially four kinds of problems have been considered: (a) orbital behaviour of stars in non-axisymmetric potentials, (b) the global response of a gaseous or stellar disk- to bar-like perturbations, (c) the construction of SB self-gravitating equilibrium models using the kinds of orbits which were found with the Schwarzschild-Pfenniger technique (direct, retrograde and stochastic orbits) and (d) N-body simulations of disk evolution involving studies of large-scale stability.

These different approaches are able to give some global and qualitative predictions on the structure of various components in SB galaxies. However, in spite of some progress in our theoretical understanding, the structure and evolution of the bars remain largely unexplained. This problem is important since the bars could be linked to the engine which governs the global evolution of barred galaxies. Some of the most important questions concern the size and axis ratios of the bars, their dynamical interaction with the bulge and halo, the 3-D structure of bars and ovals and their secular evolution, and finally their real frequencies and life-times.

Advances in this field are presently limited by the lack of quantitative photometric and kinematic data. Clearly, SB galaxies have received less attention observationally than SA galaxies probably because of their added complexity. In fact, extensive statistics on the shapes of bars do not presently exist. In order to succeed in constructing a coherent scenario of bar formation and

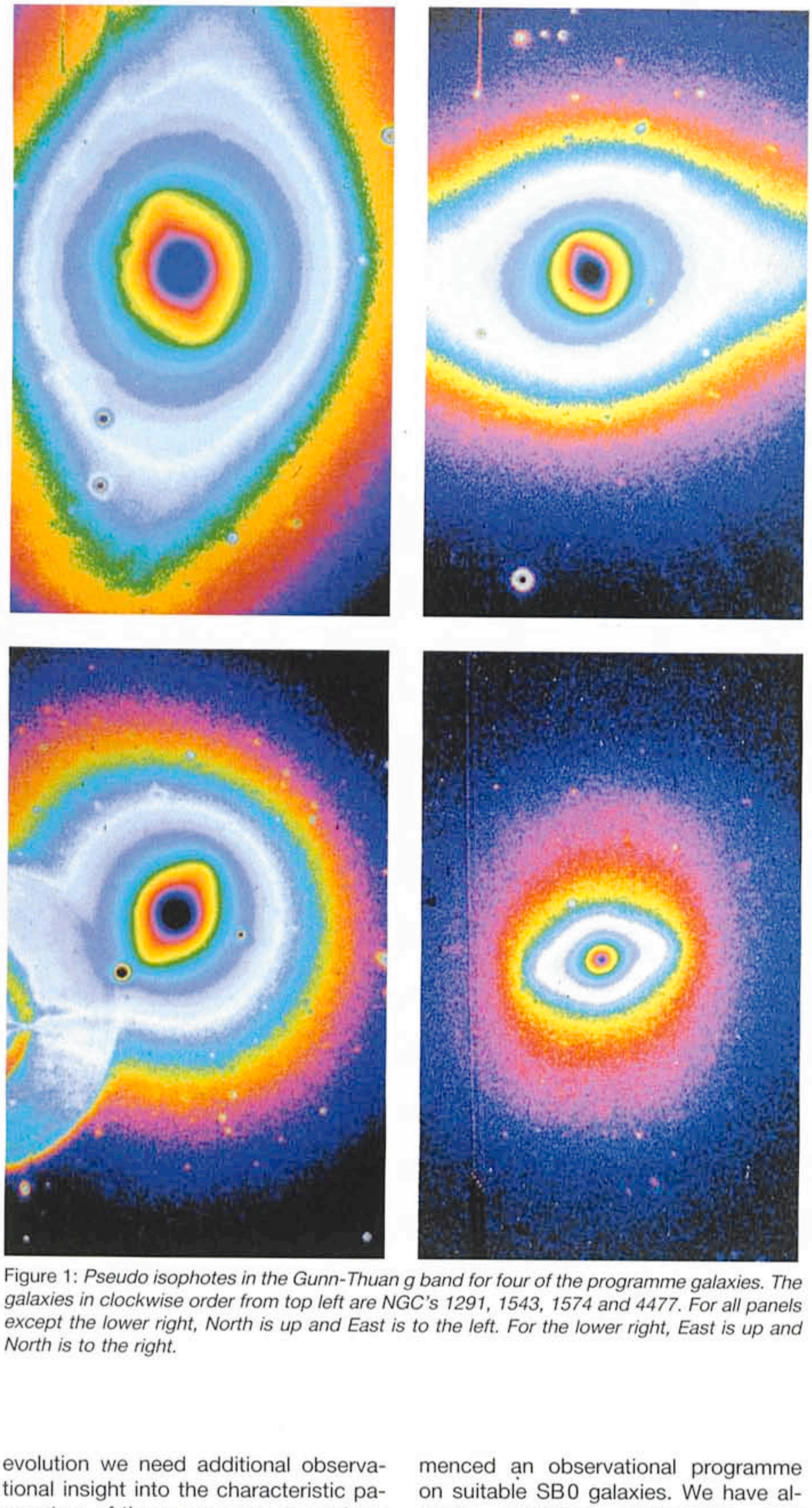

Figure 1: *Pseudo isophotes in the Gunn-Thuan g band for four of the programme galaxies. The galaxies in clockwise order from top left are NGC's 1291, 1543, 1574 and 4477. For all panels except the lower right, North is up and East is to the left. For the lower right, East is up and North is to the right.*

evolution we need additional observational insight into the characteristic parameters of these components such as their lengths, angular speed and axis ratios. Theoretical results on the possible ranges of these parameters can only be meaningfully constrained by surface photometry and kinematic data obtained from a sample of SB and SAB galaxies.

In an attempt to begin to answer some of these questions we have commenced an observational programme on suitable SB0 galaxies. We have already published photometric and kinematic data on our first sample of SB0 galaxies, namely: NGC 1543, 1574, 4477, 4754 and NGC 1291, the latter being an SBa galaxy. We present here a progress report on these observations. We chose face-on SB0 galaxies for two reasons. Firstly, the luminosity profiles are smooth and easy to follow since there is little or no dust and gas to obscure the underlying stellar structure. Secondly, face-on galaxies enable us to measure the vertical (z-direction) photometric and kinematic structure of these components. Two colour 2D surface photometry and spectroscopic measurements were planned in order to (a) obtain density profiles and subsequently deconvolve these profiles to obtain the contributions in luminosity from the different morphological components (bulge, bar, disk, etc.), (b) measure the velocity dispersions in the bulge and bar which hopefully will lead to the structure of these components perpendicular to the disk and to some measure of their triaxiality and (c) use these data for constraining our N-body simulations, now in progress.

2. The Surface Photometry

The surface photometry was obtained from CCD imagery in the Gunn-Thuan g and r system (1976) using the ESO 2.2-m (NGC's 1291, 1543 and 1574) and CTIO 0.9-m (NGC 4477 and 4754) telescopes both located in Chile. An RCA (512 × 320 pixel) CCD was employed at both telescopes orientated N-S for the 2.2-m with an image scale of 0.363 arcsec pixel^{-1} and E-W for the 0.9-m telescope with a scale of 0.495 arcsec pixel^{-1}. Figure 1 shows CCD images for four of our programme galaxies.

The raw data frames were reduced in the standard manner for CCD data. As usual, the greatest difficulty performing the surface photometry was the sky brightness determination because of the large size of the galaxies compared to the CCD field size. For those galaxies with nearly circular D_{25} surface brightness levels we used the D_{25} values to make a correction to the intensity levels measured in the extreme corners of the CCD to obtain a best estimate for the true sky surface brightness. These new sky levels were also found to be consistent with the scaled average sky levels from all the other galaxies observed on the same night. This average was also used for those cases where the D_{25} isophotes were not circular. Aperture photometry, taken from the catalogue of Longo and de Vaucouleurs (1983), and its supplement (Longo and de Vaucouleurs, 1985) was used to determine the magnitude zero points. The major and minor axis profiles for NGC's 1574 and 4477 are shown in Figure 2a and 2b, respectively.

NGC 1291 was the only galaxy in our sample for which suitable external photometry existed (de Vaucouleurs, 1975) with which we were able to compare our surface photometry reduction techniques. The agreements were good (see Jarvis et al., 1988 for details). We note, however, that in the region of most interest to us, the bars, small errors in the adopted sky brightness levels have little effect on the surface brightness profiles since the bar surface brightnesses are generally much larger than that of the sky.

3. The Kinematic Data

The kinematic data for our sample of five galaxies were obtained from long-slit spectroscopy using the 3.6-m telescope with the Boller and Chivens spectrograph on La Silla, Chile. The detector was an RCA CCD, used with a 2″ × 2.9′ slit, and a spatial scale of 1.17″ $pixel^{-1}$. The dispersion was 1.74 Å $pixel^{-1}$ over a spectral-range of 4860 Å to 5750 Å.

A standard observing procedure was adopted for all of the observations which extended over two observing runs. Each integration comprised 1,000 sec integrations on the galaxy with calibration arcs between each exposure. This was continued until sufficient counts had been obtained. For all five galaxies two slit positions were measured, one for the photometric major axis and one for the minor axis. At the beginning and end of each night, spectra of several K0 III to K1 III giant stars were observed to form templates for measuring the velocities and velocity dispersions of the galaxies.

The reduction of the data onto a wavelength calibrated logarithmic scale followed fairly standard procedures for this kind of data (see Jarvis et al. 1988 for details). Where necessary, several rows were co-added together in order to improve the signal-to-noise (S/N) ratios. Two variations of a similar method were used to determine the internal velocities, differing only in the choice of template. The velocity determinations were repeated for the different choices of template. The first choice used a template formed from the de-redshifted addition of the standard stars. Every row containing signal was then cross-correlated in Fourier space with this star template and the redshift determined from the peak of the cross-correlation (CC) function. This gave satisfactory results and at the same time the systemic velocity of the galaxy. The second technique made use of an auto-correlation method. The template was taken from the row containing the most counts in the galaxy frame. This corresponded to the photometric (but not necessarily the kinematic) centre of the galaxy. In all cases the template spectra derived in this way had sufficiently large S/N ratios. We found that the solutions were more stable at larger galactocentric distances with these templates probably because of the better match of the template spectra

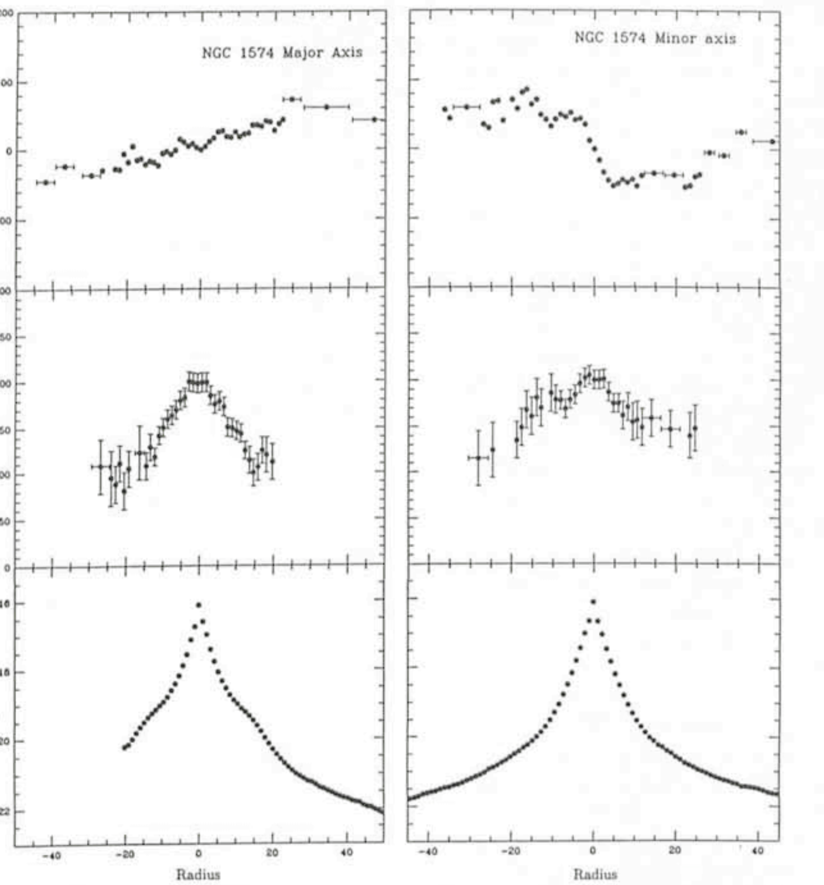

Figure 2a: *Absorption line velocities (top panel), velocity dispersions (middle panel) and luminosity profiles (bottom panel) for NGC 1574. The units of velocity and velocity dispersion are km s^{-1}. The surface brightnesses (μ) are in mag $arcsec^{-2}$ in the Gunn-Thuan g system. Radius is in arcsecs with negative radii denoting positions E of the N-S line.*

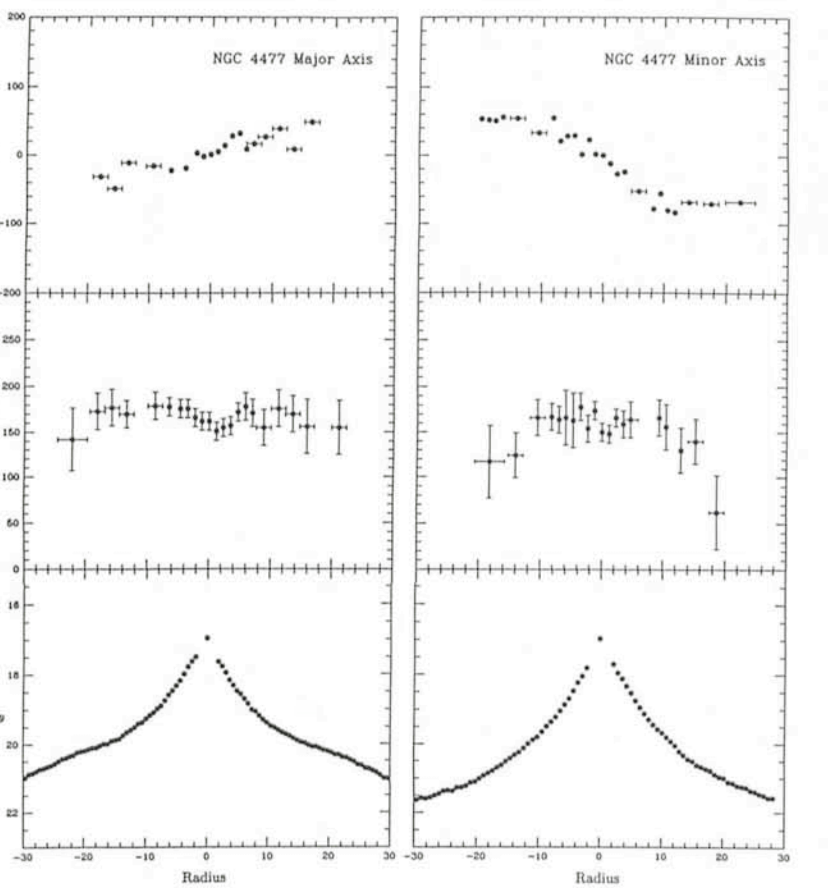

Figure 2b: *Same as for Fig. 2a, but for NGC 4477.*

to the galaxy spectra. For the central parts the match was essentially perfect. Each row of galaxy spectra was then autocorrelated with a template formed from its own central row. The final major and minor axis rotation curves for NGC 1574 and NGC 4477 are shown in Figures 2a and 2b.

The velocity dispersions were determined by a method similar to that of Tonry and Davis (1979) but with some important modifications discussed in detail by Bottema (1988). The galaxy's spectra were first cross-correlated with the star template created earlier. A standard set of CC peaks (about 20, spaced 20 km s^{-1} apart) were then produced by cross-correlating the star template with itself artificially broadened by Gaussian functions of known width. These peaks were then sequentially fitted in a least-squares sense to the galaxy CC function, calculating a goodness of fit parameter in each case. This is where this method differed from that of Tonry and Davis. They fitted only second-order polynomial functions to the CC peaks whereas we fit "real" CC functions which generally resulted in a better fit. The final adopted velocity dispersion was then taken to be the (interpolated) value at the minimum of a plot of the dispersions versus their least-square goodness-of-fit parameter. The error estimation was fairly straightforward since a plot of the best fitting CC function was overplotted on the original data together with the CC functions having dispersions typically 20 km s^{-1} smaller and larger than the adopted value. This method worked very well for our data and had several advantages over the more commonly used Fourier quotient technique (Sargent et al., 1977). One important feature is that the CC method used here works well with low S/N data since a CC peak will almost always appear. Nevertheles, we performed additional tests to see if this method produced consistent velocity dispersion profiles on galaxies with well established velocity and dispersion profiles. See Jarvis and Dubath (1988) for a comparison and detailed discussion between our velocity dispersion results and those of Kormendy and Illingworth (1982) for NGC 4594 using this method. For the purposes of this paper we note that general agreement was very good for both the dispersions and the velocities. Encouraged by this good agreement we proceeded to reduce our programme galaxy data in the same manner.

4. Discussion and Conclusions

The resultant rotation curves show that most of the galaxies have significant amounts of rotation on both axes inspite of all but one of our galaxies being close to face-on. For NGC 1574, the maximum minor axis velocity reaches almost 100 km s^{-1}. The rotation curves are also asymmetric in some cases. This feature has also been reported in other SB0 galaxies (e.g. NGC 936, Kormendy, 1983). The velocity dispersion profiles also show a variety of forms from almost flat in the case of NGC 4477 to sharply decreasing with radius on both the major and minor axes of NGC 1574. The other galaxies are intermediate cases. It is for this reason that we illustrate our results here for only NGC's 1574 and 4477 since these galaxies showed the two extremes in kinematical behaviour with respect to the slope of their velocity dispersion profiles. NGC 4477 has an almost flat velocity dispersion profile on both the major and minor axis similar to what has been observed in other SB0 galaxies (e.g. NGC 6684, Bettoni and Galletta, 1988). However, in contrast, NGC 1574 shows a rapid decrease in velocity dispersion on both axes, and especially on the major axis. Why the bar of NGC 1574 appears more uniformly hot than that of NGC 4477 is not known. However, careful deconvolution and comparison of the bars in these and other galaxies may provide some clues. These will be discussed in more detail in subsequent papers.

In conclusion, we have performed two-dimensional surface photometry in the Gunn-Thuan photometric system of the five face-on southern SB0 galaxies, NGC's 1291, 1543, 1574, 4477 and 4754. We have also obtained the rotation velocity and velocity dispersion profiles along the principal axes of these galaxies. We make the following observations concerning the large-scale features of the V, σ, and μ plots.

(1) Three of the four near edge-on galaxies NGC's 1543, 1574 and 4477 show significant amounts of rotation ($V_{max} \simeq 100$ km s^{-1}) on either the major or minor axis.

(2) The major and minor axis rotation curves of NGC 1543 and the minor axis rotation curve of NGC 1574 show a clear turnover in velocity. This is particularly notable for the minor axis of NGC 1574 where the velocity falls back to zero at r = 30″. This effect has also been observed in other SB0 galaxies (Galletta, private communication).

(3) The rotation curves of several galaxies are noticeably asymmetric with respect to their photometric centres (e.g. NGC 1574, see also NGC 6684, Bettoni and Galletta, 1988).

(4) There is a considerable variation in the slopes of the velocity dispersion profiles between galaxies from almost flat for NGC 4477 to sharply falling with increasing radius for NGC 1574. NGC 1291, 1543 and 4754 are intermediate cases, listed in order of increasing slope in dispersion with radius.

It is clear that even from our small sample of SB0 galaxies their complexity is considerable, based on the large variation of their observable parameters. The interpretation of these observations, in particular the sizes, shapes and luminosities of the bars and their relationship to the observable kinematics will be addressed in future papers through an application of our N-body numerical models.

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Tentative Time-table of Council Sessions and Committee Meetings Until the End of 1988

31 Oct.–4. Nov.	Finance Committee, Chile
14/15 November	Scientific Technical Committee
28/29 November	Finance Committee
1/2 December	Observing Programmes Committee
6 December	Committee of Council
7 December	Council

All meetings will take place in Garching unless stated otherwise.

The Most Massive LMC Star Sk–66°41 Resolved

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Introduction

The upper limit to stellar masses constitutes one of the fundamental problems of astrophysics. Here I want to deal with Sk–66°41 (Sanduleak, 1969, other designation: HDE 268743), one of the most massive stars in the Large Magellanic Cloud. Sk–66°41, with its bolometric magnitude of −11.2, appears at the second position (along with HDE 269698) in the list of the most luminous stars in the LMC compiled by Humphreys (1983). As you may know from the ESO Press Release of last May 19, we have shown that Sk–66°41 is not a single star but a compact cluster of at least six components. This result has important implications for star formation theories and the distance scale in the Universe. This is a serious evidence against the existence of stars above 100 $M_\odot$.

The Associated H II Region N 11 C

We got interested in Sk–66°41 during our analysis of an H II region in the LMC as a part of the search and investigation of the high excitation compact H II blobs in the Magellanic Clouds. The knowledge of the physical characteristics of the associated H II region N 11 C (Henize, 1956) is important for understanding the nature of Sk–66°41. N 11 C is one of the several components (A to L, the latter being a supernova remnant) of the relatively isolated H II complex N 11 lying at ~4° NW of the "centre" of the LMC bar. This giant H II region, ~20′ in diameter corresponding to ~320 pc, is interesting in several respects related to massive star formation. Towards the eastern part of the main component, N 11 B (Heydari-Malayeri and Testor, 1983), there is a high excitation compact H II blob (Heydari-Malayeri and Testor, 1983, 1985) making this region attractive for star formation studies. A molecular cloud has been detected towards the eastern part of the complex, just east to N 11 C and E (Cohen et al., 1984).

The most luminous star Sk–66°41 lies nearly at the centre of component N 11 C which measures ~3′ (~50 pc) in diameter in the Hβ emission line (Fig. 1). The region is divided at the centre by a dark absorption lane. The most excited zones are the southern and northern boundaries of the nebula at both sides of the dark lane. The star lying at ~15″ SE of Sk–66°41, called Wo 599 (Woolley, 1963), is of particular interest as we will see below. Wo 600 and Wo 647 are late-type Galactic stars. N 11 C is a very young region, as shown by the

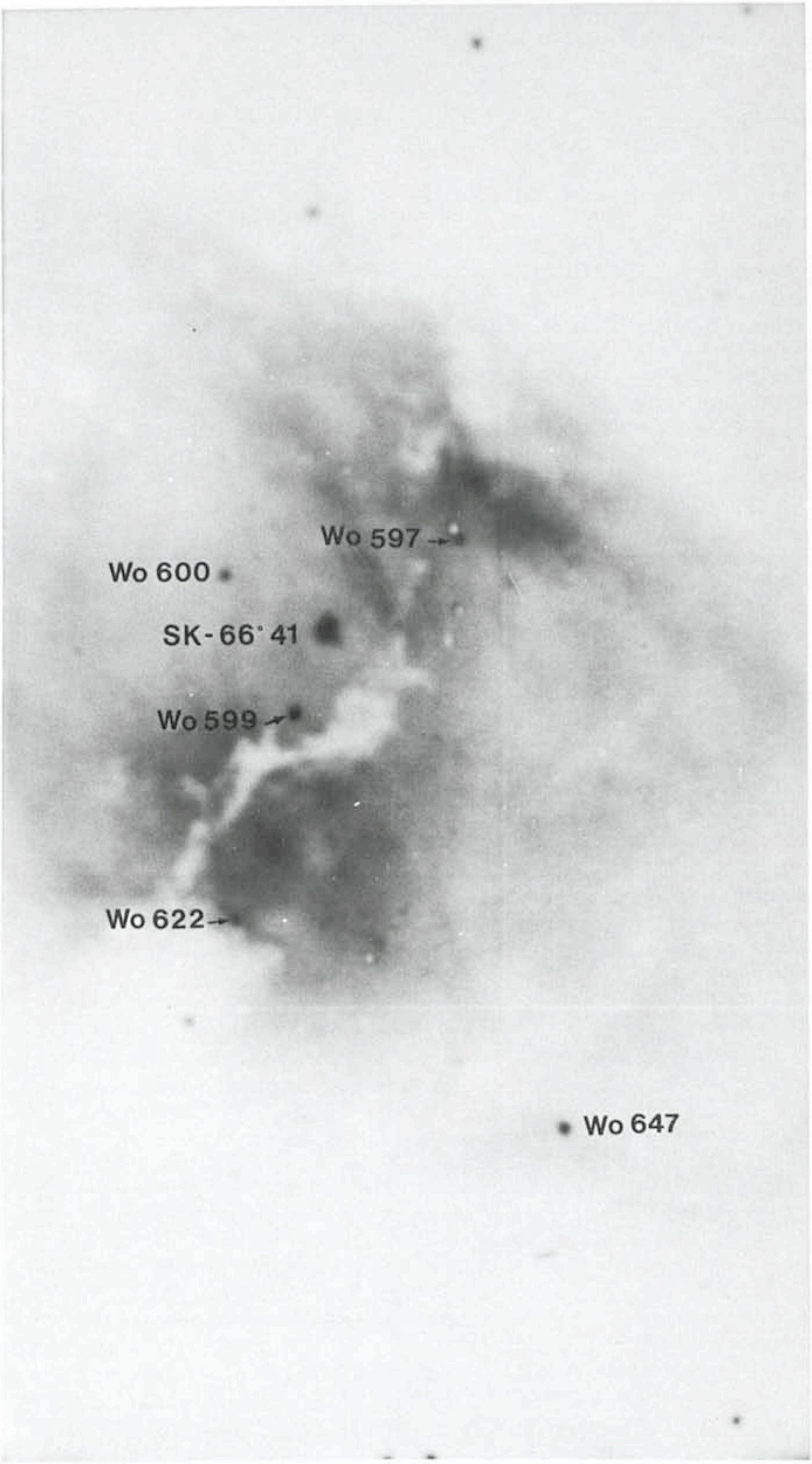

Figure 1: *An Hβ CCD image of N 11 C obtained at the Danish 1.54-m telescope. The field corresponds to 134″ × 240″. North is at the top, east to the left.*

[1] On leave from DEMIRM, Observatoire de Paris, Section de Meudon, France.

colour-magnitude diagram of the stars observed towards the region (Heydari-Malayeri et al., 1987, hereafter Paper I). The majority of the stars ($\sim$80%) lie clearly along a ZAMS centred at about B-V = −0.34 characterizing early O-type stars.

Physical Characteristics of N 11 C

The r.m.s. electron density in N 11 C is 20 cm^{-3}, while the highest value of the electron density amounts to $\sim$350 cm^{-3}. The electron temperature derived from the [O III] lines is $\sim$9200°K. The chemical abundances for He, N, O, Ne, S and Ar do not show significant discrepancy with respect to the corresponding mean values for the LMC.

The [O III] (4959+5007)/Hβ intensity ratio averaged over 166 points on the face of N 11 C is 4.1 (corrected for the reddening). The ratio is rather uniform on a fairly extended zone in the nebula. This suggests that N 11 C has several exciting sources scattered in it. The average value of the Balmer decrement Hα/Hβ derived for the same 166 points is 3.6. However, the extinction is not uniform towards N 11 C. For example, it shows a spectacular peak of $\sim$7, corresponding to $\sim$2.5 mag, along a N-S spectrum towards SE of Sk–66°41. Another remarkable feature of extinction is its enhancement northwards of N 11 C where the molecular cloud is detected. This is in agreement with the extinction behaviour southwards of N 11 E which lies north of N 11 C.

The total Hβ flux amounts to $\sim 2.2 \times 10^{-10}$ ergs $cm^{-1}s^{-1}$, while the radio continuum density flux is S(408 MHz) = 1.27 Jy (Clarke et al., 1976). From the latter value the number of the Lyman continuum flux is estimated to be $N_L = 2.70 \times 10^{50}$ ph s^{-1}, corresponding to an excitation parameter of $\sim$200 pc cm^{-2} and an ionized gas mass of 4.10×10^4 $M_\odot$.

Energy Sources

We try to estimate the number of the exciting stars responsible for the abovementioned N_L. We use stellar atmosphere models of Kurucz (1979) with the evolutionary tracks of Chiosi et al. (1978) for a ZAMS star with high mass loss. Several possibilities can be considered. For the reasons that will come up later we favour the following one: N 11 C may be excited by one star of 80 $M_\odot$ along with six stars of 60 $M_\odot$ and two stars of 40 $M_\odot$. This roughly means that we should find one star of type O4, six stars of O5 and two stars of O6 V in N 11 C.

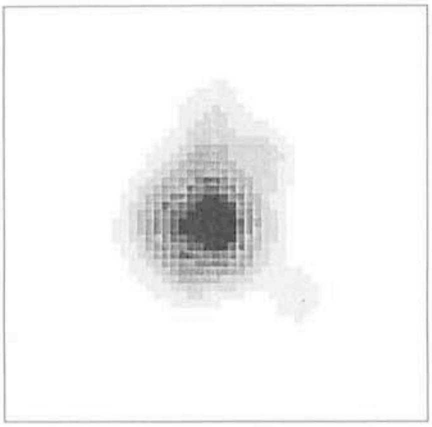

Figure 2: *The CCD R frame of Sk–66°41. The field, 51 × 51 pixels, corresponds to ~9″ × 9″ on the sky. North is at the top, east to the left.*

Spectroscopic observations were carried out at the 2.2-m telescope of several stars sitting towards the H II region (Paper I). Wo 599 (Fig. 1) turned out to be very interesting. The spectrum of this star is dominated by the He II absorption lines characterizing O type stars. Wo 599 belongs to the dwarf luminosity class because the He II λ4686 Å line is strong in absorption. Using the equivalent widths criterion for He II λ4541 Å and He I λ4471 Å we classify Wo 599 as O4 V.

Several spectra were obtained of Sk–66°41. We classify this star as O5 V. Walborn (1977) assigned a spectral type of O6 to this star "uncertain by ± 1 subclass at least". Consequently, we already have an unexpected result. Contrary to what has been believed, the main exciting star of N 11 C is not Sk–66°41 but Wo 599.

Problem

The UBVRIJHK photometry of Sk–66°41 was carried out at the ESO 1-m telescope (Paper I). The UBV magnitudes V = 11.72, B-V = −0.12 and U-B = −0.92 agree very well with Brunet et al. (1973). Using a colour index of E(B-V) = 0.18 for the star and a distance modulus of 18.45 (Stift, 1982) the absolute visual magnitude turns out to be $M_v = -7.3$. From a bolometric correction of −3.9 (Humphreys and McElroy, 1984) a bolometric magnitude of $M_b = -11.2$ can be derived for Sk–66°41 corresponding to a luminosity of 2.63×10^6 $L_\odot$, an effective temperature of $\sim$56,000°K and a mass higher than 120 $M_\odot$.

We see that there is obviously a problem. How can a main sequence star of type O5 get a mass > 120 $M_\odot$? According to star formation models the upper mass limit is inversely proportional to the metallicity, as first suggested by Kahn (1975). So, there are two

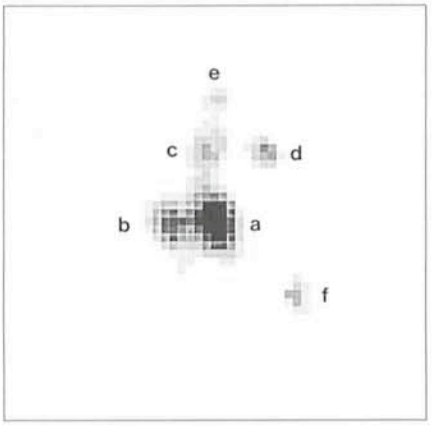

Figure 3: *Same image after deconvolution.*

possibilities: (i) Star formation mechanisms in a metal poor galaxy like the LMC have given rise to a peculiar very massive star, or (ii) Sk–66°41 is not a single star.

Compact Cluster

CCD images of SK–66°41 were obtained in March 1988 with the 3.6-m and 2.2-m telescopes at La Silla (Heydari-Malayeri et al., 1988, hereafter Paper II). At the 3.6-m telescope, the ESO Faint Object Spectrograph and Camera (EFOSC) was used. In both cases, the detector was a high resolution RCA CCD chip (type SID 503, 1024 × 640 pixels of 15 μm^2). Several images were obtained through the filters B, V and R with various exposure times. They were reduced using the MIDAS package and subsequently deconvolved using an improved version of a simple recursive restoration algorithm (Meinel, 1986) written by Magain (1988). The method was tested on several known objects and shown to lead to very reliable results (Magain, 1988). The image restoration was carried out on all the images.

A part of the R frame showing Sk–66°41 is presented in Figure 2. The exposure time was 30 seconds, the seeing 0″.9 FWHM and the pixel size 0″.176. The processed image after 10 iterations, shown in Figure 3, has a resolution of 0″.5. It is clearly seen that Sk–66°41 is resolved into 6 components. The main components, stars (a) and (b), are separated by 0″.8 (Fig. 4). From the analysis of the geometry and photometry of the system (Paper II) we find that component (a) has a bolometric magnitude of −10.5 corresponding to a star of $\sim$90 $M_\odot$, whereas component (b), with a bolometric magnitude of −9.6, may have a mass of $\sim$60 $M_\odot$ corresponding to an O5 star. The spectral

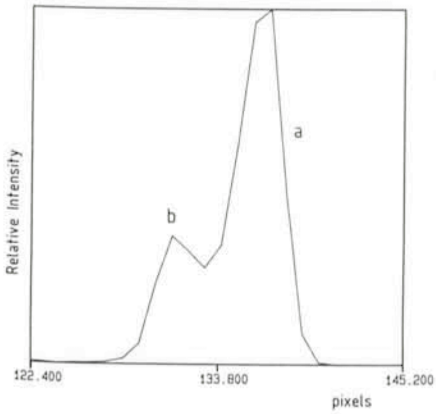

Figure 4: *An EW cross-cut through components (a) and (b).*

type of O5 derived for Sk–66°41 corresponds to the whole cluster. It is not possible that the fainter component, star (b), dominates the whole spectrum. Consequently, star (a) may itself be a multiple system. This is in agreement with the fact that the deconvolved image of star (a) shows a slight NS elongation, suggesting that it may consist of more than one component, in which case the estimated mass would of course decrease significantly.

The members of the cluster probably formed together. The fainter components (c-f) are probably early-type O stars, as the formation of low mass stars needs a longer time scale. This may be a general trend of massive star formation that they form in groups. Two recent results seem to confirm this impression. The first example is the central object of 30 Doradus (see below). The second one is provided by the star-like η Carinae which is one of the most luminous stars in our Galaxy. Recently, Weigelt and Ebersberger (1986) resolved it into four components lying within < 0″.03. It should be emphasized that the case of Sk–66°41 is of particular interest. In contrast to R 136 and η Carinae, it was not a mysterious exotic object. It was just an O-type star with a known spectral classification.

Implications

Towards 1960 it was believed that stars above a critical mass, the Ledoux-Schwarzschild-Härm limit of $\sim 60\ M_{\odot}$, were unstable. Above this limit vibrational instability would set in entailing the destruction of the star. Vibrational instability occurs when the energizing processes in the core overcome damping in the envelope. Later on, it was found that vibrations produce shock waves in the star's gas which could damp down the vibrational instability. A non-linear treatment of vibrations showed that stars can get masses up to $\sim 200\ M_{\odot}$ according to some models, especially those of Appenzeller (1970).

However, Larson and Starrfield (1970) and later Kahn (1974) took up the problem at an earlier stage, that is at the time of protostellar collapse. They found that dynamical effects due to radiation pressure can impede further infall of matter leading to an upper limit of $\sim 60\ M_{\odot}$ for the star. Today the theoretical situation remains murky. In recent years several important effects have been taken into account, for example convective overshooting, turbulent diffusion incited by differential rotation, and mass loss (Maeder, 1983 and references therein) but the question of the upper limit to stellar masses remains open. On the basis of the luminosities, Maeder (1980) estimated that the initial mass spectrum extends up to a maximum mass of $\sim 150-200\ M_{\odot}$ with no significant differences between the Galaxy and the LMC. However, recently, Maeder (1985) argues in favour of a critical mass near 100 $M_{\odot}$.

The mass of the famous R 136, the central object of the LMC giant H II region 30 Doradus, was in recent years subject of intense research. Feitzinger et al. (1980) suggested that the brightest and bluest of the three components, R 136a, might be a star of mass $250-1{,}000\ M_{\odot}$. Cassinelli et al. (1981) from the IUE data concluded that R 136a is a single supermassive star of $\sim 3{,}000\ M_{\odot}$ emitting an extremely powerful wind of $10^{-3.5}\ M_{\odot}\ yr^{-1}$ at 3,500 km s^{-1}. Today from the works of several workers (e.g., Moffat and Seggewiss, 1983; Melnik, 1983) we can rule out the possibility of these extreme masses for stars. In particular, Weigelt et al. (1985), showed that R 136a is a dense cluster of at least 8 stars embedded within a diameter of 1″. However, it should be stressed that the problem with R 136a as to the upper mass limit is not fully resolved. Walborn (1984), from an analysis of the magnitude and spectral characteristics of R 136a, finds that the main component should be $\sim 250\ M_{\odot}$. *In this situation observational results are of invaluable help.*

In the classical method of star counts for deriving the luminosity function and then the initial mass function (IMF), the sample stars are usually taken from the published catalogues the majority of which have used low resolution techniques. The possible multiplicity of the sample stars, especially for the upper mass limit, which is dependent on a relatively small number of stars, can significantly alter the shape of the upper part of the IMF. Very roughly, one star in a billion may be above 60 $M_{\odot}$. The answer to the fundamental questions such as the universality of the IMF depends strongly on the problem of the multiplicity of the most luminous stars.

Several investigators have concluded that the high mass cutoff of the IMF increases with decreasing abundances of heavy elements. For example, Vangioni-Flam et al. (1980) found that the number of the luminous stars increases along the sequence the Milky Way-LMC-SMC-IZW 18, the latter being the most metal poor galaxy known. On the contrary, Humphreys (1983) finds that although the SMC and IC1613 have comparable metallicities, the lowest in the Local Group, their brightest blue supergiants have very different luminosities. This confusion may be due to the possible multiplicity of the observed luminous stars. Anyhow, before comparing the number of the brightest stars in different galaxies one should make sure that the sample stars are not multiple. Such a project requires the use of the VLT facilities.

Another consequence of the present result concerns the application of the brightest blue and red supergiants for intergalactic distance determinations (Hubble, 1926; de Vaucouleurs, 1978; Humphreys, 1983; Sandage, 1986). These stars, classified as secondary distance indicators, are used for distances up to ~10 Mpc. If the standard candles are multiple the distances are underestimated. This favours smaller values for the Hubble constant.

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Age and Star Formation of the Radio Galaxy 0902 + 34 at Redshift z = 3.395: Constraints for Primeval Galaxies

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Introduction

Primeval galaxies are among the best test objects of observational cosmology. They will give an estimate of the density parameter of the Universe Ω_0 from a colour-redshift Hubble diagram observed to extreme values of redshifts. They also bring excellent constraints to models of formation and evolution of galaxies. In this sense, searching for distant galaxies becomes one of the first objectives of the new generation of telescopes.

On the basis of recent developments in galactic evolution (see review by Rocca-Volmerange and Guiderdoni, 1988a), it is possible to predict some of the most striking features which will be signatures of young galaxies. Moreover, the present set of observational data of faint galaxies, from deep counts (Tyson, 1988) until the most distant ($z \geq 3$) radio galaxies with a dominant stellar component (Lilly, 1988), is rapidly increasing. It can therefore now be confronted in detail with evolutionary models of galaxies. Due to high redshifts and current activity of these distant galaxies, models have to simulate the galactic evolution in extreme far-UV light, observed in the rest frame through the visible and infrared broad band filters. Scenarios of standard evolution based on a large sample of observations give template spectra. Corrections due to cosmological effect (k-corrections) and to intrinsic evolution of the galaxy (e-correction) are computed from template spectra to predict apparent magnitudes and colours at any redshift and age. Models also predict the nebular component emitted by the Lyman continuum photons N_{Lyc} absorbed by gas and the consequent gas content.

Up to now, to search for primeval galaxies from integrated colours through intermediate or broad band filters as well as from Lyα emission line through narrow band filters gave negative results and only fixed upper detection limits. The infrared and optical counterparts of radio galaxies at high redshifts ($z \geq 1.8$), the oldest stellar populations at about quasar distances, have recently been observed by Djorgovski et al., 1984; Lilly and Longair, 1984; Spinrad et al., 1985; Dunlop and Longair, 1987; Cowie, 1988, and others, from the 3CR or 1 Jy catalogues and the Parkes Selected Region Sample. One of these galaxies, 0902 + 34, was recently discovered by Lilly, 1988 at a redshift $z = 3.395$. According to its fluxes through the VIJK broad-band filters and Bruzual's models, 1983, this galaxy does not appear as a primeval galaxy; however, this result must be confirmed by other models including far-UV ($\leq$ 2000 Å) stellar spectra, nebular component and Asymptotic Giant Branch stars.

With the help of our Atlas of Synthetic Spectra of Galaxies (Rocca-Volmerange and Guiderdoni, 1988b (RVG)), based on the last version of our models (Guiderdoni and Rocca-Volmerange, 1987 (GRV)), we can give a possible age of this galaxy. In the galaxy frame, a burst of star formation is at present taking place but an older burst also happened about 3 Gyrs earlier.

The solution gives an epoch of galaxy formation at a redshift ≥ 10 and a resulting low value of the density parameter $\Omega_0 \leq 0.1$.

Signatures of a Young Galaxy

Due to the extreme distance of galaxies presumed primeval, any interpretation of their observations is a delicate problem. Simultaneous effects interact to modify apparent magnitudes and colours: cosmology, intrinsic evolution and likely environmental influences can affect their appearance in ways which are difficult to estimate with their respective weights. A classical Friedmann-Lemaître cosmological model gives a relation between the redshift z and the cosmic time t(z). This relation essentially depends on the cosmological parameters: the Hubble constant H_0, the density parameter Ω_0 and the cosmological constant Λ_0. Galactic evolutionary models coupled with cosmological models are the key to understand the respective importance of the various effects. For a galaxy observed at redshift z, the age estimated from evolution models constrains the epoch of galaxy formation and then the age of the Universe.

Some principles are used in building our models: limitation to a few free parameters, a time resolution sufficient to follow details of stellar evolution, input data preferentially observational. At least, results must simultaneously fit observational data on a large extent in wavelength range, gaseous content, emission lines, dust, etc. We proposed such models (Rocca-Volmerange et al., 1981, completed with cosmological effects by Guiderdoni and Rocca-Volmerange, 1987 (GRV) which is our present version) in which the star formation parameters are: (i) the start of the star formation process z_{for}, (ii) the time scale

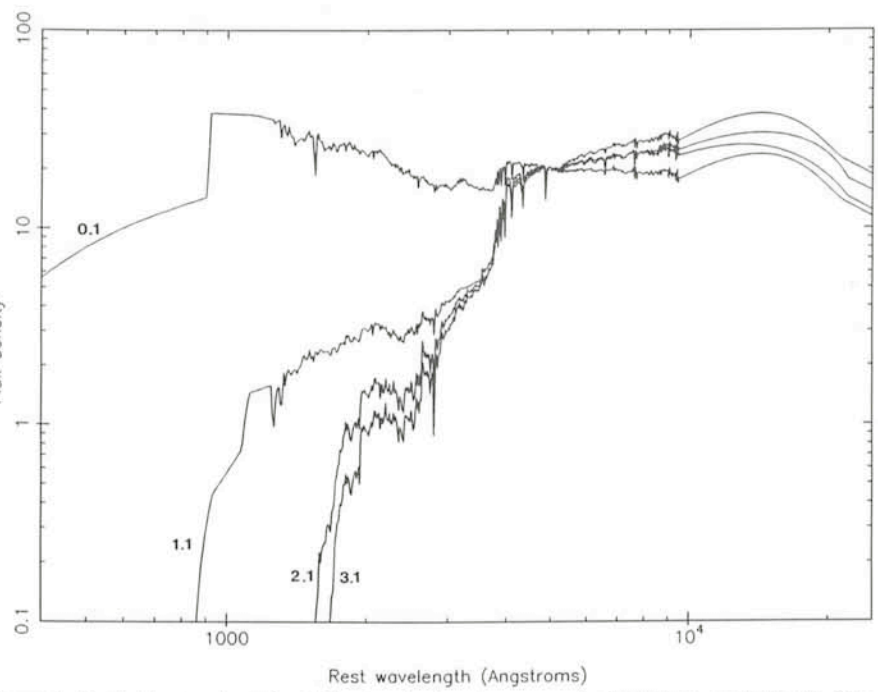

Figure 1: *Synthetic spectra of a 1 Gyr burst at various ages indicated on each line in Gyr. Spectral resolution is 10 Å. Units are arbitrary. Normalization is at 4990 Å.*

of the gas consumption t_*, characteristic of the morphological type when the bulk of stars form. The average metallicity Z is solar or half-solar and the initial mass function (IMF), defining the mass spectrum of stars at birth, is standard (Scalo, 1986). Our models use an observational library of stellar spectra which we compiled from the IUE Atlases and Gunn and Stryker, 1983. The recent results of internal structure models concerning the last phases of evolution (Horizontal Branch and Asymptotic Giant Branch) are taken into account, see GRV for details.

We gathered in two companion papers in press in *Astronomy and Astrophysics Supplement Series* an Atlas of Synthetic Spectra of Galaxies and the predictions of magnitudes and colours of high-redshift galaxies in various photometric systems from z = 0 to 4. The spectra are defined for 8 morphological types from λ = 2000 Å to infrared wavelength bands. Figure 1 gives spectra of our Atlas after a burst of star formation of 1 Gyr duration at various ages. Spectra are in arbitrary units normalized at 4990 Å. In our atlas, we give outputs normalized to the mass of the galaxy. The IMF is a power law $m^{-\varkappa}$ with $\varkappa$ = 0.25, 1.35 and 1.7 respectively between the limits 0.1 $M_\odot$, 1 $M_\odot$, 2 $M_\odot$ and 80 $M_\odot$. Different IMF will be further considered in the starburst galaxies (Larson, 1987).

Nebular Component

At each time step, the nebular emission from a photoionization process is estimated by Stasińska, 1984 models, fitted on a standard H II region in the Magellanic Clouds. The number of ionizing photons is depending on a free parameter *f* which is the effective fraction of N_{Lyc} absorbed by gas. The largest uncertainty affects this parameter. With the limit value *f* = 1, Spinrad, 1988, fits well his sample of Lyα galaxies with our models and finds a redshift of formation z_{for} = 5. Figure 2 (Rocca-Volmerange, 1988) gives a similar comparison calculated with a factor *f* = 0.7 and two redshifts of formation z_{for} = 2 and z_{for} = 5. Such fits, which favour high values of z_{for} = 5 or more, do not impose a large amount of dust as previously thought by many authors. This result is confirmed by a recent and more complete study (Valls-Gabaud et al., in preparation). Emission lines can increase the UV-flux of a burst galaxy by about 50%. The important point is that the predicted nebular component is in agreement with observations sufficiently to be used for further interpretations.

Age of the Radio Galaxy 0902+34

This radio galaxy has been observed by Lilly, 1988. According to recent observations (Lilly, private communication), this example is not unique. The redshift is well estimated at z = 3.395 from Lyα and C IV emission lines which show evidences of a non-thermal component and a metal enrichment. It is important to note that at this redshift the Lyα and Hβ lines coincide with the V and K bands, favouring the detection. It has been selected on the basis of a faint infrared emissivity associated to a very red colour J-K $\geq$ 2.75. Its emissivity in Lyα line ($\simeq 2.1 \times 10^{-18}$ W m^{-2}) and its equivalent width ($\simeq$ 1,000 km s^{-1}) are about similar to those of the 3CR radio galaxies as shown in Figure 2.

The best fit with our models of the integrated VIJK colours, corrected from the Lyα line (Figure 3) is obtained from the sum of two intense bursts of respective ages 0.1 Gyr and $\simeq$ 3 Gyr; the most recent one is going on in the rest frame of the galaxy and the oldest one transformed the galaxy mass in stars for a 1 Gyr duration. The following 2 Gyr correspond to a passive evolution. The Lyα line and the far-UV light detected through the V band are essentially due to massive stars from the recent starburst while a population of asymptotic giant branch stars is essentially emitting in the K band. The two populations are superimposed in the I band. Our scenario is in rough agreement with the images given by Lilly, 1988. In the V image, isophotes show a double component, observed in many bright distant radio galaxies. Except for the most compact one, the V components do not show counterparts in the K band. From the I image, features of both the V and K bands are recognizable. A more detailed analysis is at present going on by varying the star formation parameters into extreme limits for minimizing the start of star formation.

Constraints on the Density Parameter Ω_0

Consequences of the 3 Gyr age on the cosmological parameters z_{for} and Ω_0 are important. The age = t(z)-t(z_{for}) gives a value of z_{for}, the start of the galaxy formation in a cosmic time scale fixed by the cosmological model. The following table gives estimates of z_{for} for various values of the density parameter Ω_0. The adopted Hubble constant is 50 km s^{-1} Mpc^{-1} and the cosmological constant $\Lambda_0 = 0$.

	Ω_0 = **0**	Ω_0 = **0.1**	Ω_0 = **1**
Universe Age in Gyr	19.56	17.57	13.04
t(z) in Gyr	4.45	3.13	1.41
t(z_{for}) in Gyr for an age 3 Gyr	1.45	0.13	—
z_{for}	**12**	**≥15**	—

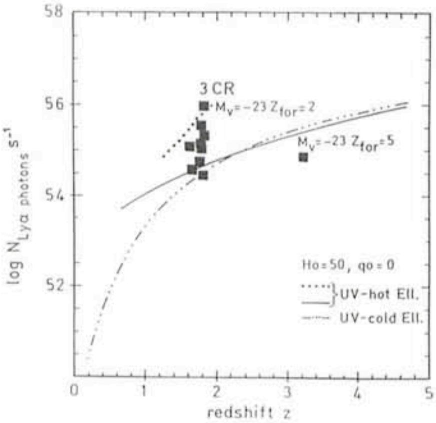

Figure 2: *Number of Lyα photons deduced from observations of Lyα galaxies (Spinrad, 1988) compared to models for two redshifts of formation z_{for} = 2 and 5 (Rocca-Volmerange, 1988). Lyman continuum photons are absorbed by gas at a rate 70 %. Normalization is $M_v = -23$.*

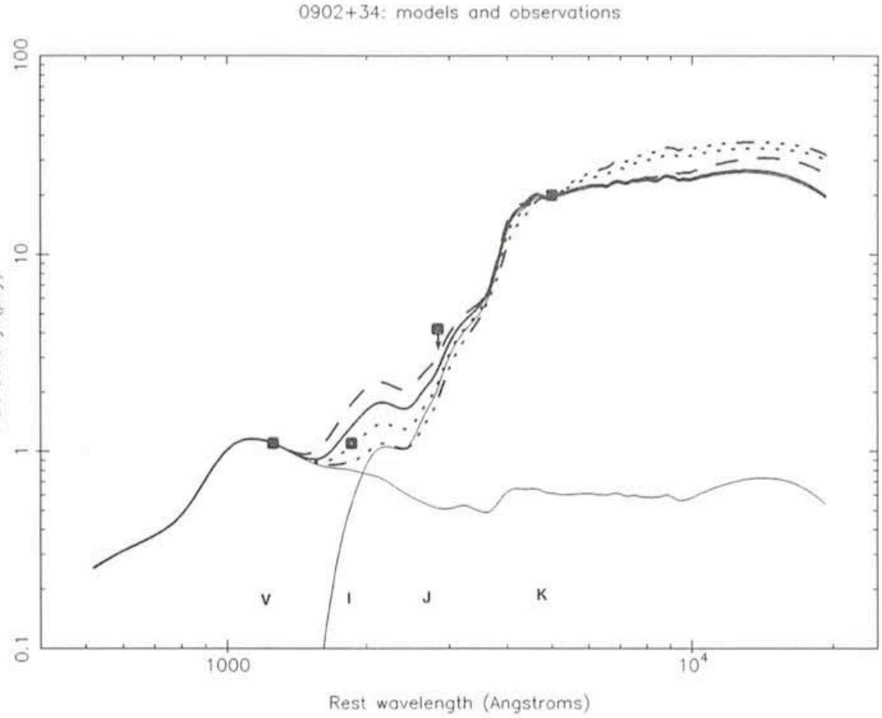

Figure 3: *Comparison of the VIJK fluxes of the radio galaxy 0902+34 (Lilly, 1988) with a model of two bursts: a recent 0.1 Gyr one plus an older one starting at different ages: 2 Gyr (dashed line), 3 Gyr (full line), 4 Gyr (dots), 5 Gyr (dashed-dots). The respective fluxes of the two bursts (0.1 Gyr and 3 Gyr) are also shown (thin lines), see text for details. The IMF is standard and the metallicity is half-solar. Normalization is at 4990 Å (K band in the rest frame).*

To impose an age of the universe long enough to support this 3 Gyr old galaxy, the most plausible values of Ω_0 are very low, likely ≤ 0.1, and the consequent values of z_{for} are high (≥ 10). This result is noticeable since it is full of constraints for the search for primeval galaxies. Also, at a first view, it does not seem quite in agreement with the present models of galaxy formation which favour a redshift of formation peaking at z = 5. Moreover, it is noticeable that similar results are deduced from the Lyα galaxies (Rocca-Volmerange, 1988), Hubble diagrams (GRV) and faint galaxy counts (Guiderdoni and Rocca-Volmerange, 1988c) which are based on independent observational data and in this sense become more confident, even if more complete studies are needed.

Conclusion

The best star formation rate given by evolutionary models for explaining the emission of the radio galaxy 0902+34 in the K band is an intense burst started 3 Gyr earlier with a 1 Gyr duration. Another present (galaxy frame) burst 0.1 Gyr explains the V and partly the I emission. The IMF is standard. The dominant stellar component emitting in the K band is on the Asymptotic Giant Branch. By taking into account uncertainties due to the stellar tracks, the metallicity effects, or changes in IMF, we could slightly improve the accuracy of such results. Anyway, the most important question is to know if this stellar component can be supergiants leading to a recent and possibly primeval burst. The duration of the supergiant phase for massive stars ($\simeq 10^8$ yr) is shorter than the dynamical time scale (10^9 yr) of a burst in these massive galaxies. This means that supergiants evolve from blue to red during the burst and then strongly emit in both the V and K bands. Some shorter bursts will be tested but their dynamical interpretation becomes difficult.

The best detailed analysis to pursue is an estimate of age and star formation parameters (bursts, IMF, metallicity) in each component (as shown in Figure 4) with models in relation with the gas content. More specifically, infrared fluxes of the radio galaxies and their surrounding

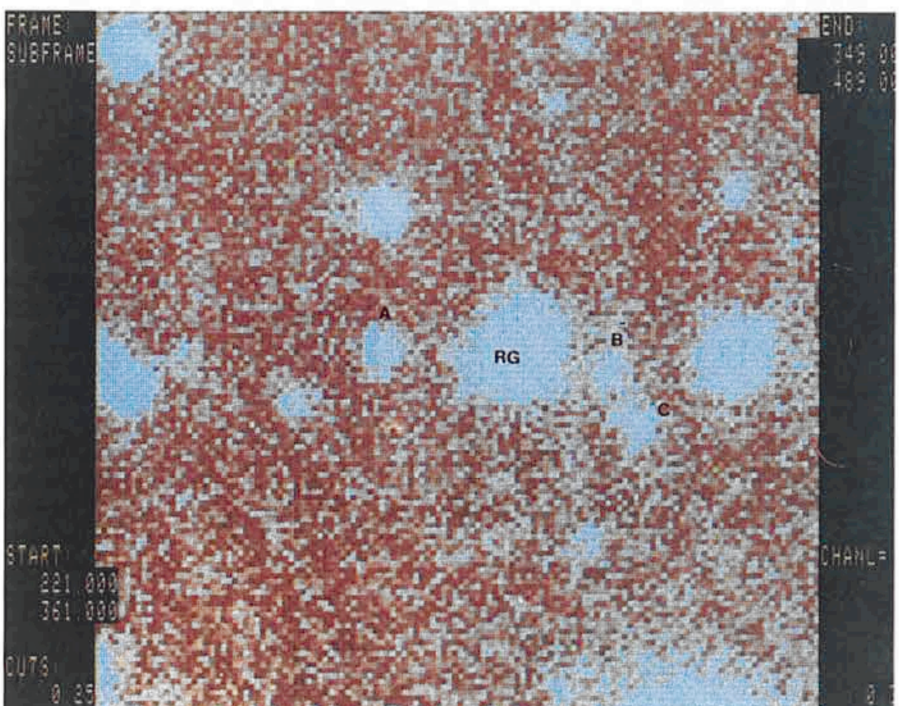

Figure 4: *A 1-hour exposure in September 1987 towards a distant radio galaxy at a redshift z = 0.68 with the ESO 3.6-m telescope and a CCD detector through the R filter. The components have also been observed through the V, I filters.*

components determine the age of the oldest stellar population and, when they are compared to UV fluxes and nebular emission lines, they give information on evolution. Exploring a significant statistical sample of distant radio galaxies with their environment through broad band filters for colours and interference filters for emission lines with the best angular and spectral resolution instrumentation is the best way of understanding the evolution of galaxies and to possibly gain access to primeval galaxies. This programme requires so much exposure time that it can only be realized in the frame of a key-programme of the type recently initiated at ESO.

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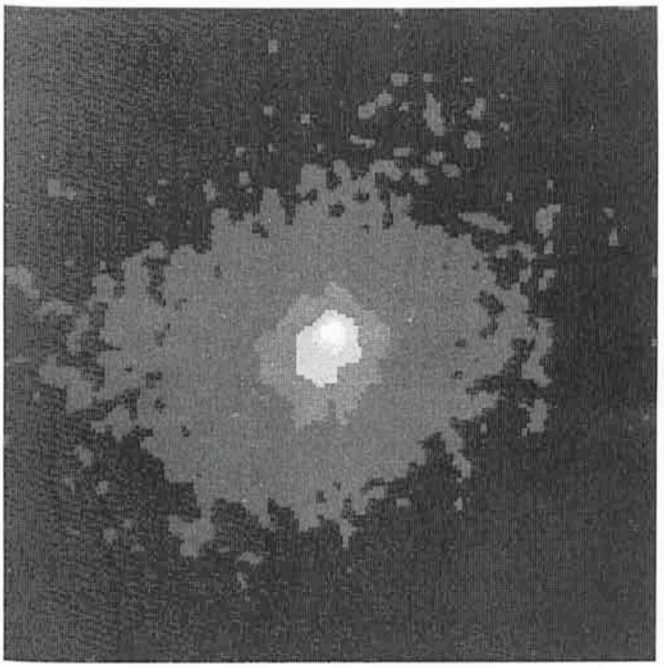
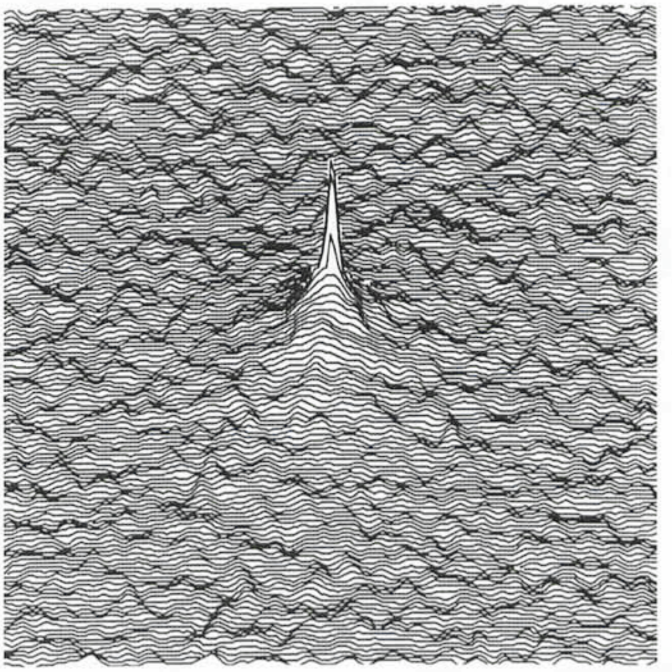
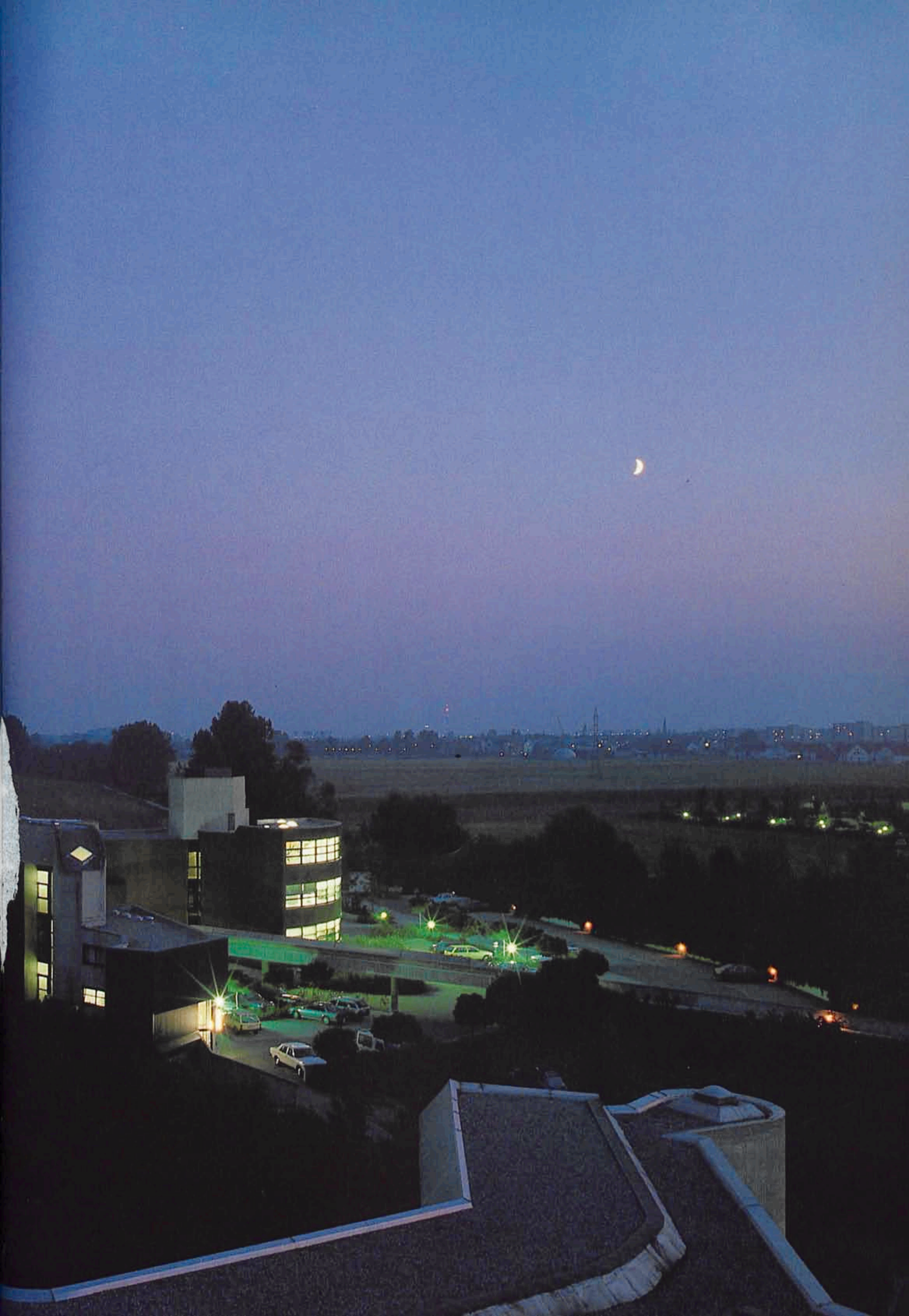
Comet Halley is Still Active





This picture of famous Comet Halley was obtained with the Danish 1.5-m telescope at the ESO La Silla observatory during April-May 1988 (observers: H. Jørgensen, P. Kjærgaard and R.M. West). It was produced by the combination of about 50 CCD frames, obtained during 19 nights, totalling 11 hours 35 minutes exposure. It shows the comet in visual light at a distance of about 1,250 million kilometres, almost as distant as the planet Saturn and demonstrates that the comet still is actively dispensing dust, even at this very large distance from the Sun. The image to the left is smoothed and has 6 light levels, in order to show the 23-mag cometary nucleus in the asymmetric, inner coma and also the much larger, elongated outer coma. To the right is a three-dimensional representation, which illustrates the relative brightness of the nucleus, as compared to the coma. The field of the picture measures 75 arcsec × 75 arcsec; North is up and East is to the left. The direction to the Sun is WNW. Pixel size: 0.47 arcsec = 2,800 km. Johnson V filter. Bias-subtracted, flat-fielded, cleaned for cosmic events, stars and galaxies removed, 3 pix × 3 pix gaussian smoothed.

The ESO Headquarters building in Garching photographed by ESO photographers H.-H. Heyer, C. Madsen and H. Zodet. ▶



CCD Photometry of Globular Clusters

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The Subject

In a similar way that humans inhabit our planet, stars are distributed in galaxies. There are regions where their density is low, such being the case where our sun exists, or places where the population is large and highly concentrated, the counterparts of the Tokios, New Yorks, denominated in the astronomical world as globular clusters, because of their globular appearance rendered by their gravitational field. Their stellar population ranges in the order of the tens of thousands up to beyond a million. About 140 of these objects are seen in our Galaxy and a few others may be hiding, obscured by the dust in the plane of the Galaxy. The majority are placed towards the direction of the galactic centre, and hence ideally situated to be observed from the southern hemisphere.

The study of globular clusters provides most relevant information, such as the minimum age of the Universe, as they are the oldest known objects, supposedly formed in the early stages of the contraction of the galaxy, percentagewise very soon following the birth of the Universe. It explains furthermore the process of stellar evolution, due to the fact that we can analyse a large sample of coeval stars all placed at the same distance; provides knowledge of the chemical composition of the original material which prevailed during the "first epoch", as well as their mass, and location within our Galaxy, and neighbouring galaxies, such as the Magellanic Clouds, close enough to scrutinize these objects.

The observations of globular clusters are performed with high-precision photometry, measuring the luminosity and the colour of a sample of stars, ideally placed not so near the cluster's centre, as to avoid the high contamination; and not so far from the nucleus, as to elude intruders from the field. The plot derived from such observations is called the colour-magnitude diagram, which is a fundamental tool in understanding the evolution of stars in these objects. It informs us on the relation magnitude as a function of the stellar colour, which can be transformed with good approximation to those theoretically derived for their luminosity and temperatures. As it is assumed that all stars in a cluster shared a common origin, their location in the colour-magnitude diagram is due to the fact that the more massive the star is, the faster it evolves, hence the different regions of the diagram, correspond to the various phases of their lives.

The theoretical tracks of different masses for identical ages provide the isochrones, in whose extension the various masses are placed on the hypothesis of a common origin. The calculation of these models provides the evolution in time of the stellar temperature and luminosity for a homogeneous chemical composition. From the comparison of the observed colour-magnitude diagrams with the isochrones we can deduce the age of the cluster. In order to be able to make these comparisons we need to know the chemical composition, distance and reddening of the cluster, and the transformation of the physical parameters of luminosity and temperature ought to be well defined.

History

In the mid-sixties, when I began to study astronomy, I gave careful thought to the kind of research that might be carried out from Chile. At that time, the European Southern Observatory was just being started. I was primarily interested in photometry, and the beautiful work on globular clusters that Allan Sandage had recently done at the Mount Wilson and Palomar Observatories had impressed me greatly, so I decided to stop off in Pasadena and talk with the expert. It was then and there that the decision was made: do photometry on the many globular clusters that lie at negative declinations (65 per cent are south of −20°). At the time, globular cluster photometry in the Southern Hemisphere was almost a virgin field, and almost any cluster that one worked on was being studied for the first time. It was possible to reach below the horizontal branch, home of the RR Lyrae stars, thereby allowing one to derive reasonably reliable distances and interstellar reddening for these objects. The approximate metallicities could also be determined.

The early photometry was carried out in two steps: first, a dozen or so stars were measured photoelectrically (UBV usually), covering as wide a range of colour and magnitude as possible. Then photographs were taken and star images measured with a suitable photometer. Later, when it became available at the ESO 3.6-m telescope, a small thin-wedge prism could be placed before the objective, thereby producing a second, much fainter image of each star. Thus, in a boot-strap manner, the relatively bright photoelectric sequence could be extended to fainter magnitudes. Then came CCDs. Suddenly it became possible to carry out photometry with a substantially higher precision owing to the stability and the linearity of this marvellous detector, especially at low light levels. Also, its sensitivity range extended beyond 1 micron making it possible to work with ease in more colours than B and V which had been the workhorse wavelength bands for many years.

In 1981, following two decades of professorship at Harvard, the American astronomer William Liller moved permanently to Chile at a time when CCDs were still not user-available at ESO. We had known each other since 1968, and because of his interest in globular clusters, we began to collaborate, initially using the now old-fashioned techniques, but then changing over to CCDs when they became available. We shall describe herewith the results of our recent work.

Current Status of Research

Colour-magnitude diagrams reaching down to the main sequence have been obtained for about 40 globular clusters in the Galaxy. The primary motivation for this research has been the determination of the ages of the clusters found by matching the observed V, (B-V) diagram to the theoretically derived luminosity-temperature relationship converted to the observed parameters. Initially, it was not clear if globular clusters had a substantial spread in ages which would imply a gradual formation of the halo of the Galaxy, or if the ages were all similar which would lead one to conclude that there was a rather abrupt galactic collapse. However, improved work of recent years, both observational and theoretical, has made it clear that there is a small spread in the ages of globular clusters, perhaps no more than 2 billion years, an average age somewhere between 16 and 18 Gyrs. As we have said, one of the most important aspects of these results is that it bears directly on the age of the Universe and the value of the Hubble Constant since globular clusters are among the oldest known objects in existence. Therefore, establishing firmly and accurately the age of the oldest clusters would set an upper limit on the Hubble Constant, the exact value of which continues to be very

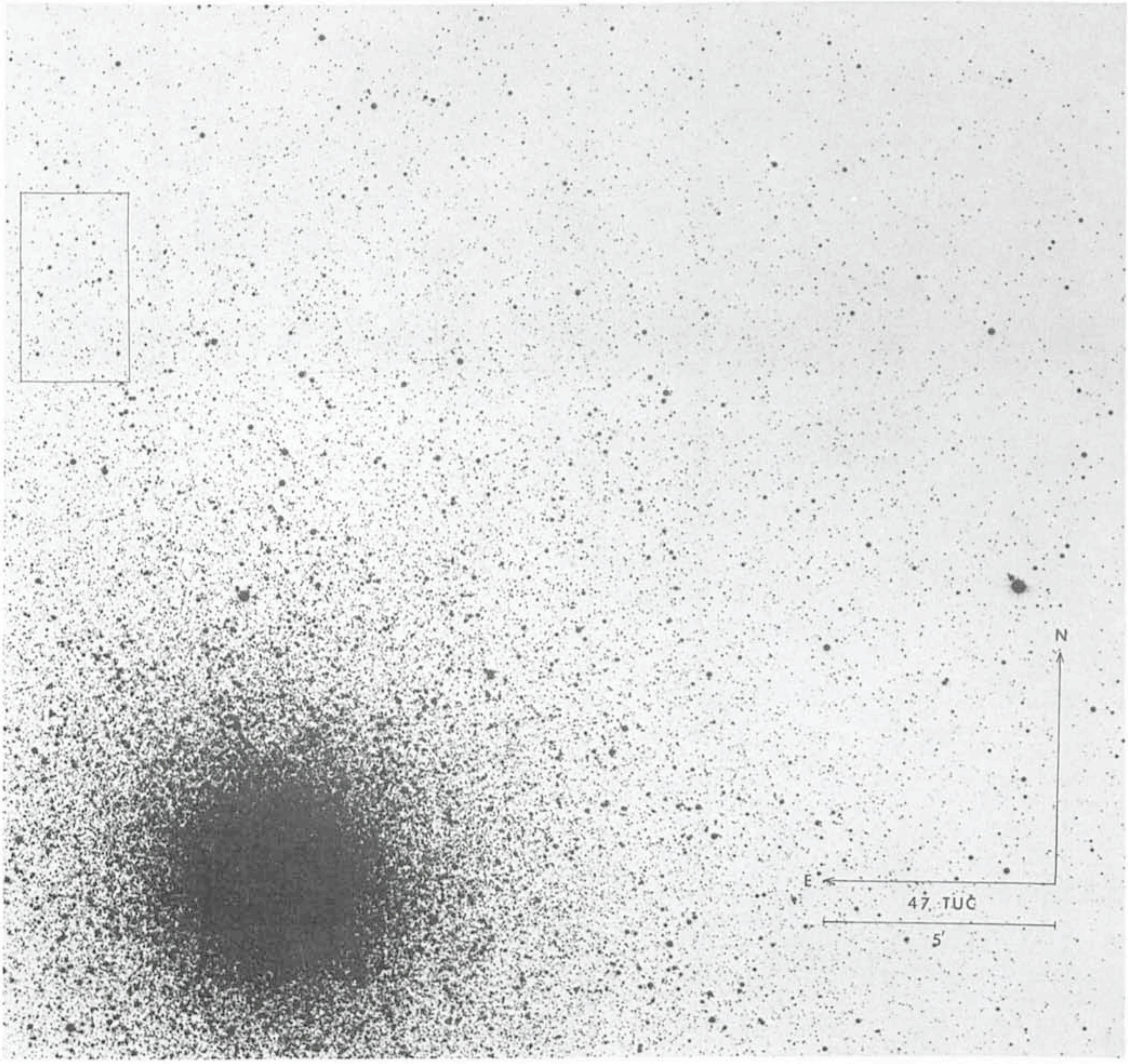
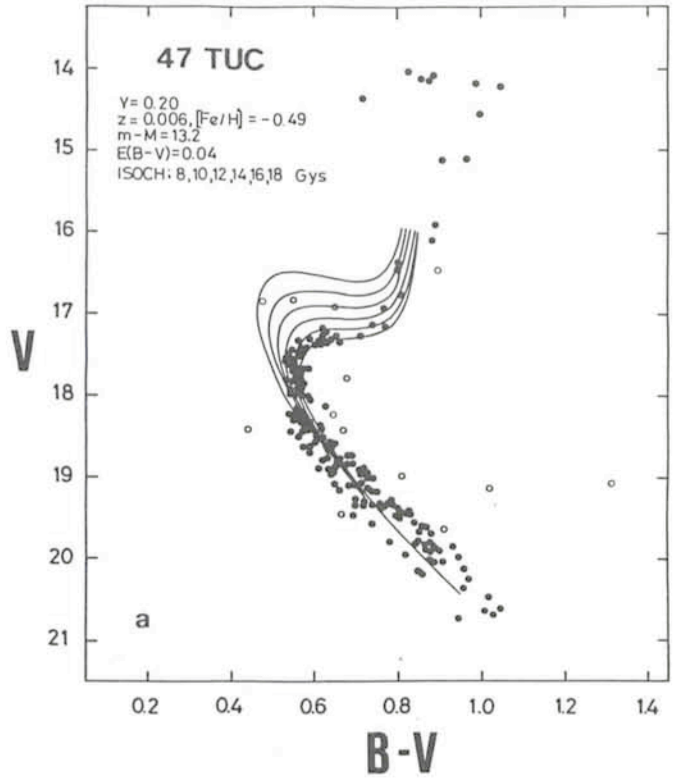
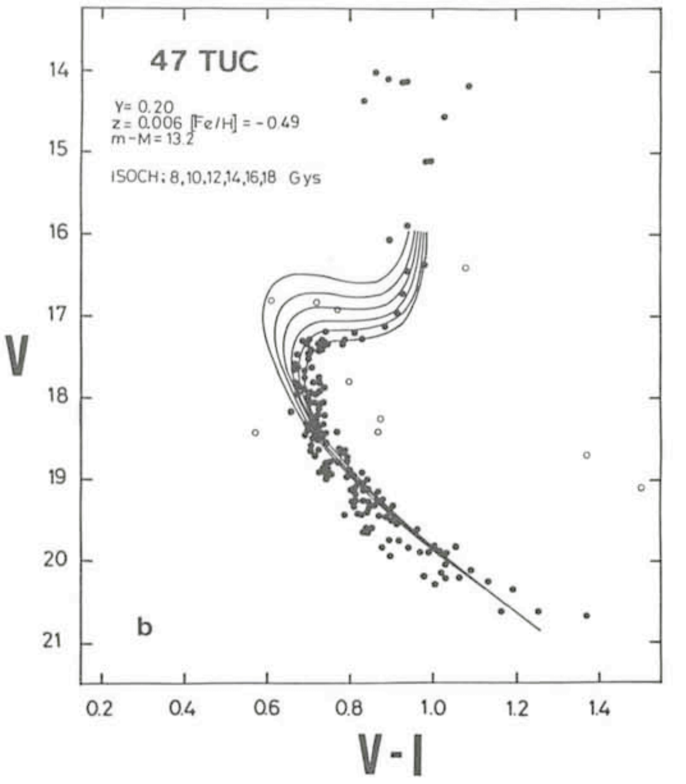


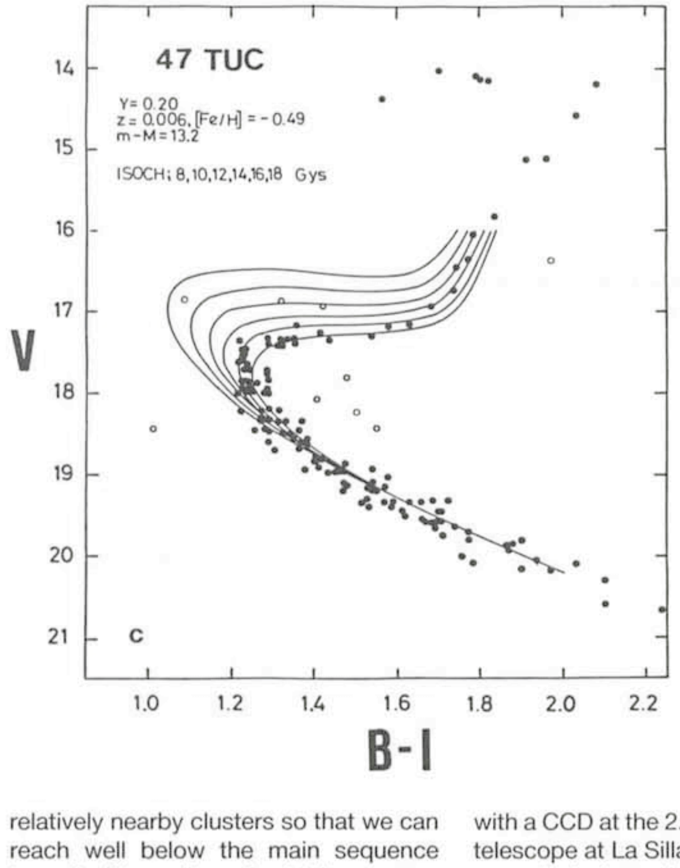
Figure 1: *The northwest sector of the globular cluster 47 Tucanae. The reproduction is from a 14-minute yellow plate (IIa-D + GG 495) obtained with the ESO 3.6-m telescope. Notice the secondary images produced by the Pickering-Racine wedge, displaced 14 arcsec towards the northeast of the brighter primary images. The general view shows the typical field that can be analysed with photographic techniques. The rectangle of 4 × 2.5 arcmin shows the region actually studied with the CCD camera.*

much under discussion at the present time.

One of the weaknesses of the extremely popular and often-used BV photometric system is that metallic line absorption in the blue and violet can be considerable. Thus, the interpretation of observations with stellar evolution theory rests heavily on model stellar atmospheres which are needed to predict the effects of this extinction in stars where often the metallicity is not well known. The metallicity of globular clusters, usually expressed by the parameter [Fe/H], has a range of over two orders of magnitudes, making a precise knowledge of absorption line effects imperative. Fortunately, VandenBerg and Bell have now carried out the difficult calculations needed to predict the location of isochrones in longer wavelength bands where metallic absorption is much less than in the blue. This work came largely as a response to the appearance of the modern generation of electronic detectors, especially the charge-coupled device (CCD), which has made it possible to carry out improved photometry at magnitudes fainter than photographic limits and at wavelengths extending into the near infrared. Besides the obvious advantage of reducing uncertainties arising from poorly known metallicities, use of the red and infrared wavelengths (R and I bands) makes possible an enlarged colour baseline which enhances effects seen less clearly with a smaller range in colour. An additional benefit of this multi-colour approach is that observational uncertainties are reduced by having several independently derived CMDs of the same cluster. With separate evaluations of the age of a single cluster, one not only can assess more reliably the accuracy of the final result, but also can derive ages with a higher precision than attained previously or with only two colours. Consequently, for the past several years we have had underway a programme of BVRI photometry of globular clusters using CCDs and new powerful reduction software. The main thrust of this programme is to concentrate on







Figures 2 (a, b, c):
a. The observed V vs B-V colour magnitude diagram of 47 Tuc, fitted to the isochrones of VandenBerg and Bell for Y = 0.2, Z = 0.006, ([Fe/H] = −0.49), α = 1.65, and ages 8–18 billion years. The isochrones were shifted to represent a cluster with $(m\text{-}M)_v$ = 13.2 and E(B-V) = 0.04.
b. The observed V vs V-I colour magnitude diagram of 47 Tuc, fitted to the isochrones of VandenBerg and Bell for Y = 0.2, Z = 0.006, ([Fe/H] = −0.49) α = 1.65, and ages 8–18 billion years. The isochrones were shifted to represent a cluster with $(m\text{-}M)_v$ = 13.2 and E(V-I) = 0.05.
c. The observed V vs B-I colour magnitude diagram of 47 Tuc, fitted to the isochrones of VandenBerg and Bell for Y = 0.2, Z = 0.006, ([Fe/H] = −0.49) α = 1.65, and ages 8–18 billion years. The isochrones were shifted to represent a cluster with $(m\text{-}M)_v$ = 13.2 and E(B-I) = 0.09.

relatively nearby clusters so that we can reach well below the main sequence turnoff with medium-sized telescopes.

We have now completed BVRI reductions on clusters: NGC 104 (47 Tuc), NGC 2298, NGC 3201, NGC 5139 (Omega Cen), NGC 6121 (M 4), and NGC 6362. All observations were made with the superb CCD system of the 1.54-metre Danish Telescope at La Silla. An additional eight globulars have now been observed in these four colours with a CCD at the 2.2-metre Max-Planck telescope at La Silla, and these data are currently being reduced at the computer centre at La Silla and analysed at the Isaac Newton Institute in Santiago. In order to minimize the errors that arise from comparing cluster fields with standards in other parts of the sky, we have set up photo-electric standards in the same cluster fields observed with the CCD. Thus, the effects of inaccurately known or varying atmospheric extinction are totally avoided. Because we can use smaller telescopes to set up the standards (most often the ESO 1-metre reflector), valuable large telescope time is not wasted moving back and forth between widely separated fields.

Observations

The camera that we have used at the Cassegrain focus of the Danish 1.54-metre telescope uses a CCD with 512 × 320 pixels. Each 30 × 30 micron pixel corresponds to an area on the sky of 0.47 × 0.47 arcsec; thus, the total field is 4.0 × 2.5 arcmin. Typically, the number of exposures of the BVRI frames obtained for each cluster ranged from a few seconds to several minutes in order to cover the full range of magnitudes without image saturation. Field positions were chosen, following careful inspection of deep photographs, as the best compromise between maximum cluster membership and workable contamination caused by crowding of im-

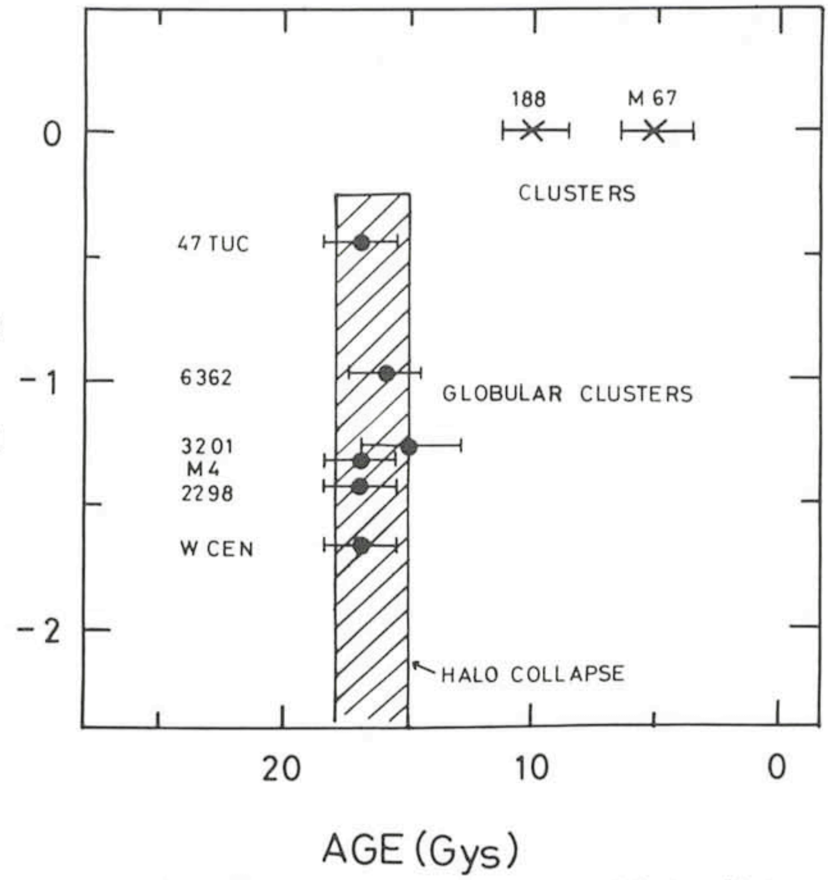


Figure 3: *Age versus metallicity for our studied globular clusters and the two oldest open clusters (NGC 188 and M67).*

ages. All reductions have been carried out at La Silla using the MIDAS/INVENTORY software employing point spread function techniques. Precise colour equations have now been established for the CCD telescope system based on 140 BVRI frames and a total of 40 standard stars with a large range of colour.

The Results

As an example, we will discuss in somewhat more detail the results for 47 Tucanae, the second brightest globular cluster in the sky. With a total population of more than one million stars, and at a distance of 13 thousand light-years, the object is faintly visible with the naked eye northwest of the South Magellanic Cloud. The cluster is shown in Figure 1, from a plate obtained by us at the ESO 3.6-m telescope. About two hundred stars were measured in a 4.0′ × 2.5′ field, and the MIDAS/INVENTORY reductions yielded the V vs B-V, V vs V-I, and V vs B-I CMDs shown in Figures 2a–2c. These diagrams also include the theoretical isochrones of VandenBerg and Bell for ages ranging from 8 to 18 Gyrs. From the figures we can see that the brightest stars investigated in our field are four red horizontal branch stars at a mean magnitude of V = 14.07. While no red giants are present in the field, the sub-giant branch and the main sequence are well defined in all diagrams. The magnitudes of the main sequence turnoff points in the three colours all fall very close to $V_{TO} = 17.6 \pm 0.1$.

The VandenBerg and Bell BVRI isochrones are presented with the helium content alternatives of Y = 0.2 and Y = 0.3, and abundance alternatives of [Fe/H] = −0.79 (Z = 0.003) and [Fe/H] = −0.49 (Z = 0.006) for $\alpha = 1.65$. The reddening value for 47 Tuc is well determined at E(B-V) = 0.04 ± 0.02 from which we derive E(V-I) = 0.05 ± 0.02 and E(B-I) = 0.09 ± 0.02. The best fit for all the isochrones shown in Figures 2a, 2b, and 2c results from Y = 0.2, [Fe/H] = −0.49, with E(B-V) = 0.04 ± 0.02 and a distance modulus of $(m\text{-}M)_v = 13.2$. In all three colour-indices we find that the isochrones match the CMDs best for an age $17 \pm 2 \times 10^9$y. The V vs B-I CMD in Figure 2c shows the good sequence definition provided by the use of the extreme bands as colour-indices. Using the horizontal branch magnitude of V(HB) = 14.05, we find that the absolute magnitude of the red horizontal branch is M_v (HB) = 0.85 with an uncertainty around ± 0.1. This result clearly suggests that indeed the intrinsic brightness of horizontal branch stars is fainter for metal rich clusters than the canonical value of M_v (HB) = 0.6.

In Figure 3 we have plotted the ages vs metallicity of these clusters plus the two oldest known open galactic clusters: M67 and NGC 188. We can observe that the ages derived for all of them are $17 \pm 2 \times 10^9$ years, hinting that the globular cluster system might be coeval, and that the epoch of the galactic contraction was short. These ages set a lower limit for the age of the universe and thus an upper limit for the Hubble constant of $H_o = 58 \pm 5$ km s^{-1} Mpc^{-1}, assuming $q_o = 0$.

ESO and La Silla

For nearly two decades I have been observing from La Silla, for a total of around 300 nights, witnessing the dramatic rate of improvement of astronomical technology and accumulating data that have given birth to about one hundred scientific papers. It is a moment to pause, both to express my gratitude to the many friends that have enabled me to take part in this formidable adventure, as well as to make public my recognition to the thirteen years leadership of Lodewijk Woltjer and his key collaborators who have made La Silla what it now is: the best astronomical observatory in the world, a line of excellence assured to be sustained and expanded by the current administration and the advent of the VLT, the visionary vanguardship of European astronomy.

Correction

We are sorry to inform you that some IRAS measurements listed in Table 1 of our article "IRAS Molecular Clouds in the Hot Local Interstellar Medium" (P. Andreani, R. Ferlet, R. Lallement, and A. Vidal-Madjar), published on page 47 in the last issue of the *Messenger* (No. 52), are wrong. In fact, we reported by mistake some IRAS fluxes of the Clouds # 126 and # 113 that further checks on the IRAS maps do not confirm. Here is our corrected version of that table.

P. Andreani

TABLE 1. *Infrared and CO Properties of the Clouds*

	Cloud	Coordinates				IRAS			
#	name	α (h)	δ (°)	l (°)	b (°)	12 μ	25 μ	60 μ (MJy/sr)	100 μ
20	L 1642	4 33	−14 20	210.9	−36.5	–	–	.8 ± .2	11.2 ± 2.8
126	ρ-Oph	16 16.3	−19 48	355.5	−21.1	–	–	20 ± 5	71 ± 8
113	–	15 17.1	−29 25	337.8	−23.04	–	–	4.6 ± 1.4	26.4 ± 6

Search for Faint Nearby Stars

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1. Introduction

Some of the most frequently discussed subjects in the astronomical literature during the last decades are related to the problem of the "missing mass" or dark matter in the Universe. The possibility that the "missing mass" in the solar neighbourhood might be accounted for by the existence, in sufficient numbers, of very low mass stars (brown dwarfs), and very old dead stars observed now as cold low luminosity degenerates is very attractive. See for example the works by D'Antona and Mazzitelli (1986) and Liebert, Dahn and Monet (1988). The solar neighbourhood is the only place where one might expect to find and study such low luminosity objects.

Luyten's LHS Catalogue (Luyten, 1979), containing stars with proper motions larger than 0.5 arcsec/year, is still the main source of nearby stars considered by different authors in their estimates of the contribution to the local dark matter due to brown dwarfs and cold degenerates. Unfortunately Luyten's LHS Catalogue, which is the source of many interesting results, is not adequate for the purpose of selecting a statistically significant sample of nearby faint stars because it is incomplete for $m > 19$ while the magnitudes of the relevant objects (brown dwarfs and cold degenerates) are $M \geq 16$. Therefore, the volume for which the sample is complete is very small. The LHS Catalogue is also incomplete for proper motions smaller than about 0.7 arcsec/year, introducing a strong kinematical bias.

In 1986 we began a programme to search for and study faint nearby stars using glass copies of the ESO R Survey plates. The magnitude limit of these plates is about $m_R = 21$. We selected areas near 12 h and 0 h of right ascension, hoping to identify faint members of the Hyades and Sirius Superclusters (Eggen, 1984), which in these regions should have most of their space motions in the plane of the sky.

During the blinking process we found that for most stars, that is those with $m > 13$, displacements down to 0.7 arcseconds from one plate to the other could be detected. For instance, in area 439 we have a time base of 7 years and we found 160 stars with proper motions larger than 0.1 arcsec/year. In what follows we will describe the statistics of the proper motions in area 439 and the interesting potential of these studies in understanding the solar neighbourhood. We will also present some results of a spectroscopic follow-up for a selected group of proper motion stars found in area 439.

2. The Search

For this project we obtained glass copies of pairs of plates taken at La Silla for the ESO R Survey (IIIaF + RG 630) with time intervals from 3 to 7 years. They were searched using a Zeiss Jena stereocomparator (blink). Every single image was carefully checked for proper motion. It takes some 50 hours to scan a pair of plates.

Coordinates α, δ for each star were determined using the Perth 70 stars as reference. To measure proper motions we divided each plate into 9 zones 10 cm by 10 cm each. With an x-y measuring engine (Zeiss Jena) we measured the proper motion stars in each zone along with a group of 25 reference stars selected to be faint (about 18^{th} magnitude) and evenly spaced in each zone.

A simple computer programme was developed to map one plate into the other through a linear transformation. This was done for each zone separately. The reference stars were used for this purpose. The rms errors achieved after discarding from 4 to 7 reference stars were always less than 2 μm, typically 1.6 μm. The x-y measuring engine has a precision of the order of 1.2 μm, therefore the rms errors achieved with our method are getting down to the measuring errors. When the final transformation equations were found the proper motion was computed for every programme star previously selected. Typically, for a 5-year time base, the formal error is about 0.02 arcsec/year.

3. ESO Area 439: Statistics of Proper Motions

For this area we have two plates taken 7 years apart. We have found 250 stars

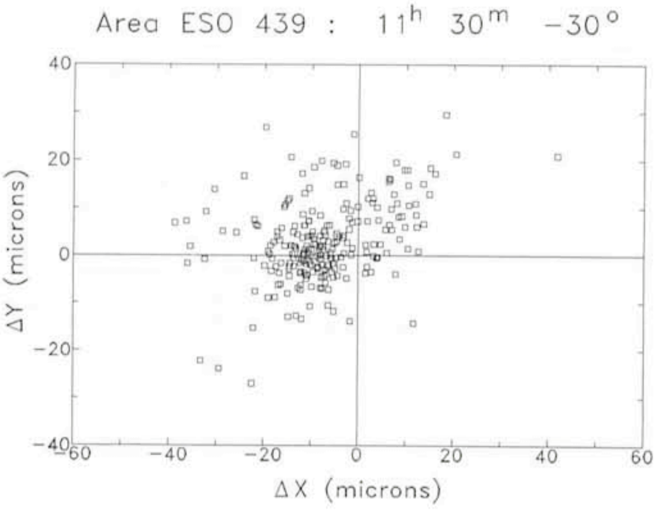


Figure 1 a: *Δx versus Δy for 250 proper motion stars found in area ESO 439.*

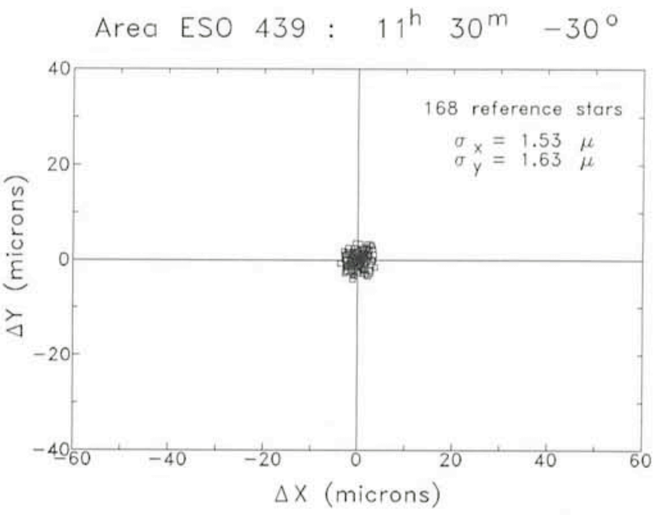


Figure 1 b: *Δx versus Δy for 168 reference stars used to obtain the stellar motions. The average residuals for x and y are indicated.*

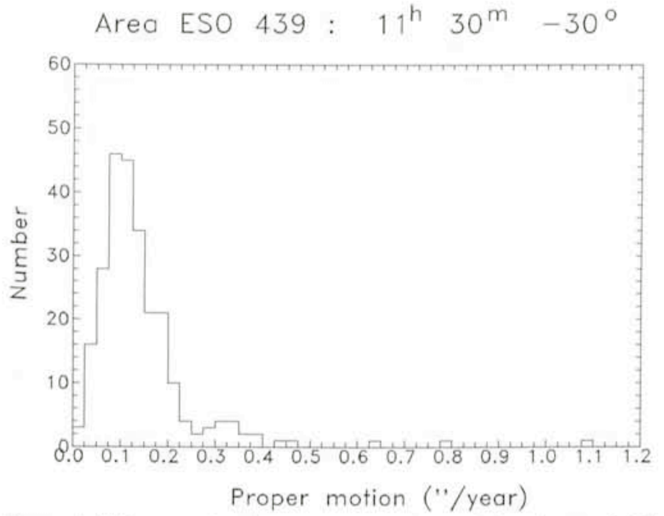


Figure 2: *Histogram showing proper motion stars binned every 0.025 arcsec/year. The apparent magnitudes of the sample are distributed as 21 % with $m_R \leq 15$; 54 % with $15 < m_R \leq 18$ and 25 % fainter than 18th magnitude.*

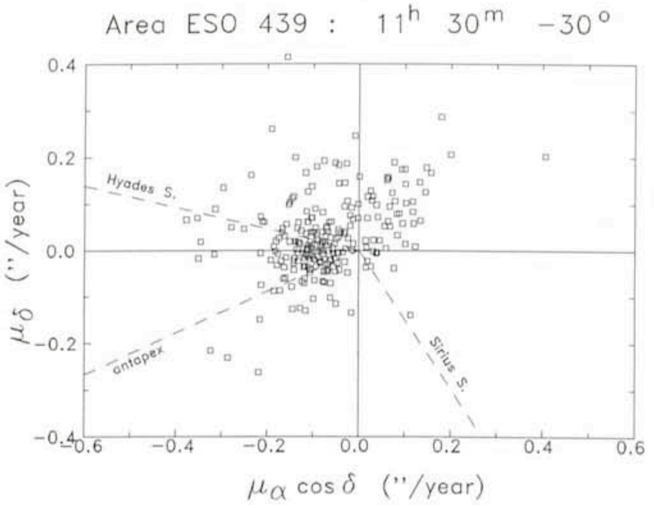


Figure 3: *Same as Figure 1a but showing the proper motions. Drifts' directions due to Hyades and Sirius superclusters and the general drift towards the antapex are indicated.*

with detectable proper motions, including 7 common proper motion pairs. Figure 1a shows the x and y displacements in microns for all the programme stars. Figure 1b shows the same for 168 reference stars used for the whole plate (an average of 18.7 stars per zone). Comparing Figure 1a and 1b, it is clear that this method of detecting and measuring proper motions works for stars with proper motions down to about 0.05 arcsec/year for a time base of 7 years. In Figure 2 we present a histogram of the proper motions in area 439.

Figure 3 shows $\mu_\alpha \cos_\delta$ vs. μ_δ for the proper motion stars in area ESO 439. The direction towards which stars should be drifting if they were members of the Hyades Supercluster, the Sirius Supercluster and the general drift towards the antapex are indicated. There seems to be a large proportion of stars with proper motions compatible with membership in the Hyades Supercluster or sharing the general drift towards the antapex. Only one star might belong to the Sirius Supercluster in area 439.

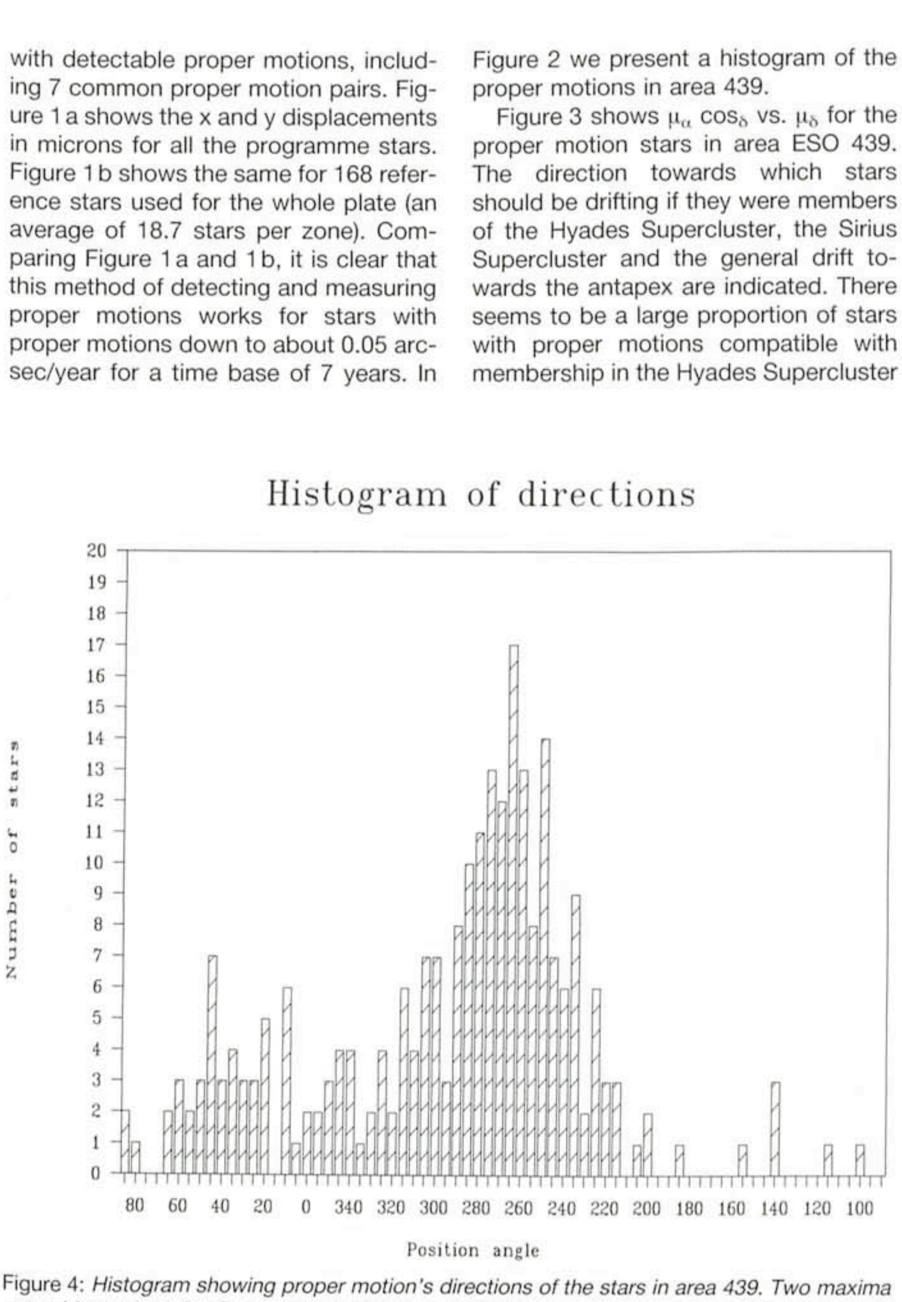
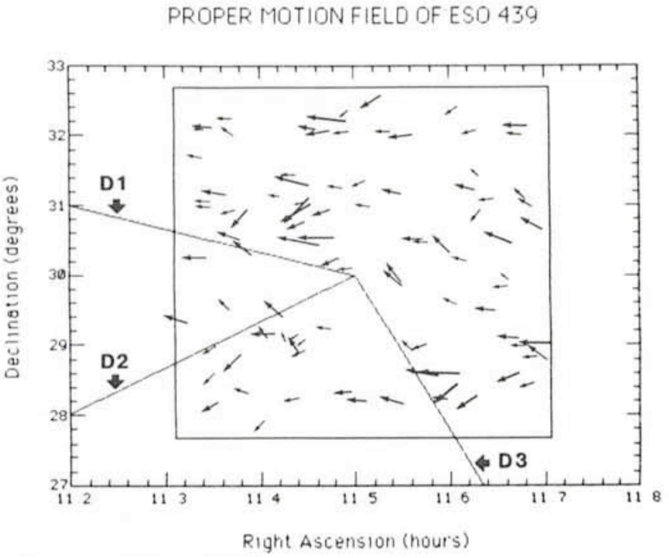


Figure 4: *Histogram showing proper motion's directions of the stars in area 439. Two maxima are evident centred at P.A. = 268° and P.A. = 38° (P.A. is measured from north through east).*

From Figure 3, it is clear that the stars in area 439 do not have random motions; instead, they seem to be oriented towards certain directions. This is even more evident from Figure 4, where the motion's directions (position angles) distribution is shown. The histogram has two peaks: the main one is centred at P.A. = 268°, and contains members of the Hyades Supercluster and stars reflecting the solar motion (drifting towards the antapex); in addition, a second maximum at P.A. = 38° is clearly evident. The lack of stars moving towards directions between 100° and 200° is striking. In Figures 5a and 5b the two main streams (at 268° and 38°) are graphically shown. The size of the arrows is approximately proportional to the proper motions.

It has been suggested (Elmegreen, 1983) that in the galactic plane molecular clouds with low mass cores could be the sites of a very efficient star forming process, giving birth preferentially to low mass stars which quietly evolve while remaining gravitationally bound as a group. This prediction has not been supported by observations. Very few groups of this kind have been found, partly due to the intrinsic faintness of low mass stars. This makes their observations difficult unless they are nearby, in which case any such group will extend over a large fraction of the sky and would not be easily identified as a star cluster.

The star stream at 38° found in area 439, might be one of these low mass stars aggregates. This idea is supported by the fact that stars belonging to this stream show a flatter μ distribution be-



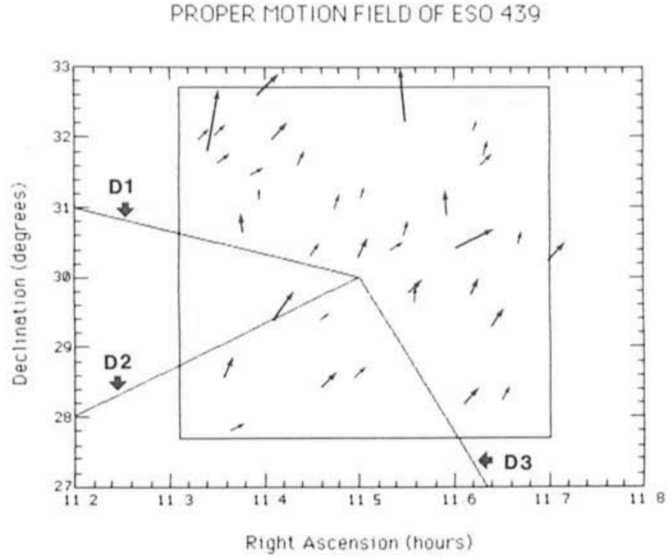


Figure 5a: *Proper motions of stars in area ESO 439 with directions centred around P.A. = 268°. D1, D2 and D3 correspond to the directions of the Hyades supercluster, antapex and Sirius supercluster drifts. It is clear that the stars shown are either members of the Hyades S. or are drifting towards the antapex. The size of the arrows is approximately proportional to the proper motions.*

Figure 5b: *Same as Figure 5a for stars in the 38° stream.*

tween 0.100 and 0.200 arcsec/year, with very few stars with μ between 0.085 and 0.100 arcsec/year where the maximum number of stars is found for the complete sample shown in Figure 2. This suggests that stars belonging to the 38° stream occupy a small volume in space with dimensions equal to about half the distance to the group. The typical magnitude of these stars is m(R) = 18.

4. ESO 439: The Spectrophotometric Follow-up

Low resolution spectra of the stars in area 439 with proper motions larger than 0.3 arcsec/year have been obtained at the CTIO 4-m telescope using a 2D Frutti detector and at the La Silla 3.6-m telescope with the EFOSC. As a result we found that from a total of 13 stars with $\mu > 0.3$ arcsec/year and $10 < m(R) < 21$ in area 439, eight are M dwarfs, one is a possible DA white dwarf and the other four stars are low luminosity degenerates with $M(V) > +15$.

As an example of the interesting objects found in this plate, we present in Figure 6 the spectra, obtained at La Silla in March 1988, using the 3.6-m telescope with EFOSC (B 300 grism and the RCA # 3 chip), of a faint common proper motion pair (with $\mu = 0.38$ arcsec/year formed by a cold degenerate (ESO 439-163) and a magnetic white dwarf (ESO 439-162) showing the Swan bands of C_2 broadened by a magnetic field of about 10^8 G. The spectrum of the cold degenerate ESO 439-26 is shown in Figure 7. Its trigonometric parallax, obtained by C. Anguita and M.T. Ruiz using a CCD at the CTIO 1.5-m telescope, is $\Pi = 0\farcs0240$ (with $\mu = 0.397$ arcsec/year), placing the star at a distance of 41.7 pc. Considering that the apparent visual magnitude of this star is ≈ 20, and that the bolometric correction for it should be B.C. ≤ 1, the luminosity of ESO 439-26 turns out to be $L \approx 3 \times 10^{-5} L_{\odot}$ (with $M_{bol} \approx 16$). Faint degenerates like ESO 439-26 have escaped detection in spectroscopic surveys of proper motion stars, and so far only a handful of them have been found. The importance of finding out the frequency of these objects in the solar neighbourhood is crucial when trying to account for the missing mass, given that they are massive objects, that is, they have masses of the order of 1 $M_{\odot}$, compared to less than 0.1 $M_{\odot}$ for M dwarfs and brown dwarfs of similar luminosities; relatively few cold degenerates are needed to acount for the missing mass in the solar neighbourhood.

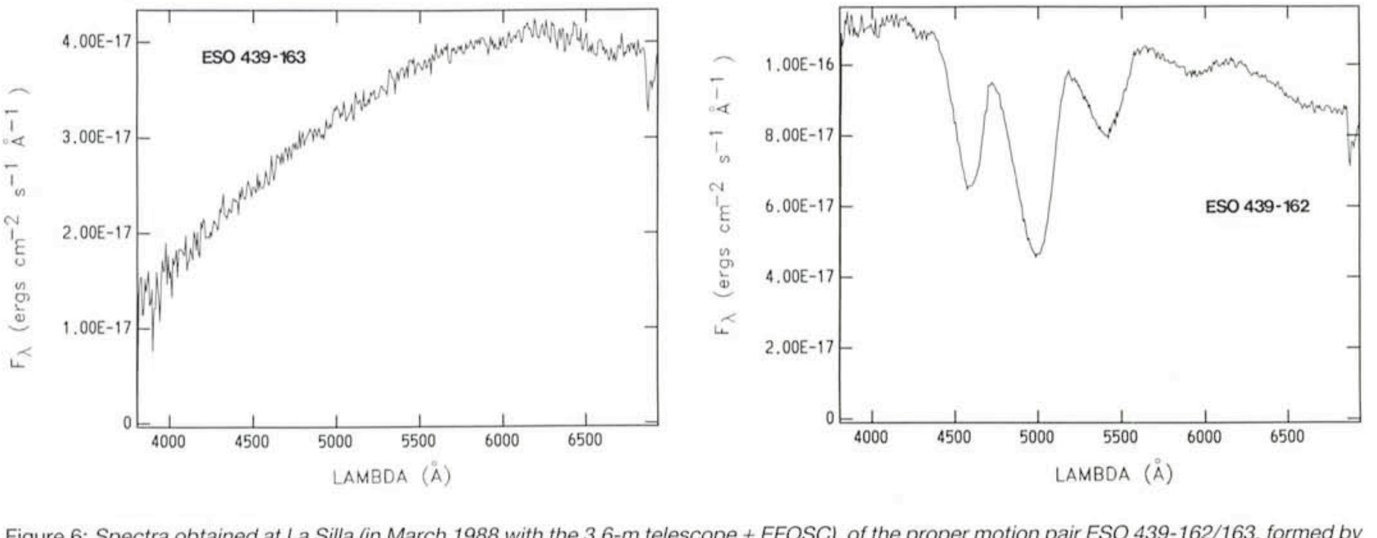


Figure 6: *Spectra obtained at La Silla (in March 1988 with the 3.6-m telescope + EFOSC), of the proper motion pair ESO 439-162/163, formed by a cold degenerate (439-163) and a magnetic WD (439-162) that shows the Swan bands of C_2 broadened by a magnetic field of about 10^8 G.*

In ESO area 439 we have found 4 low luminosity degenerates, that is 30% of the stars between $10 \leq m \leq 21$ and $\mu \geq 0.3$ arcsec/year) belong to this group. If this holds true for the whole sky, we then estimate that the missing mass might be accounted for by these faint objects.

Acknowledgements

We would like to thank Dr. R. West for kindly sending us glass copies of the ESO R plates. This research received partial support from FONDECYT grant # 359/87-88.

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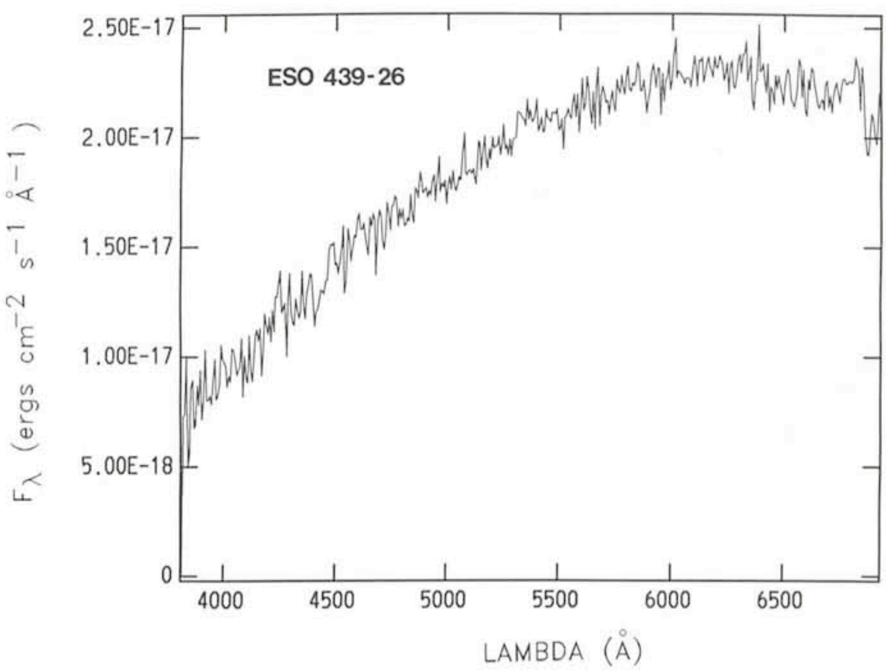

Figure 7: *Spectrum of the cold degenerate ESO 439-26. At a distance of 41.7 pc (measured by trigonometric parallax) its luminosity is $L \approx 3 \times 10^{-5} L_\odot$.*

A Search for Magnetic Fields in Blue Stragglers of M 67

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Introduction

Blue stragglers (hereafter BS) are members of star clusters whose location in the HR-diagram of the cluster is beyond the turnoff point, in the vicinity of the zero age main sequence (ZAMS). The existence of these stars appears to be in contradiction with the current views about the formation of star clusters and the stellar evolution. Namely, if all the stars belonging to a cluster have formed contemporaneously, standard evolution theory does not predict the presence of stars in the region of the HR-diagram where BS are found.

Various tentative explanations of the BS phenomenon have been put forward. The most popular ones are that BS:

(i) have formed later than the rest of the cluster,

(ii) result from mass exchange in close binaries, with the consequence that the former secondary component of the pair has moved up the main sequence,

(iii) are coalesced stars (an extreme case of mass transfer),

(iv) are stars undergoing quasi-homogeneous evolution.

The latter hypothesis can be intuitively understood as follows: if mixing takes place inside a star, part of the processed material in the core is moved up to outer layers and is replaced in the central stellar regions by unprocessed material, so that core hydrogen burning can last longer and main sequence lifetime is accordingly extended. Recent detailed modelling carried out by Maeder (1987) actually shows that, at least for massive stars, a star that undergoes internal mixing, rather than evolving along the standard redwards track in the HR-diagram, would as it ages raise bluewards near the ZAMS, and would thus be observed as a BS.

The main observable manifestation of quasi-homogeneous evolution, apart from the BS nature of the star, is expected to be the appearance of nuclear processed material from the core on the stellar surface. More precisely, the abundances of carbon and nitrogen determined from the analysis of the stellar spectrum should markedly differ from the standard main sequence abundances of these elements and be characteristic of the CN-equilibrium in the CNO cycle of hydrogen burning. On the other hand, the triggering agent responsible for the mixing of the stellar interior could possibly als reveal itself to observation. Internal mixing of a star could for instance be induced by turbulent diffusion resulting from rapid rotation or from tidal forces in binaries, or could be produced by magnetic buoyancy.

The BS of M 67

In order to get a new insight into the nature of BS, I initiated a programme of observations of the BS of M 67, with the aim of testing the hypothesis that they are quasi-homogeneously evolved stars.

M 67 (= NGC 2682) is one of the oldest galactic clusters known (with an age of 3.5 10^9 yr), and one of those having the richest BS populations. A colour-magnitude diagram of M 67 is shown in Figure 1, which was kindly provided by J.-C. Mermilliod. V is plotted against B-V for all the stars having a membership probability higher than 80% and $V < 16$ for which Mermilliod has been able to compute average photometric parameters from measurements found in the literature. The BS, represented by filled squares, are easily distinguished. Their spectral types range from late B to early F; most of them are thus A-type stars.

The main goal of the observing programme is to determine the abundances of C, N and O in the BS of M 67 in order to see whether they have standard main

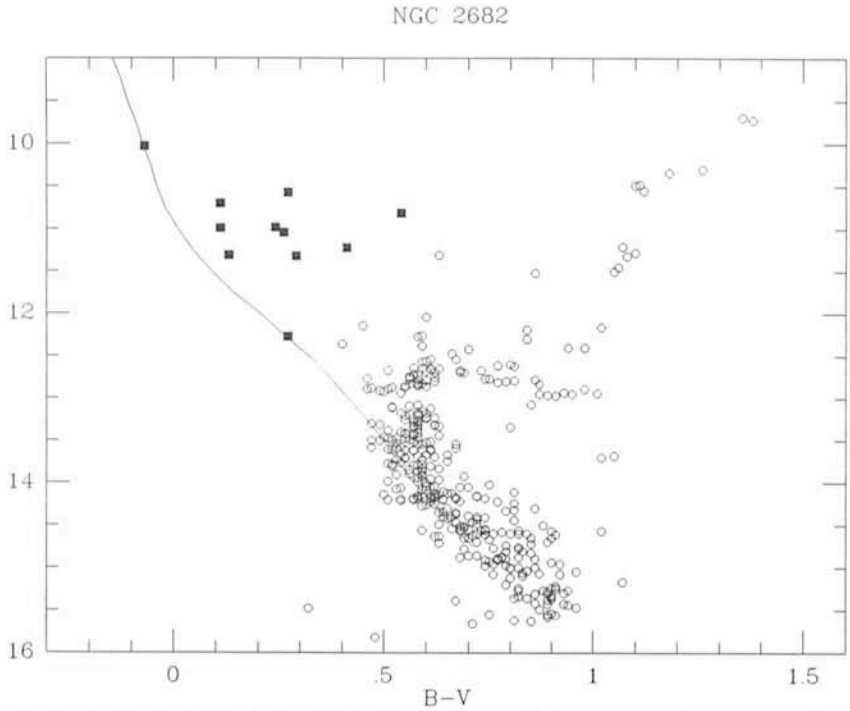

Figure 1: (B–V, V) *diagram of the open cluster M 67. All the stars with a membership probability greater than 80% and V < 16 for which Mermilliod has been able to compute average photometric parameters from measurements found in the literature have been included. The eleven BS are represented by filled squares. The ZAMS is also plotted.*

sequence values or, rather, values characteristic of CN-equilibrium. In addition, it was decided to look for evidence of the presence of two agents that could be responsible for a possible mixing of the stellar interior, namely rapid rotation (from the determination of *v* sin *i*) and magnetic field. Here I present a preliminary report about the latter point, the first one to have been completed within the frame of this project.

Observations

The observations were carried out in January 1988 with the 3.6-m telescope and the CASPEC. The choice of the instrumentation was dictated by the need for observing lines of C, N and O, which in A-type stars mostly are found in the red portion of the spectrum and are weak (with typical equivalent widths of the order of 50 mÅ or less) making it necessary to obtain spectra of fairly high resolution and S/N ratio. Using the CASPEC furthermore had the advantage that, due to the availability of a Zeeman analyzer as a standard option of this instrument, it was possible to look for magnetic fields in the studied stars at little extra cost. With the Zeeman analyzer one simultaneously records the stellar spectrum in right and left circularly polarized light. The difference between both polarizations yields information about the magnetic field, while their sum gives back the full intensity spectrum as it would be obtained in the standard mode, without the Zeeman analyser.

The 11 BS of M 67, as shown in Figure 1, were first observed in the spectral range 6900–7900 Å, which is the most interesting one as far as the primary goal of this study, the determination of the C, N, O abundances, is concerned. The CASPEC was used in its standard configuration, with the 32 lines/mm^{-1} échelle grating. The spectra obtained that way were used to select those stars in the sample whose lines were sharp enough to be observed with the Zeeman analyzer in an attempt to evidence a magnetic field. Four stars proved to be suitable for such a study; they are listed in Table 1. These four BS were observed in the spectral range 5300–6250 Å, with the Zeeman analyzer. The 52 lines/mm^{-1} échelle grating had to be used in order to avoid the overlapping of adjacent orders due to their splitting by the Zeeman analyzer (see Mathys and Stenflo, 1986, for more details). With this grating, in the considered spectral region, there are gaps in the wavelength coverage between adjacent orders (portions of up to 15 Å of the spectrum are missing); fortunately, none of the lines of interest of C, N or O lies in these gaps. The remaining 7 BS were observed in the same spectral range without the Zeeman analyzer, but otherwise with the same instrumental configuration.

TABLE 1. *The four sharpest-lined BS of M 67*

Star*	V	B–V
F 131	11.22	0.42
F 153	11.31	0.13
F 185	11.04	0.26
F 238	10.57	0.27

* Fagerholm number

The four spectra obtained with the Zeeman analyzer will be discussed in the rest of this paper. The journal of observations is given in Table 2. Each spectrum is the average of three exposures that have been consecutively taken and from which the "cosmic ray" spikes have been removed as much as possible through intercomparison prior to taking the average. The reduction was performed within MIDAS, using procedures that have been specifically written to deal with spectra obtained with the CASPEC and Zeeman analyzer. Great care was taken in the wavelength calibration step, and the normalization of the spectral orders to the continuum was performed by an automatic routine so that it is as objective and uniform as possible. More details about the reduction will be given in a forthcoming paper. The final spectra have a S/N ratio $\gtrsim 70$ in the continuum, in each polarization. A sample plot of them is shown in Figure 2.

Results and Discussion

Before discussing the results of the present observations, it should be pointed out that the hypothesis that BS are related to the presence of a magnetic field receives some indirect support from a number of observational evidences, at least for BS in intermediate-age clusters, from $10^{8.3}$ to 10^9 years old (see Abt, 1985, for more details). Indeed, it is noticeable that a significant fraction of the BS in these clusters are Ap stars, of the Si and Sr-Cr-Eu varieties. It has even been suggested that all the BS in the considered age range

TABLE 2. *Journal of observations*

Mid-observation time (HJD)	Exposure duration (min)	Star
2447189.601	60	F 131
2447189.655	60	F 153
2447189.703	60	F 185
2447189.751	60	F 238

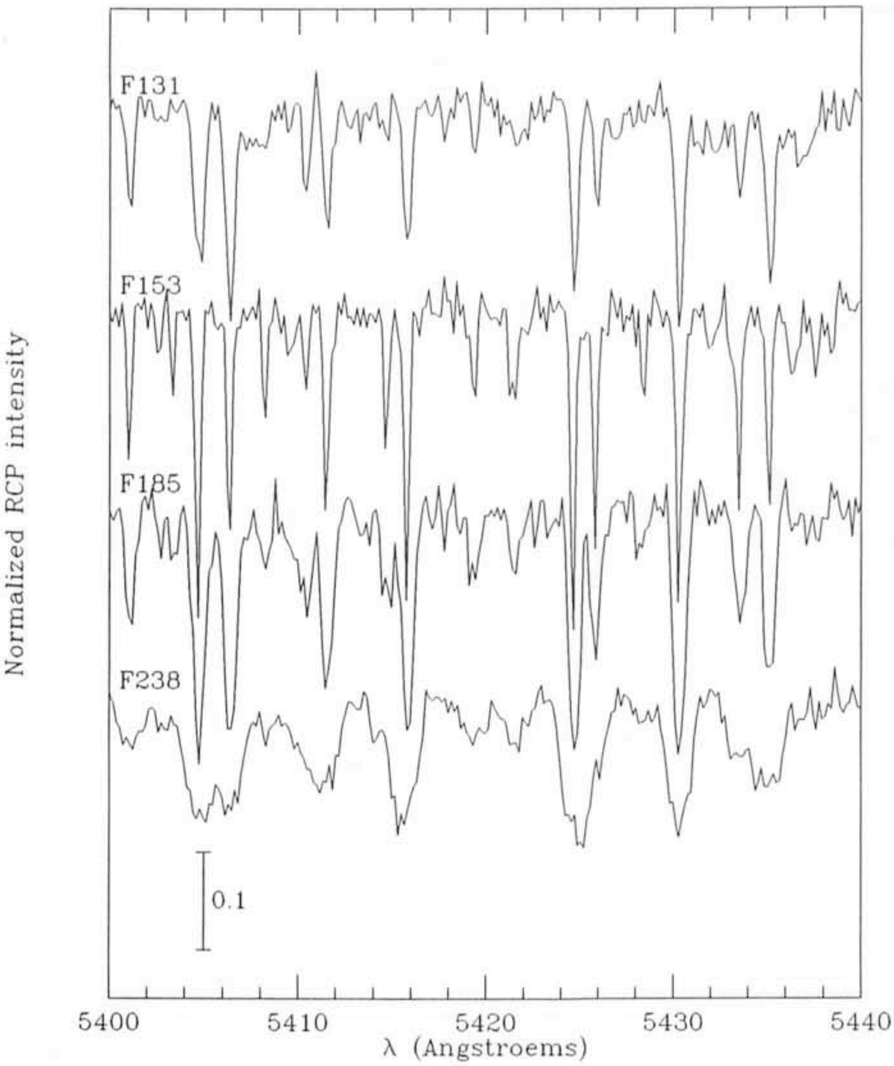

Figure 2: *Part of the spectrum of the four BS where magnetic fields have been looked for, as recorded in right circularly polarized (RCP) light with the Zeeman analyzer of the CASPEC. It can be noticed that, due to the faster rotation of F 238 and the related line blending, there are considerably fewer lines suitable to search for a magnetic field in the spectrum of this star than for the other three stars.*

are Ap stars (Pendl and Seggewiss, 1976). Ap stars are the only nondegenerate stars definitely known to possess a magnetic field with a large-scale organization, which is detectable by the observation of circular polarization inside spectral lines. The order of magnitude of this magnetic field is a few kG; the measured field of most Ap stars varies periodically due to the changing aspect of the visible stellar hemisphere resulting from stellar rotation. On the other hand, it has recently been discovered that several A-type BS have a flux deficiency between 1200 and 2000 Å similar to that observed in Ap Si stars and possibly related to the presence of a magnetic field in the latter (Durán and Graziati, 1986). It thus appeared to be worthwhile to attempt a direct detection of a magnetic field, more exactly of a large-scale organized magnetic field (see below), in some A-type BS.

Stellar magnetic fields can be diagnosed by taking advantage of the Zeeman effect that they induce in spectral lines. The most convenient approach is to measure the shift between the wavelength of a line as recorded in right circular polarization, λ_R, and the wavelength of the same line as recorded in left circular polarization, λ_L. This shift can in a first approximation be expressed as:

$$\lambda_R - \lambda_L = k\bar{g}\lambda_0^2 H_z,$$

where λ_0 is the nominal wavelength of the line and $\bar{g}$ is its effective Landé factor, an atomic parameter which characterizes the sensitivity of the line to a magnetic field. H_z is the average over the visible stellar disk of the component of the magnetic vector along the line of sight, suitably weighted to account for the different relative contribution of the various regions of the stellar surface to the observed lines. H_z is called the mean longitudinal magnetic field or, less precisely, the effective magnetic field. k is a constant, whose numerical value is 9.34 10^{-13} Å^{-1}.G^{-1}. It can be seen that the wavelength shift $\lambda_R - \lambda_L$ is usually quite small: for a field of 1 kG and a line at λ_0 = 6000 Å having an effective Landé factor $\bar{g}$ = 1.5 (a typical value), one finds $\lambda_R - \lambda_L$ = 0.05 Å. This explains why magnetic fields can only be determined with the described method in stars rotating slowly enough. On the other hand, it must be stressed that the quantity that is measured that way is the average value of the line of sight component of the field vector. Therefore, if the magnetic field has a complex structure, somewhat like the structure of the solar field, with many small regions of the stellar surface covered by fields of opposite polarities and approximately the same strength, there will be no detectable effect in circular polarization recordings of spectral lines averaged over a whole stellar disk. Only if it has a sufficient large-scale organization, so that the contributions of various parts of the stellar surface do not cancel out, will the field be detectable through the considered kind of observations. That is the reason why the Ap stars are the only nondegenerate stars in which magnetic fields have been measured through spectropolarimetry, because their field has a unique large-scale organization. Stars that are not detected as magnetic from spectropolarimetric observations may nevertheless possess fields of the same order as those of the Ap stars, but with a more complex structure – and some do indeed. Consequently, the present approach is restricted to the search for stellar magnetic fields having a large-scale organization, similar to those of the Ap stars.

I have, to my knowledge, been the only visiting astronomer to this date to have used the Zeeman analyzer of the CASPEC to measure stellar magnetic fields. This instrumentation has never been calibrated with respect to other spectropolarimeters. It is however essential to check the consistency of the magnetic field measurement obtained with the CASPEC Zeeman analyzer against those that have been achieved at other observatories. Such a calibration is currently in progress, within the framework of a more specific programme dedicated to systematic stellar magnetic field measurements, which I am pursuing in collaboration with J. O. Stenflo. This project is not fully completed yet, and the discussion of the performance of the Zeeman analyzer of the CASPEC would anyway be out of the scope of the present paper. I will just mention here that the results obtained up to now indicate that the magnetic field values determined with the Zeeman analyzer of the CASPEC are essentially correct. This is illustrated in Figure 3,

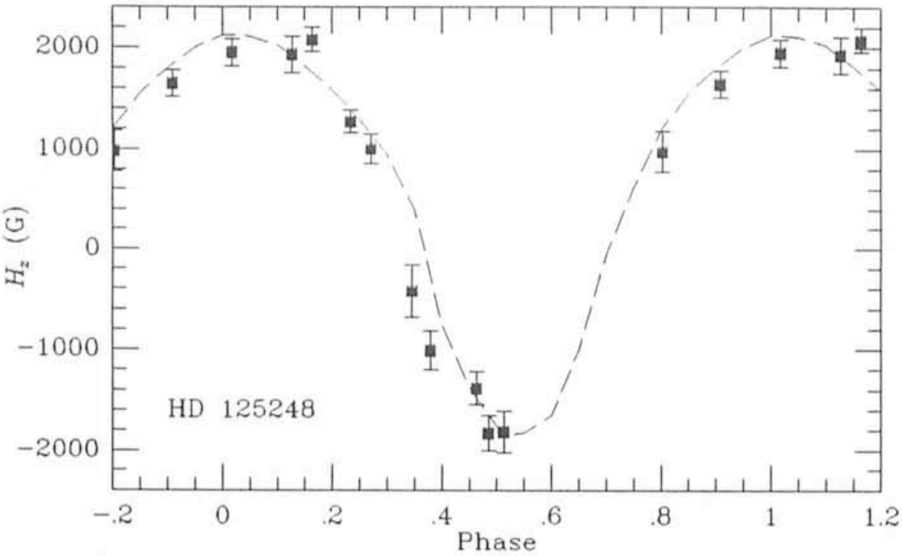

Figure 3: *Comparison of my measurements* (filled squares with error bars) *of the mean longitudinal magnetic field of HD 125248 with the curve of magnetic variation of this star* (dashed curve) *as obtained by Babcock (1960). The abscissa is the rotation phase (see Mathys and Stenflo, 1988, for more details).*

where as an example my measurements of the magnetic field of the A star HD 125248 are plotted together with the curve of magnetic variation for this star that was obtained by Babcock (1960).

The mean longitudinal magnetic field of the four BS observed in this programme is given in Table 3. It was obtained from the measurement of the shift between right and left circularly polarized spectra of the wavelength of FeI lines. The number of such lines used in each case is given in Col. 3 of the table. This number is smaller for stars rotating faster, because only unblended, sufficiently well defined lines can be measured for the present purpose. The values of the field H_z that are given in Col. 2 of Table 3 were obtained by carrying out a linear regression of the measured wavelength shifts $\lambda_R - \lambda_L$ for the lines of the sample, as a function of their respective $\bar{g}\lambda_0^2$. The quoted uncertainties affecting the derived values of H_z correspond to the rms deviation of the $\lambda_R - \lambda_L$ measurements about this regression. They are quite consistent with the random measurement errors in $\lambda_R - \lambda_L$ that are expected from the consideration of the S/N of the spectra and of the depth and width of the measured lines. It can be seen that no large-scale organized magnetic field was detected in any of the four observed BS. This does not mean that none of these stars, taken individually, can have a field like those of the Ap stars. Indeed, as already mentioned, the mean longitudinal field of the Ap stars varies with the rotation period of the star. It cannot be excluded that, observing a star of this type only once, one could unluckily spot a phase where H_z is close to zero, while it becomes much larger at other phases (see the case of HD 125248 in Figure 3, around phases 0.25 and 0.75). However, it would be very unlikely, if all four observed BS had Ap-like magnetic fields, that all of them could have been observed at such an unfavourable phase. Hence it can be inferred that BS in old open clusters do not in general possess large-scale organized magnetic fields similar to those of the Ap stars with strengths in excess of a few hundred gauss.

TABLE 3. *Mean longitudinal magnetic fields*

Star	H_2 (G)	Number of lines
F 131	257 ± 206	19
F 153	− 261 ± 236	20
F 185	− 51 ± 272	14
F 238	748 ± 700	6

In conclusion, large-scale organized, strong magnetic fields do not appear to be responsible for the BS phenomenon in old open clusters, or at least all BS in such clusters cannot be explained by the presence of such fields. This, of course, does not rule out the interpretation that BS are quasi-homogeneously evolved stars, since mixing of the stellar interior can be achieved independently of the presence of a large-scale organized magnetic field. This latter point will be tackled through the determination of the C, N, O abundances in the BS of M 67, which is currently in progress. It should finally be mentioned that the programme that has partly been reported in this paper participates in a broader project aiming at setting constraints on the stellar evolution theory through the consideration of the changes in surface abundances of the C, N, O elements along stellar lifetimes.

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Molecular Probes of the Cosmic Background Radiation

P. CRANE, ESO

1. Introduction

In the late 1930's observers at the Mount Wilson observatory using the 100-inch telescope and the Coudé Spectrograph discovered absorption lines of the interstellar molecules CH, CH^+, and CN. In the case of CN, an absorption line from an excited rotational state in addition to the ground rotational state was also seen. In fact, an excitation temperature of about 2.3 K was deduced, but the connection to cosmology and the cosmic background radiation was not realized. The full significance of these observations only became obvious in 1964 when the cosmic background radiation (CBR) was finally discovered using radiometers, and found to have a temperature of about 3.1 K.

Subsequently, several investigators reanalyzed old data, or obtained new data on the interstellar absorption lines of CN as well as of CH and CH^+. This work was well summarized in 1972 by Thaddeus (1972) who emphasized the importance of studying these interstellar molecules in connection with the short wavelength portion of the CBR spectrum. Nevertheless, the subject lay dormant for several years until modern electronic detectors permitted about a factor of 10 increase in the precision with which these absorption lines could be measured.

Studying the intensity of the CBR at different wavelengths allows us to probe the thermal history of the Universe back to redshifts of about 1,000, or, in more prosaic terms, to times before the formation of stars and galaxies. Intensities in the short wavelength region of the CBR are particularly interesting since it is here that departures from a pure blackbody spectrum due to energetic events in the early Universe might first become evident. Figure 1 shows a 2.79 K blackbody spectrum, and indicates several recent measurements.

Interstellar molecules permit us to study the intensity or equivalently the temperature of the CBR at specific wavelengths determined by the separation of the rotational levels of the particular molecule involved (see Fig. 2). For CN, these wavelengths are 2.64 mm and 1.32 mm. For CH, this is 0.56 mm. All that is required is that an interstellar cloud containing the molecules lie along the line of sight to a star. If the star is bright enough and of the correct type so that the stellar continuum can be precisely determined, then the molecular absorption lines will show up prominently (see Fig. 3).

This technique for determining the CBR temperature is particularly simple and free from major systematic corrections that could give false answers. The relative intensities of visible absorption lines, representing electronic transitions of the molecule, give a direct measurement of the populations of the rotational states. For the stars we have studied, it is a very good assumption that the CN molecule is in thermal equilibrium with the CBR, and therefore the CBR temperature can be determined from the Boltzmann equation.

$$\frac{N_u}{N_l} = exp(- \frac{hc}{\lambda k T_{exc}})$$

where N_u is the upper state population, and N_l is the lower state population. λ is the wavelength of the rotational line splitting and T_{exc} is the CBR temperature.

In order to make a 1 % determination of T_{CBR}, it is necessary to test the assumption that CN is in thermal equilibrium with the CBR or, in other words, to show that $T_{exc} = T_{CBR}$ to better than 1 %. Also, the ratio N_u/N_l must be measured with the necessary precision. This requires that the observed absorption line strengths be corrected for saturation effects. (This is basically a correction for the fact the molecules on the near side of a molecular cloud see less radiation at the appropriate wavelength because molecules on the far side have already absorbed it.)

Two groups have recently taken up this approach to measuring the CBR temperature. One group headed by David Meyer at Northwestern University has used primarily the Lick Coudé. The other group at ESO has used the ESO 1.4-m CAT telescope and the Coudé Echelle Spectrograph. This group includes in addition to the author, N. Mandolesi (Bologna), E. Palazzi (Bologna), D.J. Hegyi (Ann Arbor), M. Kutner (RPI, Troy), J.C. Blades (STScI, Baltimore), and A.C. Danks (ARC, Landover). In the

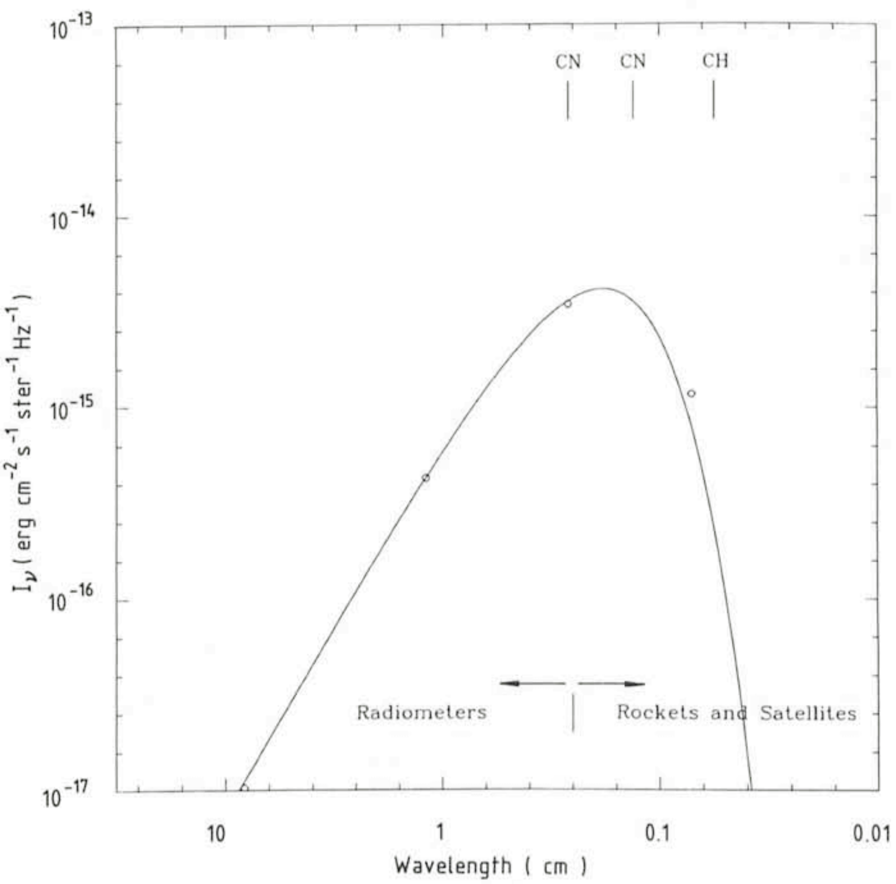

Figure 1: *2.79 K blackbody spectrum. The positions of the CN and CH lines are indicated. The indicated measurements are from Smoot et al. 1987 and from Matsumoto et al., 1988. The regions where ground based radiometers and rockets and satellite technology are most effective are also indicated.*

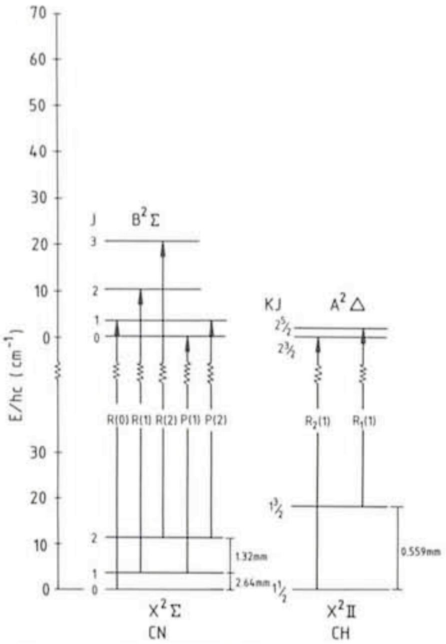

Figure 2: *Term diagram for CN and CH. The vertical lines show the observed optical transitions. The lower horizontal lines represent the various rotational levels and their relative separation in wavelength.*

paragraphs below, the recent work of the ESO group is dicussed.

2. Measurements at 2.64 mm

Previous work published in 1986 (Crane et al., 1986) on the absorption lines of CN toward ζ Ophiuchi yielded a value of T_{CBR} = 2.74 ± 0.05 K. Recent work has aimed at reducing the uncertainty in this measurement. The uncertainty is made up of the three parts: uncertainty in the measurement of the optical absorption lines, uncertainty in the saturation correction, and uncertainty on the extent to which CN is in thermal equilibrium with the CBR. Each element of this uncertainty has been studied in detail, and a value for T_{CBR} with an uncertainty approaching 1% seems to be probable.

Improving the precision of the optical absorption line measurements required developing a new technique for analysing the spectra (Crane and Hegyi, 1988). This procedure gave a much better understanding of the origin of the noise in the data and hence greater faith in applying standard statistical procedures to the results. Currently, the uncertainty in T_{CBR} due to the optical absorption lines is about 19 mK. or 0.7%.

The value of T_{CBR} from the 1986 result contained a correction due to local excitation processes in the interstellar cloud,

$$T_{corr} = -0.060 \pm 0.040 \text{ K}$$

This was based on a theoretical calculation of collisional excitation of CN by electrons, and an estimate of the electron density in the cloud. However, if the CN is not in thermal equilibrium with the CBR, then it would be expected to emit radiation at 2.64 mm. Thus it is possible to measure the correction to T_{CBR} directly rather than to depend on an estimate. We have made such a direct measurement, and find that the correction must be less than 30 mK. This translates into an uncertainty of at most 0.6% in T_{CBR}.

In the previous work, we quoted the formal uncertainty in the saturation correction to be 3 mK, but this was based on the assumption that the CN was contained in a single cloud with a gaussian velocity distribution of 0.88 ± 0.02 km s^{-1}. We have reviewed that assumption in the light of recent high resolution CO spectra of this interstellar cloud that show several clouds with small velocity dispersions and which are possibly consistent with the optical measurements. It appears that even the most extreme assumptions concerning the cloud model used to determine the saturation corrections cannot add more than 15 mK to the uncertainty in T_{CBR}. Since the various sources of error add in quadrature, the goal of a 1% measurement of the CBR temperature using the CN molecule seems to be within reach.

3. Measurements at 1.32 mm

The determination of the CBR temperature at 1.32 mm using CN is considerably more difficult than at 2.64 mm because the corresponding absorption lines are considerably weaker in the direction of ζ Oph. However, other stars with more CN along the line of sight can be used if we are willing to concentrate on the 1.32 mm determination. One such star is HD 154368 which was originally observed by Blades (1978) to have large molecular column densities.

We have reobserved this star at the CAT using the short camera plus the CCD. Analysis of the data is still in progress, but preliminary results indicate that a value of T_{CBR} at 1.32 mm with an uncertainty of 10 mK or maybe slightly smaller will be possible. This is more than a factor of two improvement over our result at 1.32 mm from the ζ Oph data. However, since the R(0) line needed to determine T_{CBR} at 2.64 mm is so heavily saturated in this star, we cannot determine a precise value for T_{CBR} at 2.64 mm.

Since the CN column density towards HD 154368 is much higher than toward ζ Oph, there is more concern that the CN may be collisionally excited. To test for possible local excitation of CN in this cloud, we have used the new SEST telescope at La Silla to look for CN emission at 2.64 mm from the diffuse cloud in front of the star HD 154368. We did not detect any emission at 2.64 mm and since collisions would be more effective in exciting emission at 2.64 mm than at 1.32 mm, we feel safe that local excitation is not effecting the observed CN temperature at 1.32 mm.

4. Measurements at 0.56 mm

Figure 2 shows that the separation of the first excited rotational level of CH could be used to probe the intensity of the CBR at 0.559 mm. However, as Figure 1 shows, the intensity of the CBR is falling very quickly in this wavelength range and therefore the excitation of the first rotational level is very small compared to that of CN. Nevertheless, in view of a recent rocket measurement (Matsumoto et al., 1988) which showed a large excess intensity in this region, and because of the broad implications for cosmology, it seemed important to try to see if any excess radiation could be detected using the CH molecule.

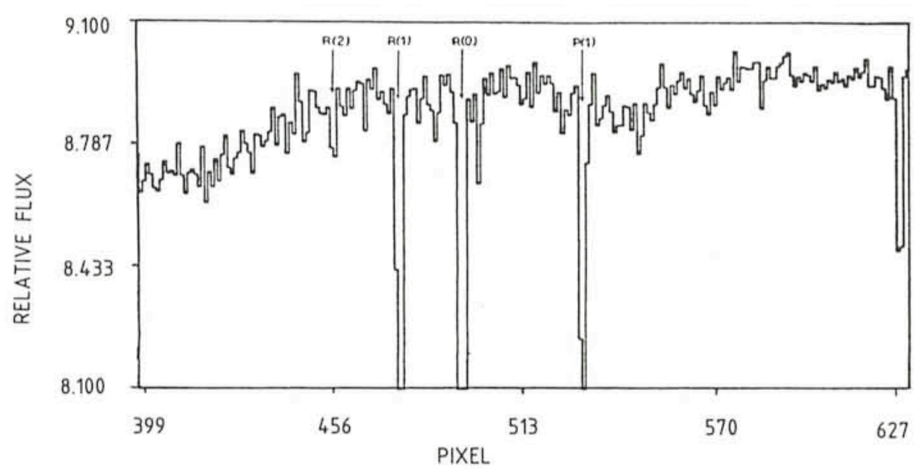

Figure 3: *Spectrum of the star HD 154368 showing the absorption lines R(1), R(0), P(1), and R(2). The ratio of the strength of P(1) or R(1) to R(0) is a measure of the ratio* N_u/N_l *discussed in the text.*

In pursuing this project, we have recently observed ζ Oph using the new combination of the long camera and the CCD detector. Although ζ Oph is quite bright, and the column density of CH is quite high the equivalent width of the CH $R_1(1)$ line is expected to be only about 0.005 mA. Using a spectral resolution of 150,000, such a line would require a signal-to-noise in the stellar continuum of 10,000 : 1 for a 2 standard deviation detection. Needless to say, this is a very difficult project and the results will depend critically on the details of CCD performance.

Even if we don't detect the line, we feel confident that we can provide a useful upper limit on T_{CBR} at 0.559 mm that will serve to constrain the models for the thermal history of the Universe.

5. The Future

Future work on determining the CBR temperature using interstellar molecules will focus on reducing the uncertainty at 1.32 mm and on finding other lines of sight where the results at 2.64 mm can be confirmed with equivalent precision. Reducing the uncertainty at 1.32 mm can be achieved either by continuing to work on the CN lines toward HD 154368, or by working on another, as yet, undetermined line of sight. Finding new lines of sight in which to study the CBR temperature has been one of the ESO group's objectives in the last few years. So far, about 20 stars have been surveyed and several good candidates have been identified. Unfortunately, the ideal candidate has yet to be found.

Although cosmological theory assumes that the CBR is ubiquitous, the only direct evidence we have that it does not have a local origin is through molecular temperature determinations. These show that the CBR is similar to what we see locally out to distances of roughly 200 parsecs. A confirmation of the universal nature of the CBR on a much larger scale would provide further confidence in our cosmological models. This, however, is a project for the VLT and an appropriate spectrograph, since the stars required being further away will be considerably fainter than those studied to date.

On a very different front, if all goes according to plan, the NASA sponsored Cosmic Background Explorer satellite (COBE) should be launched by June 1989. This satellite should provide very accurate measurements of the CBR spectrum from 0.1 to 10 mm. Although COBE will very likely provide definitive data on this problem, the most accurate measurements possible by other means will still be needed to confirm the satellite results.

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The Abundance of Manganese in Halo Stars

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1. Introduction

The chemical composition of halo stars provides primary data about the nucleosynthesis processes that built up the metals present in young stars and in the interstellar medium. Theoretical information about the basic mechanisms of metal production are rather scarce. We know that only a tiny amount of metals was produced during the Big Bang; and we think that most of the heavy elements presently observed were manufactured in massive stars, or in intermediate-mass binaries, exploding as supernovae. However, the relative role of type I und type II (and/or type IIb) supernovae is quite unknown. Furthermore, we do not know precisely the composition of the ejecta of such supernovae. Therefore, empirical data are still at the basis of an interpretation of the chemical evolution of our Galaxy.

Considerable progress has been made in the last years in establishing clear runs of the ratios among the abundances of different elements with overall metallicity, as it is testified by a number of recent reviews (Spite and Spite, 1985; Sneden, 1985; Lambert, 1987; Gustafsson, 1988). This progress was mainly made thanks to the advent of arrays of linear detectors, which allowed very high S/N at high resolution, even for relatively faint stars. ESO has a leading position in this field, mainly thanks to the CES spectrograph at the CAT, and the CASPEC at the 3.6-m telescope. In particular, the combination CAT and CES was at least for five years the most efficient instrumention worldwide for high resolution (> 50,000) spectroscopy. This is most noteworthy since only a rather small telescope is used.

Most of the investigations on the composition of metal poor stars concentrated on the interesting light elements, and on the heavier ones, like Barium and the rare earths. However, Fe-group elements merit a particular inspection, since the presence of an enhanced odd-even effect was first reported by Helfer et al. (1959). The investigation of this enhanced odd-even effect was for a long time hampered by the poor knowledge of the hyperfine structure of lines of elements like Vanadium, Manganese, Cobalt and Copper, which have appreciable nuclear magnetic momenta. However, two papers from the Oxford group (Booth et al., 1983, 1984) provided detailed hyperfine structure and oscillator strengths for quite a large number of Manganese lines. This allowed a preliminary investigation of the abundance of Manganese in 13 metal-poor stars (mainly giants) using blue CASPEC spectra (Gratton, 1988). This investigation showed that Manganese is indeed deficient in metal-poor stars, as originally proposed by Helfer et al. However, the use of the resonance lines, which are located in a crowded spectral region, required a careful consideration of synthetic spectra and of (uncertain) damping parameters. Furthermore,

Erratum

Dust in Early-Type Galaxies. M.P. Véron-Cetty and P. Véron. *The Messenger,* No. 52, June 1988, p. 41.

In Figure 1, the names of two galaxies have been interchanged; the picture of NGC 4526 is labelled NGC 4696, while the picture of NGC 4696 is labelled NGC 4526.

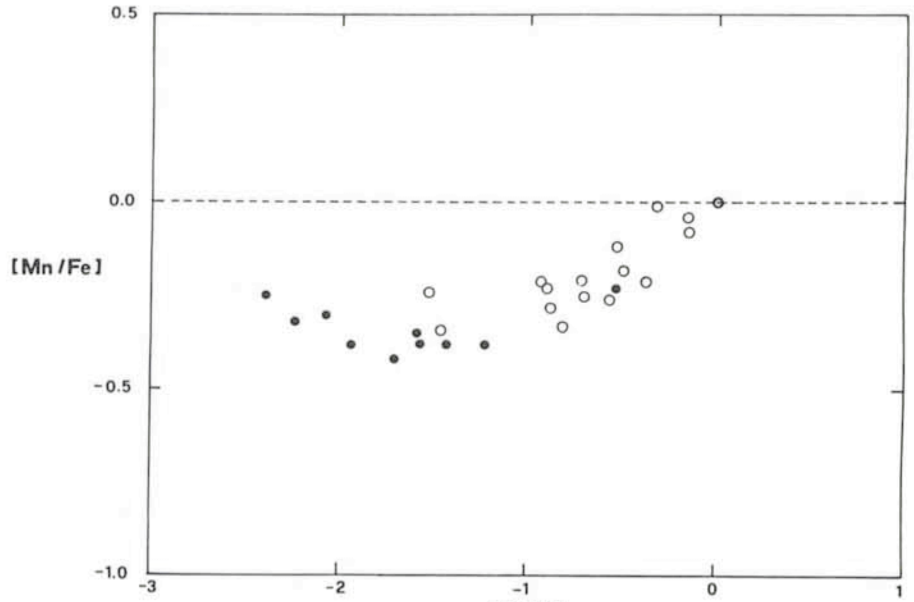

Figure 1: *[Fe/H] vs [Mn/Fe] for field halo stars. Dots are giants, circles are dwarfs. The Sun is also shown.*

there is concern for deviations from LTE for these lines, which form in the very outer layers of the atmospheres of these stars.

I therefore decided to use the best available instrumentation (the short camera at the CES, equipped with a high resolution RCA CCD), to investigate higher excitation transitions of Manganese, which are likely to be less affected by deviations from LTE, and are located in the visual spectral region, where crowding is not a problem at a resolution of 50,000.

2. Observations and Analysis

A very good observing run was made in the second half of October, 1987. I obtained high S/N (> 200), high resolution (~ 60,000) spectra in six spectral regions for 25 metal-poor field stars, most of them fainter than V = 8. The instrument proved easy to use, efficient and reliable: no time was lost due to instrumental failures. Furthermore, the availability of on-line IHAP facilities allowed a complete reduction of the spectra during the same observing nights. Practically, I came back to Rome ten days after my departure with the final list of the equivalent widths on my hands! By mid-November, I had the final abundances.

Details of the abundance analysis are presented in a paper currently in press in *Astronomy and Astrophysics.* They are typical of the investigations of the composition of metal-poor stars. Consideration of the hyperfine structure of Manganese lines is made by means of detailed synthetic spectra. About ten lines due to Manganese were observed in each star; typically, standard deviations of abundances derived from individual lines are less than 0.10 dex.

3. Results

The results are summarized in Figure 1, which displays the run of the abundance ratio between Manganese and Iron, against the Iron abundance, which is a measure of the overall metal abundance. The presence of an enhanced odd-even effect in metal-poor stars is confirmed by the general underabundance of Manganese. Observations suggest that the ratio between Manganese and Iron is constant in the halo ([Fe/H] < −1), at a value of [Mn/Fe] = −0.34 ± 0.06. It then increases for larger metal abundances, up to zero for solar abundances. In the disk, the present results merge with those obtained some years ago by Beynon (1978).

The run of the Manganese to Iron ratio is symmetrical to the run of the Oxygen to Iron ratio (Barbuy, 1988); and to the runs found for even light elements (see e.g. Magain, 1987; and François, 1988). Observations for Oxygen and other even light elements are usually explained as due to the interplay between the timescale for star formation, and the evolution of the progenitors of type II (massive stars) and type I (intermediate mass binaries) supernovae (see e.g. Matteucci, 1988). Within this framework, it is possible to attribute the observed run of the Manganese to Iron ratio to a smaller neutron excess in the region of Si-burning in type-II supernovae, with respect to the neutron excess in analogous regions in type-I supernovae.

4. Globular Clusters

My observations are based on a sample of field halo stars in the solar neighbourhood. Is the run of Figure 1 representative of the entire halo population? Are the conclusions valid also for e.g. globular cluster stars?

To investigate this point, I reexamined a group of about eighty high-dispersion spectra of forty-one globular cluster stars, taken during several observing runs from October 1984 to May 1987, with the CASPEC spectrograph at the

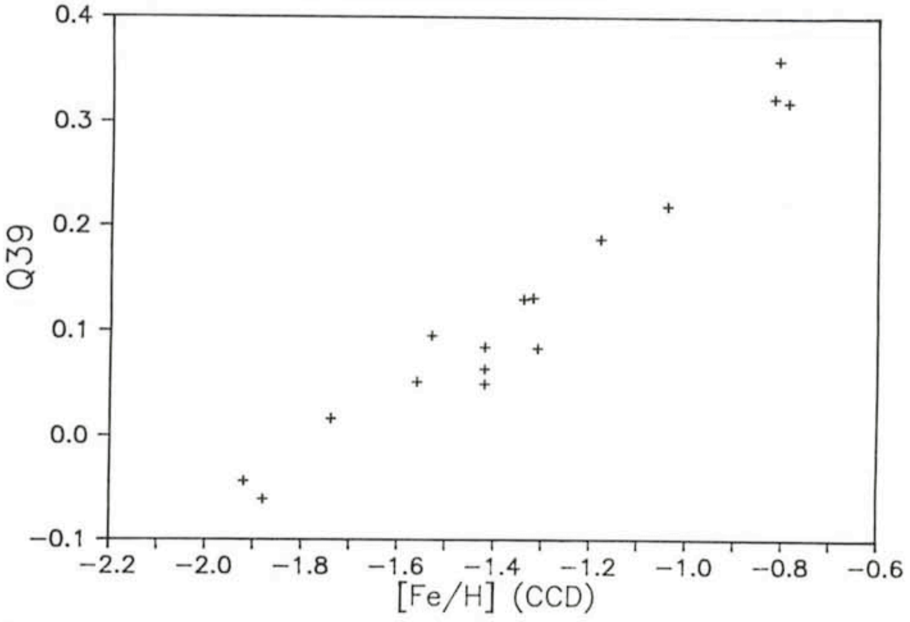

Figure 2: *Comparison between mean Fe abundances obtained from high dispersion CCD spectra and the integrated Q_{39} index (Zinn and West, 1984).*

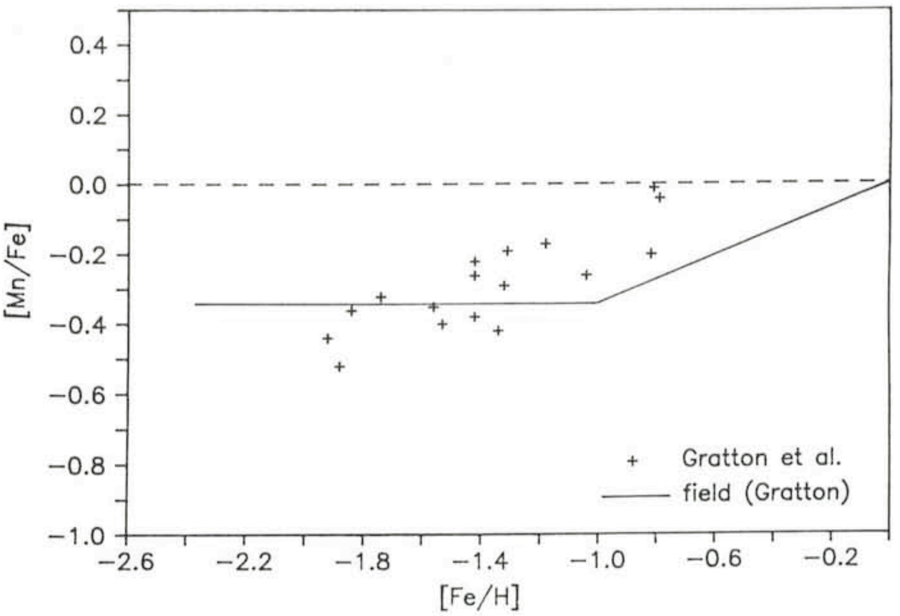

Figure 3: *[Fe/H] vs [Mn/Fe] for globular clusters. The solid line is representative for field halo stars.*

3.6-m telescope on La Silla. These spectra were used to obtain metal abundances which allowed the derivation of a highly accurate metallicity scale for globular clusters. The good correlation existing between metal abundances obtained from these spectra and photometric indices like Q_{39} (Zinn and West, 1984) is shown in Figure 2.

I performed an analysis similar to that made for the field halo stars on these spectra. There are three good Manganese lines, near 6000 Å, in these spectra. Mean abundances for seventeen globular clusters were thus obtained. The results are displayed in Figure 3, which is analogous to Figure 1; each point represents a globular cluster. The mean results for field halo stars are also displayed here. Like field halo stars, also globular cluster stars exhibit an enhanced odd-even effect with respect to population-I stars, approximately by the same amount (~0.3 dex) as field halo stars. However, the results suggest that Manganese is more and more deficient as metallicity drops in globular clusters. If confirmed by more extensive results, this fact suggests a systematic difference in the nucleosynthesis processes in globular clusters and field halo stars.

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Chemistry at High Galactic Latitudes: CH, CH^+ and CN Absorption Lines

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Introduction

The molecular clouds detected at high galactic latitudes by Magnani, Blitz and Mundy (1985) through CO line emission at 2.6 millimetre have attracted a lot of attention. They are particularly interesting because most of them appear to lie within the hot, local ($d \leq 150$ pc) interstellar medium, where they may be condensing out of loops and filaments of atomic hydrogen (Blitz 1988). The clouds can also be characterized by their optical obscuration, and by their emission at 100 μm as seen by IRAS (de Vries and Le Poole 1985; Désert, Bazell and Boulanger 1988).

Although a considerable amount of data has been gathered over the past few years on the global properties and morphology of the clouds, still little is known about the physical and chemical state of individual clouds. Because the high latitude clouds are embedded in a different environment, it is intriguing to ask to what extent they differ from the "classical" diffuse clouds (such as the ζ Oph or ζ Per clouds), or the "classical" dark clouds (such as the Taurus molecular cloud TMC 1 or L 134 N). For example, the high latitude clouds have low visual extinctions, $A_v \approx 1-2$ mag, similar to those of the diffuse clouds that have been studied extensively by optical absorption line observations; yet their strong CO millimetre emission is much more characteristic of that found in dark clouds. Are the abundances of other simple molecules also enhanced in high latitude clouds compared with diffuse clouds? If so, what process is causing this enhancement?

Observations and Results

In order to investigate this question, we proposed to search for molecular absorption lines in Southern high latitude clouds using the Coudé Echelle

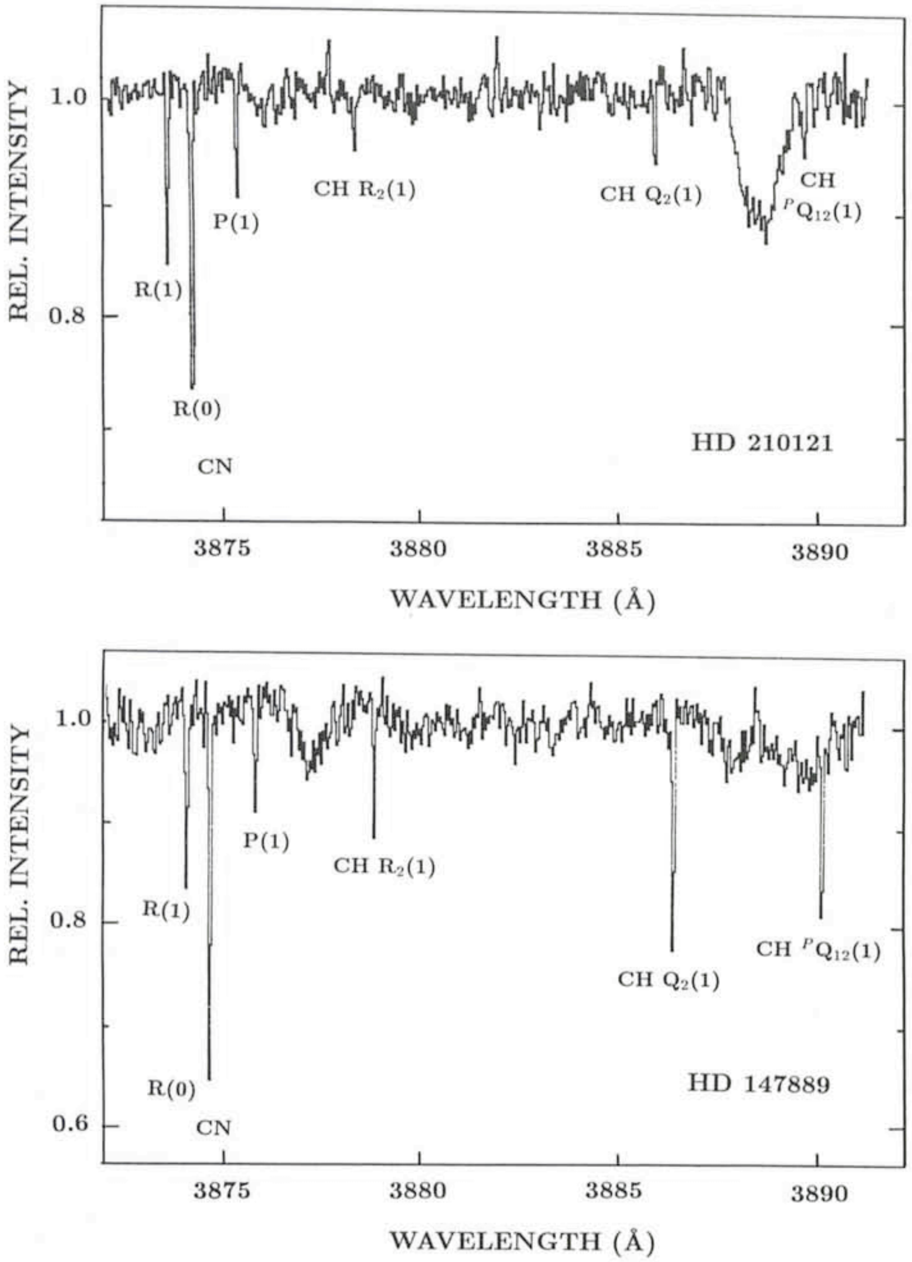

Figure 1: *Absorption spectra of HD 210121 and HD 147889 in the wavelength region of the interstellar CN and CH absorption lines. The line of sight towards HD 210121 passes through a high latitude cloud; that towards HD 147889 through a translucent cloud. The broad depression in the HD 210121 spectrum is the He I 3888 Å line that arises in the atmosphere of the star itself. Differences in relative CN and CH abundances in the two clouds are apparent from these spectra. The individual CN and CH lines are indicated, and for CN, lines arising out of* N = *0 and 1 are detected. In the HD 210121 cloud, the resulting CN excitation temperature* T_{ex} = *2,85 K is consistent with excitation in the 2.7 K cosmic background radiation field only. For the HD 147889 cloud,* $T_{ex} > 3$ *K is found, which suggests that local excitation effects play a role as well.*

Spectrometer (CES) on the ESO CAT telescope. One observational problem is that only few bright, early-type stars are available as background light sources at high latitudes. However, the improved sensitivity of the CCD detector, combined with the high spectral resolution ($\lambda/\Delta\lambda \approx 60{,}000$), makes the CES a uniquely qualified instrument to obtain high quality spectra towards less bright ($V \approx 8-9$ mag), somewhat later-type stars (latest we observed were late A-type). The suitability of the CES for atomic interstellar absorption line observations towards high latitude stars can be seen from the beautiful Na spectra presented by Andreani et al. in the previous issue of the *Messenger*.

The Southern high latitude clouds studied in this work were not taken from the Magnani et al. catalogue, but were chosen on the basis of IRAS 100 μm sky flux maps. Background stars were selected by comparison with the catalogue of stellar identifications (CSI). Eight different clouds with a total of about 40 background stars were selected for observations, which took place in July 1987 and 1988, and December 1987. Because little information is available on the reddening towards the stars, we first looked briefly at the interstellar Na D lines at 5890 Å to obtain an impression of the amount of interstellar matter in front of the stars. Stars which show strong, saturated interstellar Na lines in their spectra with equivalent widths W_λ larger than 100 mÅ clearly lie behind the cloud; stars with weak or no Na Lines lie in front of the cloud. If the distances to the stars are known from photometry, the Na line observations can also be used to place limits on the distances to the clouds (Hobbs et al. 1986; Andreani et al. 1988). Lines of interstellar CH, CH^+ and/or CN were sought towards about 25 stars which had strong interstellar Na absorption. More details of the observations and reduction can be found in de Vries and van Dishoeck (1988).

During our first two observing runs, one of us (CPdV) was present at La Silla; the third run in July 1988 was our first experience with remote observing from Garching. On the whole, we encountered only minor problems due to the fact that we were more than 10,000 km away from the telescope, although the observations were slightly less efficient, because it took a bit more time to point the telescope. We think remote observations are a good alternative for going to La Silla if the observation period is relatively short (a few nights). For longer periods however, remote observing was experienced to be far more exhausting than observing at La Silla because of the weird times you are busy, due to the 6 hours time difference with La Silla. However, we noticed one significant disadvantage in Garching compared with La Silla, namely the food service! Fortunately, *our* integration times were usually long enough to allow us sufficient time to go to Garching in the mornings to shop for our next meal . . .

CH

In the case of CH, we looked primarily for the $A^2\Delta$-$X^2\Pi$ (0,0) band at 4300.3 Å. Lines of interstellar CH with equivalent widths in excess of 1 mÅ were detected in the spectra of about 10 stars. The strongest CH line with $W_\lambda \approx 22$ mÅ was found for the line of sight towards HD 210121, a bright B5–6 V star (V = 7.5; E(B–V) = 0.32; l = 56°.9, b = –44°.5) which is fortuitously located behind the thickest part of a high latitude cloud. The CH measurements are of special importance, because the CH abundance has been found to be well correlated with the H_2 column density in interstellar clouds (Danks et al. 1984; Mattila 1986). They thus allow an independent determination of the H_2 column densities in high latitude clouds, a subject of considerable controversy. Estimates of H_2 column densities from integrated CO millimetre line intensities usually adopt conversion factors that have been calibrated from Giant Molecular Clouds in the Galaxy, and it is not clear a priori that these factors are also appropriate to high latitude clouds. For the cloud in front of HD 210121, four different methods for determining the H_2 content (CH abundance, CO millimetre emission, extinction, and IRAS 100 μm flux) have been compared by de Vries and van Dishoeck (1988). The various estimates suggest that most of the hydrogen is in molecular form in this cloud.

TABLE 1. *Comparison of the HD 210121 cloud with other clouds*

Species	HD 210121	ζ Oph	HD 169454	HD 147889
H_2	(0.6–1.0)(21)	4.2(20)	(1–2)(21)	> 2(21)
H	(1–5)(20)	5.2(20)	≥ 9(19)	—
CH	3.5(13)	2.5(13)	4.6(13)	8.0(13)
CH^+	6.0(12)	2.9(13)	—	3.0(13)
CN	1.4(13)	2.9(12)	5.5(13)	1.5(13)
CO	(0.5–1.5)(16)	2.0(15)	(1–9)(16)	> 1(16)
A_v (mag)	1.0	0.9	3.5	~ 4

Note: The table lists column densities in cm^{-2}. The notation a(b) indicates $a \times 10^b$.

CH^+

Quite surprisingly, the CH^+ ion is not very abundant in high latitude clouds. The CH^+ $A^1\Pi$-$X^1\Sigma^+$ (0,0) line at 4232.5 Å was detected ($W_\lambda > 1$ mÅ) towards only 3 of the 10 stars observed. These observations are interesting because CH^+ is thought to be formed only in shock-heated gas. The fact that the CH^+ abundance is comparatively low suggests that shocks do not play a dominant role in the chemistry in the cloud. This is in contrast with the conclusion of Magnani, Blitz and Wouterloot (1988), who had conjectured that shocks might be important based on large OH and H_2CO abundances found from radio measurements.

CN

During our most recent observing run in July 1988, we also searched for lines of CN in the violet $B^2\Sigma^+$-$X^2\Sigma^+$ system around 3875 Å, where the response of the CCD detector is still good. Strong interstellar lines were detected in the spectra of 4 of the 5 observed stars. Figure 1 shows the observed spectrum towards HD 210121. As a bonus, the spectrum also includes lines of the nearby CH $B^2\Sigma^-$-$X^2\Pi$ (0,0) system around 3890 Å. Although these CH lines are intrinsically weaker than the A-X 4300.3 Å line, they provide an independent check on the inferred column density.

The strongest CN line is the $R(0)$ line, which has an equivalent width of about 25 mÅ towards HD 210121. Unfortunately, this line is strongly saturated, so that the determination of column densities requires some assumption about the velocity spread parameter b in the cloud. One method to obtain an estimate of b is to compare the strengths of the $R(1)$ and $P(1)$ lines, which are also clearly visible in the spectrum. These lines originate in the same lower level $N = 1$ of the molecule, and should therefore give the same column density. For HD 210121, the $R(1)$ and $P(1)$ data are in harmony for $b \approx 1$ km s^{-1}, a value that is consistent with the width of the CO millimetre line towards the star (Knapp et al. 1988). A more powerful method for constraining both the CN column density and the value of b is to compare the CN violet system results with measurements of CN in the red $A^2\Pi$-$X^2\Sigma^+$ (2,0) system around 7900 Å (cf. van Dishoeck and Black 1988*a*; see also the *Messenger* **38,** 16). Searches for the CN red system towards HD 210121 revealed no interstellar lines with $W_\lambda >$ 2 mÅ. This negative result immediately provides an upper limit on the CN column density in the lower $N = 0$ level of 10^{13} cm^{-2}, and suggests that b cannot be smaller than 1 km s^{-1}. Thus also information on the "turbulence" in high latitude clouds can be obtained from these observations, which may provide further insight into their origin.

Once the column density in $N = 0$ is well constrained, the remaining CN data can be used to determine the excitation of the molecule. The observed relative populations in the $N = 0$ and $N = 1$ levels can be characterized by an excitation temperature T_{ex} (1–0) = (2.85 ± 0.25) K. The upper limits on lines out of $N = 2$ result in T_{ex} (2–1) ≤ 4.7 K. Thus the CN excitation in the HD 210121 cloud is controlled by the 2.7 K cosmic background radiation, and local effects play a negligible role. This conclusion, in turn, provides limits on the electron density in the cloud.

Comparison With Other Clouds

How do the CH, CH^+ and CN results for the high latitude clouds compare with those for classical diffuse and dark clouds? Table 1 lists the observed column densities for the HD 210121 cloud together with those for the ζ Oph diffuse cloud. Table 1 also includes the results for two thicker, so-called translucent clouds with visual extinctions of about 3 mag (van Dishoeck and Black 1988*a*). The observed spectrum of the translucent cloud in front of HD 147889 around 3880 Å is reproduced in Figure 1 as well. From this figure, it is clear that the relative abundances of CN and CH differ greatly in the two clouds: the CN lines are about equally strong in the two spectra, but CH is clearly relatively much stronger towards HD 147889 than towards HD 210121. From Table 1, it appears that the CH column density is only slightly larger in the HD 210121 cloud compared with the ζ Oph cloud, whereas the CH^+ column density is even smaller. On the other hand, both CN and CO are more abundant in the high latitude cloud, although their column densities are not yet as large as those found in translucent clouds.

Detailed steady-state models are currently being developed to interpret these findings (van Dishoeck and Black 1988*a, b*). Initial results suggest that the large CO and CN abundances most likely result from the fact that the high latitude clouds are exposed to less intense ultraviolet radiation than clouds in the galactic plane. The relatively low CH abundance is most easily explained if carbon is more depleted onto grains in high latitude clouds compared with diffuse clouds. Finally, as mentioned before, the small amount of CH^+ suggests that shock processes play a less important role in the chemistry of high latitude clouds compared with diffuse or translucent clouds.

In our future absorption line observations, we intend to investigate whether gradients occur in relative abundances across a cloud in cases where we have identified several background stars. Also, we intend to search for millimetre emission of several other molecules to test the chemistry further and to constrain the physical conditions. In summary, a considerable amount of information on the origin and the physical and chemical state of these interesting high latitude clouds can be obtained from combined optical and millimetre observations.

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Evolutionary Features in Distant Clusters of Galaxies

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1. Introduction

The study of distant clusters of galaxies is fascinating and fundamental for a variety of astrophysical problems ranging from the understanding of the evolution of the galaxies as a function of the cosmic time to the comprehension of the large scale structure of the Universe. Relevant contributions on this topic occurred in the recent years, following the pioneering work of Gunn and collaborators (Gunn, Hoessel and Oke, 1986) in the detection of clusters at high redshift, of Butcher and Oemler (1984) in emphasizing possible evolutionary effects present in distant galaxies and of Tinsley (1977) with her theoretical work.

No matter what our goals are, in observational cosmology we are always faced with the problem of using galaxies as tracers of the geometry of space, measuring their position in the sky and estimating their luminosity and distance. This is a relatively simple task if we refer to the nearby region of space, say, at cosmological distances smaller than z = 0.2. Here galaxies are still relatively bright and extended objects and they can be recognized and easily separated from stars. However, as soon as we look deeper in space, attempting to study galaxies located farther away, we start dealing with almost unresolved faint objects and it becomes difficult both to measure redshifts and estimate uncontaminated counts as a function of the magnitude (Fig. 1).

A way around the problem may be to use a combined approach by means of a multicolour photometry (Loh and Spillar, 1986, Rakos, Fiala and Schombert, 1988) properly matched with a set of evolutionary photometric models of galaxies. With this in mind, we started some time ago with a long term project on distant clusters. In this paper we present some of the preliminary results we have obtained; the observations have been carried out at La Silla and the analysis in Milano where, with the help of the ESO staff, we have installed the needed software for the data reduction.

2. Observations

We observed two high redshift clusters taken from the survey published by Gunn, Hoessel and Oke (1986): 2158 + 0351 at a nominal redshift of z = 0.445 and 0020 + 0407 at z = 0.689. The redshifts were taken at their face value and should eventually be confirmed.

A set of CCD frames were collected during two observational runs at the Cassegrain focus of the ESO 3.6-m telescope in November 1986 and November 1987. We used the three-colour Gunn photometric system (Thuan and Gunn, 1976, Wade et al. 1979) and the EFOSC focal reducer.

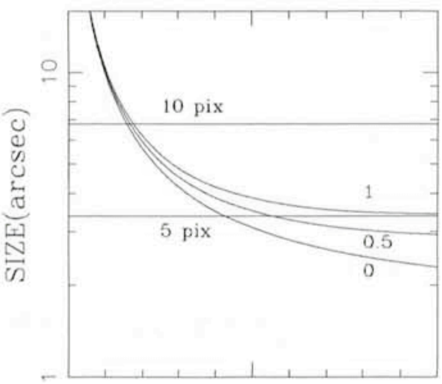

Figure 1: *The apparent size of the galaxies versus redshift. A galaxy size of 25 Kpc and a Hubble constant H_o = 50 are assumed. Each curve is labelled with the value of the deceleration parameter q_o. As a reference also the linear dimensions on our CCD frames are reported (the scale is 0.675 arcsec/pixel).*

The images were reduced using the MIDAS package (see Users Guide, Image Processing Group ESO V 4.3) installed in the reduction facilities of the Observatory of Brera while the detection of the objects in each frame and their photometric measurements have been carried out using the INVENTORY software (West and Kruszewski, 1981) implemented in MIDAS. We are confident that our completeness is down to the magnitude r = 23.5 as it is apparent from a direct inspection of the features detected automatically in the CCD images. The uncertainty in the photometry of the faintest objects detected should be less than ± 0.3 magnitudes (for details see Molinari, 1988).

The two clusters are shown in Figures 2 and 3. These images have been obtained by adding the CCD frames at our disposal in the r band and are equivalent to an integration time of 50 minutes for 2158 + 0351 and 85 minutes for 0020 + 0407. In Figure 4 we have marked all the objects photometered in 2158 + 0351 just as an example of the completeness attained. No serious attempt has been pursued to discriminate between stars and galaxies using the analysis of the photometric gradient of the single features. This is because at such redshifts the galaxies are expected to be essentially seeing limited images and cover only a few pixels on the CCD frame. As shown also in Figure 5, the brightest members of 2158 + 0351 are 8 × 8 pixels wide and obviously the situation gets worse for the more distant cluster. It is because of this and the difficulty to always have subarcsec seeing that we decided to use a statistical approach to the photometric information available (magnitudes and colours).

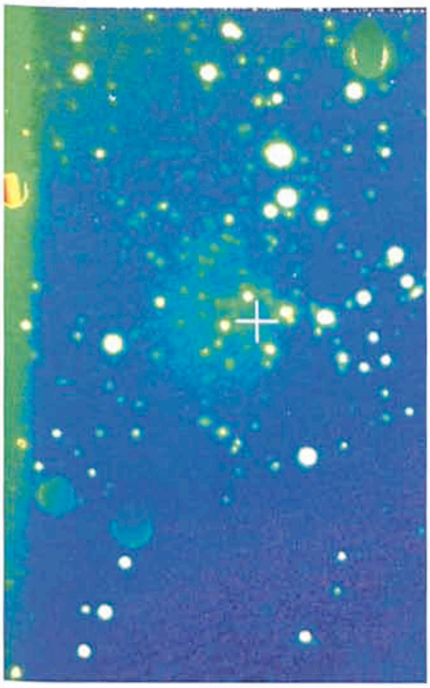

Figure 2: *Composed CCD frame in the r band of the central region (3.5 × 5.7 arcmin) of the cluster 2158 + 0351 at redshift z = 0.445. Cross marks the assumed centre of the cluster (see text for details). North is up, east to the left. (ESO 3.6-m + EFOSC; equivalent exposure time: 50 min.)*

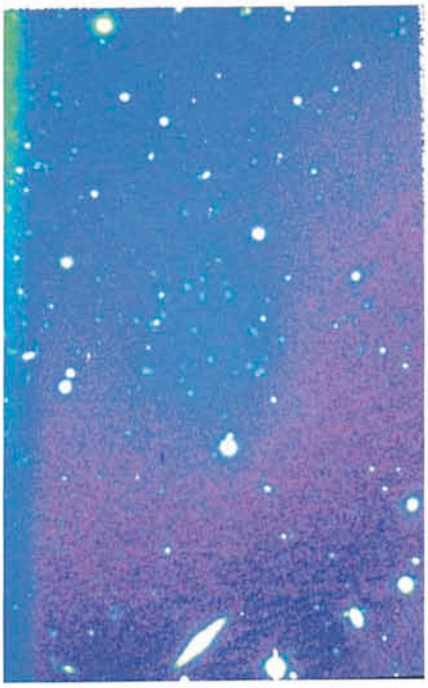

Figure 3: *The same as Figure 2 for the cluster 0020 + 0407 at z = 0.689. The magnitude limit is at least r = 24. (ESO 3.6-m + EFOSC; equivalent exposure time: 85 min.)*

Of course, when possible and at the cost of a large integration time, the analysis must be complemented by spectrophotometric observations.

3. Results

Assuming a $(H_o, q_o) = (50,0)$ cosmology we derive a scale of 0.455 Mpc/arcmin and of 0.561 Mpc/arcmin respectively for the clusters at z = 0.445 and z = 0.689. A cluster core of about 0.5 Mpc would then cover about 98 and 79 pixels in our frames. That is the outermost region of each frame of 512 × 330 pixels is much more contaminated by fore-/background (stars and field galaxies) than the innermost one. We may attempt therefore a cleaning action (effects by non-members) by removing statistically the field as it is defined by the outermost region. We find 245 objects photometered on the whole r-frames of 2158 + 0351, whose 73 are placed in the region inside a circle centred as displayed in Figure 2 and of radius 92 pixels (a value very close to the expected core radius of the cluster). For 0020 + 0407 we divided horizontally the r-frames into three zones of equal area, assuming the cluster to be mainly in the central one. We find 196 objects in total, whose 88 are in the innermost region. Note however that due to the scarcity of objects the method suffers of some intrinsic uncertainties in carrying out a proper analysis of the cluster density profile. In any case the procedure overcomes the need of the individual identification of the galaxies and ensures the determination of the photometric information that is related to the cluster population.

The luminosity functions in the r band for the two clusters are plotted in Figure 6. They have been drawn in the integral form (i.e. cumulative counts) and have been normalized to their maximum value in order to ease their comparison. Such a normalization should be consistent, since the longer exposure time provided the completeness in the photometry of 0020 + 0407 at least at the same level of 2158 + 0351. The cluster 0020 + 0407 seems to be dominated by a larger amount of faint objects, when compared to 2158 + 0351. Moreover the overall morphology of the two clusters, as seen in Figures 2 and 3, is quite different. The cluster 2158 + 0351 is much more compact, symmetric and dominated by some bright elliptical galaxies while 0020 + 0407 shows a more spread (almost filamentary) structure with no evidence of dominating members; indeed even the fact that it is a real cluster may need spectroscopic confirmation.

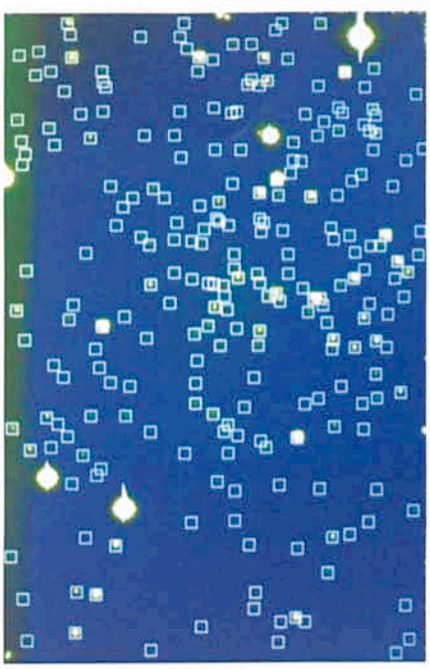

Figure 4: *The photometry of the cluster 2158 + 0351. Squares mark all the objects detected by the INVENTORY package and photometered in at least the r band (245 in total).*

4. Discussion

In the series of Figure 7 we have displayed the (g-r) vs. (g-i) colour diagrams for three subsamples of the objects photometered on our frames of 2158 + 0351. Panel (a) shows all the objects detected on the whole frame, panel (b) displays only the innermost region of the cluster (inside the 92 pixels radius) while in panel (c) come into view only the features of the outermost region (5 times wider in respect to the area of the innermost one). As a reference, contour levels are also reported on the panels. These refer to a smoothed representation of the overdensity due to the cluster galaxies after the field was removed statistically by properly combining panel (b) and (c). The smoothing has been obtained by filtering panel (b) and (c) with a beam of radius 0.15 magnitudes (displayed at the bottom of the figures). Four other curves are reported in the

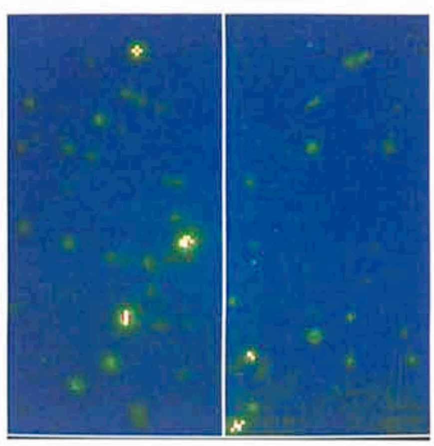

Figure 5: *A zoom of some typical features in the two clusters: 2158 + 0351 is on the left, 0020 + 0407 on the right. One sees that galaxies at these redshifts are essentially seeing limited objects.*

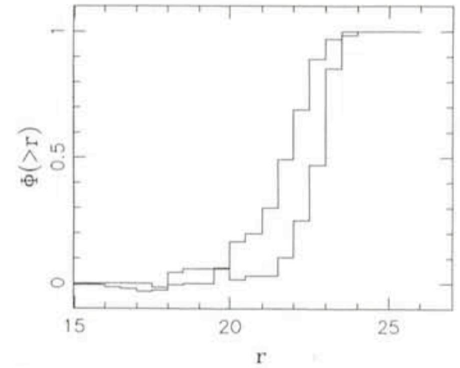

Figure 6: *The luminosity functions of the two clusters. The faintest curve refers to 0020 + 0407. Cumulative counts have been normalized to their maximum. A similar completeness in the photometry of the two clusters is assumed.*

figures: they show the expected changes in the apparent colours of the different morphological types of galaxies with varying redshift. In particular, the two "hooked" curves refer to the spirals and they have been calculated by passively redshifting mean spectral energy distributions of the present-day galaxies as they result from the work by Coleman, Wu and Weedman (1980).

The two other S-shaped curves refer to the models for elliptical galaxies (Buzzoni, 1987, 1988) and evidence the differences in the colours after evolution is taken into account. In the figure, the curve labelled with "nev" refers to a passive redshifted present-day model (closely representing mean local ellipticals) while the curve "ev" accounts for the rejuvenescence of the galaxies at higher redshifts. Crosses also mark the expected positions in the diagram for the different morphological types at the stated redshift z = 0.445. It is clearly seen that a marginal evidence of evolution in colour of the ellipticals seems to be present, within the photometric uncertainties, in the sense that the observed population is intrinsically bluer than the present-day descendants accounted for by the curve "nev". This fact is interpreted as due to the presence of a younger stellar component active in the past. One can also see in the figure that the splitting between evolved and non-evolved colours starts to be detectable around z = 0.4, increasing with increasing redshift. Note also from Figure 7 that an appreciable population of Sbc spirals seems to be present, since a bump in the colour counts peaks very close to the position expected for these galaxies around [(g-r), (g-i)] = [1,1].

This so fair accordance leads us to confirm that even at high redshift we do not expect a strong evolution in the intrinsic colours of the spirals: due to their continuous star formation rate they seem to be always dominated by young blue bright stars.

To completely exploit cosmological information coming from the photometry of the distant clusters we need to link observed magnitudes and colours with the two primary parameters that enable us to infer on the model of the universe: the absolute distance and the redshift. To do it we need a reliable calibration in order to take into account changes in the intrinsic properties possibly occurring in distant (young) galaxies. In this sense the direct comparison with the new grid of theoretical models of stellar populations (Buzzoni, 1987, 1988) seems to provide an effective tool to match the observed colours of the elliptical galaxies with redshift.

Indeed, one of the most encouraging results stemming from the work performed is that comparison of the observed mean colours of the ellipticals in the clusters with evolutionary models can provide a powerful method to determine redshift by only photometric information. As shown in Figure 8, if we plot the merit function in order to minimize the "distance" of the observed ellipticals from the theoretical locus in the colour-colour diagram, we are able to estimate z with an uncertainty of the order of ± 0.05: in fact for 2158 + 0351 we derive a formal value of z = 0.41, very close to the spectroscopic determination given by Gunn, Hoessel and Oke (1986). Our result confirms also the conclusions by Koo (1981), Couch et al. (1983, 1984), Ellis et al. (1985) and MacLaren et al. (1988) concerning the effectiveness of the photometric approach to recognize morphological types of distant galaxies and to estimate their redshift. However, since evolutionary effects become almost dominant at large distances they must be taken into account: otherwise photometric measurements of colours and redshift would be strongly biased in the sense that galaxies would be recognized to belong to later types and have systematically lower values of z.

As a further complementary evidence of the intrinsic evolution in luminosity of the galaxies, we note here that the observed difference of the distance moduli of the two clusters, as it appears from Figure 6, is less than the value expected for non-evolving galaxies, that turns to be around 2.0 magnitudes in the r band. This means in other words that the galaxies of the farthest (youngest) cluster 0020 + 0407 are intrinsically brighter than those of 2158 + 0351.

5. Conclusions

Work on high-redshift clusters of galaxies seems to contribute a quantity of meaningful constraints on the evolutionary status of the different hierarchical structures that populate the universe in the present and in the past. In particular we have shown here that the statistical analysis of the colour-col-

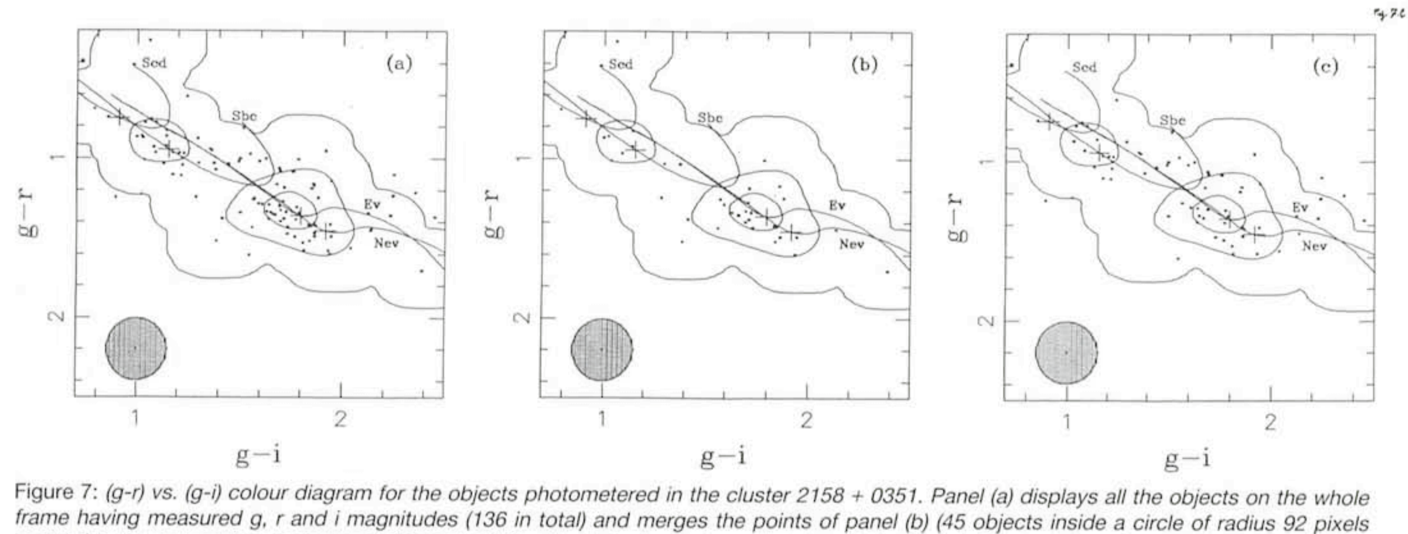

Figure 7: *(g-r) vs. (g-i) colour diagram for the objects photometered in the cluster 2158 + 0351. Panel (a) displays all the objects on the whole frame having measured g, r and i magnitudes (136 in total) and merges the points of panel (b) (45 objects inside a circle of radius 92 pixels centred in the core of the cluster) and of panel (c) (91 objects in the outermost region of the frame). See text for other details.*

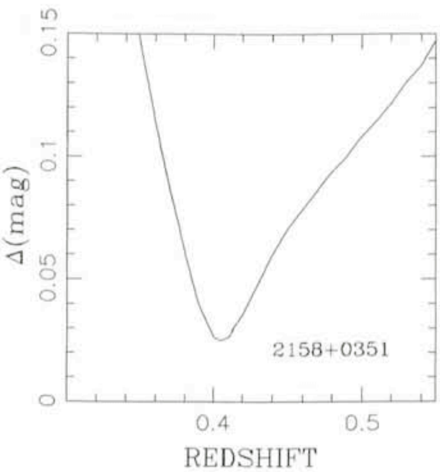

Figure 8: *The photometric determination of the redshift of the cluster 2158 + 0351. Displayed is the merit function which minimizes the difference between the colours (g-r) and (g-i) of the elliptical galaxies detected and those predicted by the evolutionary model of Figure 7.*

our diagram and of the luminosity function of the clusters obtained via an accurate multicolour photometry may provide an effective method (a) to discriminate galaxy morphology, (b) to evaluate their intrinsic evolution and (c) to estimate redshift with an accuracy of ± 0.05. We emphasize that two main requirements have to be fulfilled in order to reach such a fair resolution in exploring the universe at large distances:

(i) we need to observe clusters instead of field galaxies to be able to recognize them with high statistical confidence;

(ii) we need a combined comparison with evolutionary models, in order to properly account for the intrinsic photometric properties as we use galaxies as standard candles in the cosmological framework.

Such an approach is also preparatory to more detailed studies using the new generation telescopes (VLT) and will be complemented by deep surveys on selected fields possibly supported by spectrophotometric work.

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Trojan Search at ESO

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Doing minor planet research is sometimes considered a proof of bad taste among astronomers. It is a fact that asteroids, these rocky pieces between the orbits of Mars and Jupiter, have lost much of their interest, now that most of the larger ones have been catalogued: their orbits are well known, their chemical structure has been studied and their rotation properties investigated. Hence, chasing the smaller kilometer-sized members does not seem a useful occupation. Indeed, why should they be different from the larger ones?

I got engaged in asteroidal work in May 1986 (first GPO mission at ESO). Since that time my interest in asteroids has grown rapidly. In March 1988 I attended the "Asteroids II" conference in Tucson, Arizona. There I was really impressed by the wealth of possibilities in the field of minor planet research.

My primary interest are the Trojan asteroids, these objects that are describing their orbits at a mean distance of 5.2 A.U. from the Sun, i.e. at the 1 : 1 commensurability with Jupiter.

It is known from celestial mechanics that the problem of three bodies does not, in general, admit a finite solution in terms of known functions. Joseph Louis Lagrange (1736–1813), however, has shown that there is a solution in the special case that the three bodies (Sun, larger planet, asteroid) are moving in a fixed plane at equal distances from each other (triangular configuration). It is assumed that the mass of the third body (the asteroid) is negligible (Fig. 1).

The first object of this kind was found in 1906 at the Observatory of Heidelberg. The discoverer was the famous Max Wolf, and for some reason, he called his newly discovered asteroid "Achilles", after the hero from the Trojan war.

With the discovery of Achilles, a theoretical problem found an observational confirmation. Since then, more minor planets have been found at the so-called libration point L_4 and L_5 and all have been called after the heroes of Homer's Ilias.

It is interesting to note that we find only "real" Trojans (Priamus, Aeneas, Anchises . . .) at the libration point L_5 (preceding point) and Greeks (Achilles, Nestor, Agamemnon . . .) at L_4 (following point). This is of course a consequence of the appropriate naming convention.

However, one Trojan (Hector) is at L_4 and one Greek (Patroclus) at L_5. The motion of a Trojan is very complex, it will not remain constantly at L_4 or L_5; small changes from the triangular configuration will result in oscillations around these points. The theory of predicting

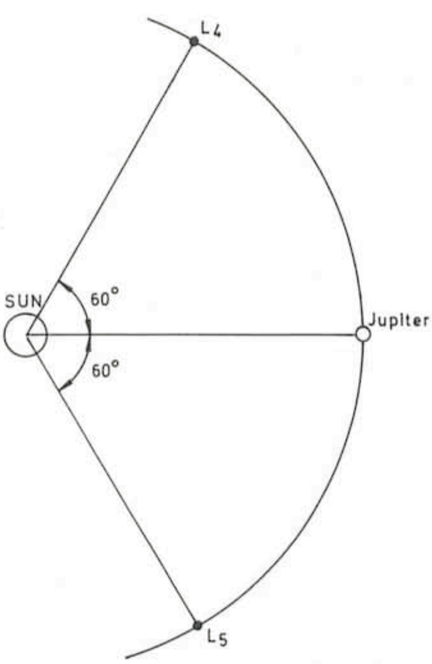

Figure 1: *Triangular configuration.*

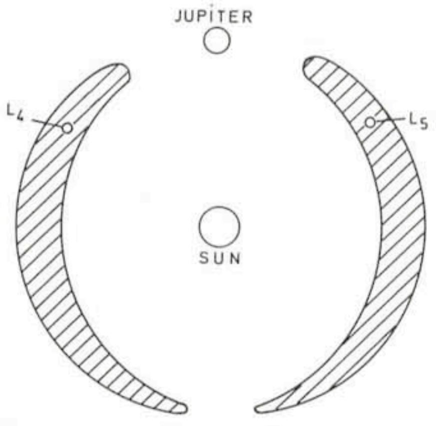

Figure 2: *Oscillation zones around the libration points.*

the exact oscillation amplitudes and frequencies is difficult, and much work has still to be done (Fig. 2). Observation and discovery of new Trojans is therefore highly important.

Since the mean distance from the Sun is about 5.2 A.U., the mean motion of a Trojan is almost 1/3 of the mean motion of main belt asteroids. In order to detect their trails on the GPO plates, it is therefore necessary to expose them much longer which is rather time consuming. Another way to discover them is by taking two plates in succession. Blinking of the plates may then reveal the unknown objects.

I must confess that I do not understand why asteroidal research has such a bad quotation among astronomers. During the last two years since I got involved in this kind of work, this occupation grew out to a real passion. The "infinite minor planet game" of Kohoutek became for me a most fascinating reality (see below).

From the point of view of observational work I may mention the following: in 1986 I discovered the Trojan object 1986 VG_1 at the observatory of Haute-Provence and in 1987 at ESO the Trojan objects 1987 QN, 1987 YT_1 and 1987 YU_1. But there are more interesting objects. In September 1986, I observed the long lost planet Nolli (473) at the Bulgarian National Observatory. Since it was not recognized as such, it received from the Minor Planet Center in Massachusetts a new provisional designation (1986 PP_4).

In September 1987, I discovered the Apollo object 1987 SB in collaboration with the Bulgarian astronomers at Rozhen. The object was followed at various observatories up to the 15th of January 1988. This object (a = 2.20 A.U.) is characterized by a very high excentricity (e = 0.66) and a low inclination (i = 3°). It therefore can approach three planets to within less than 0.050 A.U.: Venus (0.023 A.U.), Earth (0.045 and 0.052 A.U.) and Mars (0.019 and 0.034 A.U.). It means that 1987 SB has 5 possibilities of close encounters to these planets, which makes it rather "dangerous" on long terms. The diameter is of the order of 2.5 km (*l'Astronomie,* May 1988, p. 192). I could recover the object on a plate taken by Oscar Pizarro with the ESO-Schmidt in November 1987.

Other interesting objects (from the point of view of resonance studies) are the Phocaea objects (1987 BO_1 discovered at ESO; 1987 CR, discovered at Haute-Provence), and the Hungaria objects (1988 BJ, discovered at Haute-Provence, 1988 CR and 1988 CM_3, discovered at ESO; 1 prediscovery at the Bulgarian National Observatory at Rozhen: 1987 SJ_3) (Fig. 3).

The positions of the Hungaria object 1987 SJ_3 were sent too late to the Minor Planet Center and E. Shoemaker at Mount Palomar got away with it (even when he discovered it 4 days later), but that's part of the game.

Music for Asteroids

Nausikaa, the lovely person from the Odyssey, inspired me to compose for

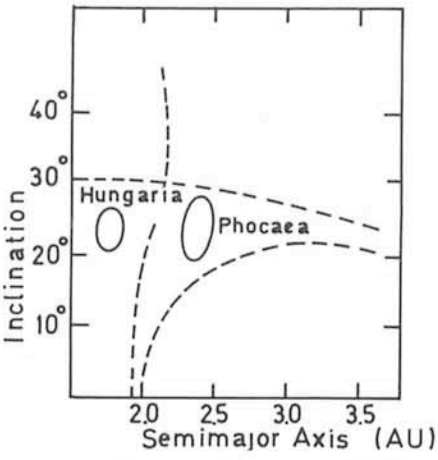

Figure 3: *The Hungaria and Phocaea asteroids.*

the piano the suite "Asteroid 192". The Trojan hero Odysseus, I have commemorated in the "Odysseus suite". The first performance of the Nausikaa suite took place in September 1986, at the town of Plovdiv (Bulgaria), not far away from the Greek border, before a small audience of Bulgarian astronomers. The Odysseus suite, I played for the first time at the home of Dr. R. Binzel, Tucson (Arizona), in March 1988.

Figure 4: *The Phocaea asteroid 1987 BO_1, discovered at ESO (January, 22, 1987).*

3.3-μm Spectroscopy with IRSPEC

T. LE BERTRE, ESO

IRSPEC is a cooled grating spectrometer in service at ESO since October 1986. It is equipped with a linear array of 32 InSb detectors and with two back-to-back-mounted gratings; in its present stage, it permits spectroscopy in the 1–5 μm region at a spectral resolution ($R = \lambda/\Delta\lambda$) of 1,000 to 2,000, depending on grating, order and wavelength. A description of it and a report on its performances can be found in Moorwood et al. (1986).

Although, in principle, data can be acquired at any wavelength between 1 and 5 μm, astronomical observations in some spectral regions (for instance, 1.35–1.45 μm or 2.5–3.0 μm) are impossible due to the large atmospheric extinction. There are regions (e.g., 1.10–1.18 or 3.1–3.5 μm) where atmospheric transmission is not zero, but still poor. There is great interest in performing spectroscopy in the 3.0–3.5 μm range. Such observations are difficult, not only due to the bad atmospheric transmission, but also due to the thermal background which rises in this range. Not much can be done by regular users on the thermal background issue and, hereafter, only the first source of difficulties will be addressed.

Figure 1 shows the raw (3.15 – 3.45 μm) spectrum of a K2III star. This spectrum was obtained in May 1988 during a good photometric night; relative humidity at ground level was ~10%. It has been acquired by stepping the grating at three different positions; the spectrum segments are contiguous and do not overlap. Spectral resolution is ~1,100. At this resolution and in this range, a K2III star is not expected to present any strong spectral feature and, therefore, what is presented in Figure 1 is basically the atmospheric transmission. One notes many absorption features, some of which are due to several overlapping lines and could be resolved at higher resolution. A feature at 3.318 μm is particularly deep and strongly affects observations even at low resolution. A low resolution spectrum (R ~80) of the atmospheric extinction can be found in Martin (1987); this spectrum, obtained with a circular variable filter (CVF), shows a peak around 3.3 μm. It is interesting to study this kind of spectrum before considering observations in the 3.0–3.5 μm range. As several atmospheric lines of different intensities (some of which are even saturated) affect the same spectral element, it is of prime importance to observe scientific target and comparison star at airmasses as close as possible; using the comparison star spectrum as a template allows, in principle by simple division, to correct the target spectrum for all its atmospheric features. However, experience shows that even during good nights, atmospheric absorption in the 3.0–3.5 μm range is not always stable with time. Therefore, it appears advisable to select a comparison star as nearby in the sky as possible from the object, and to observe it before and after in order to control the stability of the atmospheric transmission. Also, to avoid variation in airmass during exposure, one should observe preferentially around the meridian. It is only by carefully applying such guidelines that the observer might be able to cancel atmospheric features in its spectra. This advice is relevant to medium resolution spectroscopy with IRSPEC and, *a fortiori,* to low resolution spectroscopy with CVF's.

Among the most exciting observations to perform in the 3.0–3.5 μm region are those designed to study the so-called unidentified infrared emission features. The most prominent one is centred at 3.3 μm and has long been observed without being satisfactorily explained. Leger and Puget (1984) have proposed a consistent physical interpretation of it in terms of polycyclic aromatic hydrocarbon (PAH) molecules. Another feature, generally less intense, is observed at 3.4 μm. These two features are, in general, correlated with others found at 6.2, 7.7, 8.6 and 11.3 μm which may, therefore, have a similar origin. However, till now, most of the astrophysical observations have been done at low resolution (R ~80) with CVF's, and do not permit profile study of these features. With the availability of grating spectrographs like IRSPEC, physical studies based on medium resolution spectroscopy are feasible; also, now, comparison with laboratory data should be more meaningful in identifying the carriers. For instance, working at a resolution of 400, de Muizon et al. (1986) have observed structures in the 3.3-μm and in the 3.4-μm features and have discovered three new features at 3.46, 3.51 and 3.56 μm; accurate wavelengths, profiles and relative intensities of these different features give information on particle size, chemical composition, ionization state, etc. of the carriers.

To illustrate more specifically the potential offered by IRSPEC, a spectrum in the range 3.15–3.55 μm of Hen 1044 is presented by a WC star. Its progenitor is probably an intermediate mass ($1\,M_\odot < M < 9\,M_\odot$) star evolving from the Asymptotic Giant Branch (AGB) to the white dwarf stage. The high excitation of the nebula is clear from its H-band spectrum where Brackett lines up to (20-4) can be seen. Cohen et al. (1985) studied its IRAS low resolution spectrum (LRS); they show that, in addition to features at 7.7 and 11.3 μm, this

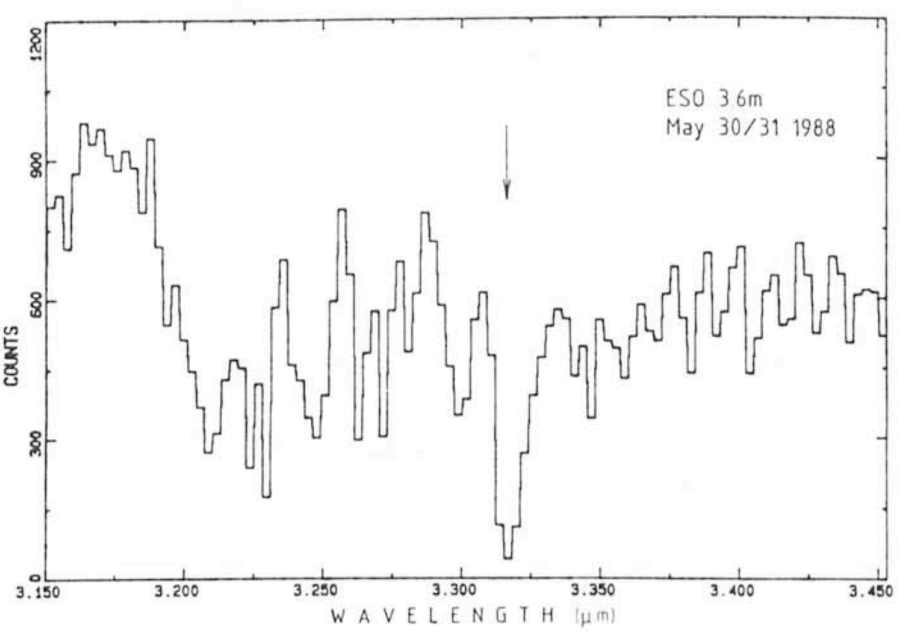

Figure 1: *Raw spectrum of a K2III star. The strong telluric feature at 3.32 μm, due to Methane, is indicated by an arrow.*

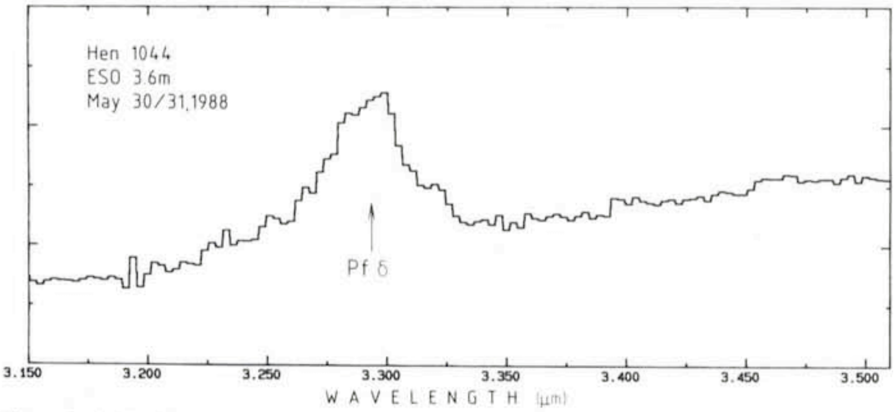

Figure 2: *3.15–3.50 μm spectrum of Hen 1044. The expected position of Pf δ at 3.296 μm is indicated by an arrow.*

source presents a plateau of emission extending from 11.3 to 13.0 μm. They discovered this new feature in the LRS's of 20 IRAS sources which exhibit emission at 7.7 and 11.3 μm and attributed it also to PAH's.

The spectrum presented in Figure 2 has been corrected for atmospheric extinction as explained above; no other treatment of the data (smoothing, etc.) has been performed and its resolution is exactly the one given by IRSPEC in this wavelength range (i.e., R ~1100). As the object is bright (L ~4.3), the noise in the final spectrum is mainly due to imperfect cancellation of atmospheric features. The 3.3-μm emission is clearly seen in the Hen 1044 spectrum; the feature is resolved and presents asymmetric wings. Adjusting it with a gaussian profile (which is somewhat equivalent to degrading the resolution of the spectrum), one finds a central wavelength of 3.292 μm and width of .044 μm. However, as the contribution of the Pfund δ hydrogen line (9-5) at 3.296 μm might not be completely negligible, a careful analysis is needed; this line is expected to affect at most two contiguous pixels. An interesting characteristic of this spectrum is the total absence of feature at 3.4 μm and longwards. The clear absence of emission at 3.4 μm suggests that the features at 7.7 and 11.3 μm and the plateau at ~12 μm are not correlated with it. Such recognition of correlation (or absence of correlation) between features, in combination with laboratory studies, will allow to constrain the identification of the different PAH's existing in astrophysical environments (see, for instance, de Muizon et al., 1986). The complete infrared spectrum as well as a discussion of all the data acquired on this interesting object will be presented elsewhere.

In Figure 3, the spectrum of Hen 1379 (another post-AGB object studied by the author) is presented. Most atmospheric features are well cancelled, except the strong telluric absorption at 3.318 μm which varied during the observations in such a way that an "emission line" appears around 3.3 μm. At CVF resolution, such an effect may mimic the unidentified 3.3-μm emission; with the resolution of IRSPEC, there is no ambiguity on its telluric origin: the 3.3-μm feature is clearly absent from the spectrum of Hen 1379. Some reported detections of the 3.3-μm feature with CVF's have not been confirmed later; the reason may simply be a rapid variation of the atmospheric absorption around 3.3 μm.

In conclusion, spectroscopic observations in the range 3.0–3.5 μm are feasible at La Silla using the 3.6-m telescope equipped with IRSPEC and promising prospects are offered by the utilization of this instrument. However, a careful preparation of the observations is required to get useful data; the observing planning should not be improvised at the telescope. Such a preparative work is surely time consuming and painful, but, at the end, it may make the difference between a successful mission and an unsuccessful one.

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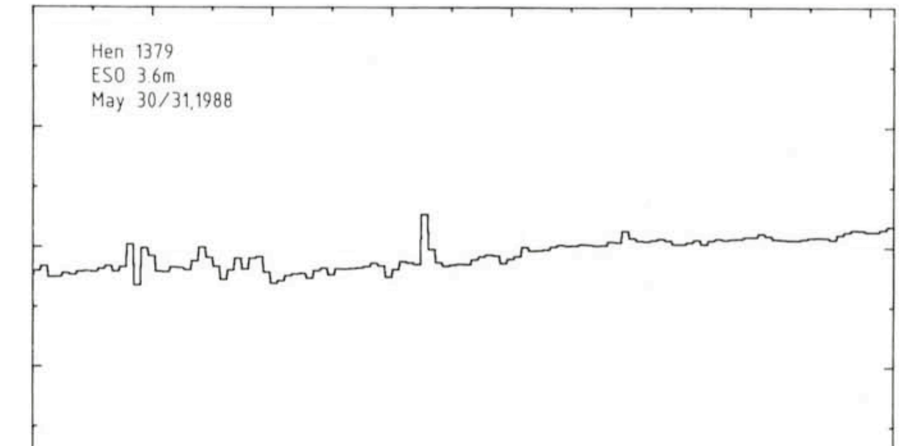


Figure 3: *3.15–3.50 μm spectrum of Hen 1379. The "emission line" at 3.32 μm is an artifact due to atmospheric Methane (see Figure 1).*

STAFF MOVEMENTS

Arrivals

Europe:

ALBERTH, Manuela (D), Administrative Clerk Purchasing
BECKERS, Jacques (USA), Experimental Astrophysicist
JANSSEN, Edmund (NL), Draughtsman
OOSTERLOO, Thomas (NL), Fellow
PIENEMAN, Hendrik (NL), Accounting Assistant
PIRENNE, Benoit (B), Fellow (Science Archive Software Specialist)
PRIEUR, Jean-Louis (F), Fellow
VAN RIJN, Gunilla (NL), Administrative Assistant
WALLANDER, Anders (S), Software Engineer
WIELAND, Gerd (D), Procurement Officer

Chile:

AUGUSTEIJN, Thomas (NL), Student
HUTSEMEKERS, Damien (B), Fellow
JARVIS, Brian (AUS), Fellow
PASQUINI, Luca (I), Fellow
VAN DROM, Eddy (B), Coopérant

Departures

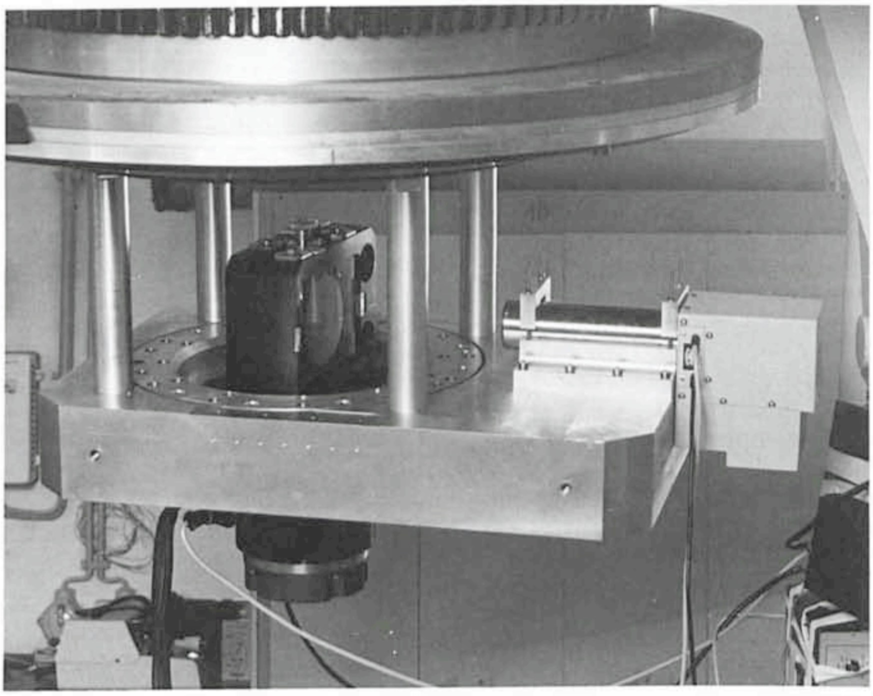
Europe:

GIRAUD, Edmond (F), Fellow
MAGAIN, Pierre (B), Fellow
RICHICHI, Andrea (I), Student
RUSSO, Guido (I), Fellow (Data Archivist)

Chile:

BOHL, Thomas (D), Infrared Instrumentation Engineer

EMMI Grating Unit under Test



The photograph shows a grating unit of EMMI (ESO Multi-Mode Instrument, the optical-range spectrograph for one of the Nasmyth foci of the NTT) that is currently being tested in ESO's integration laboratory in Garching. The mechanical parts for this unit have been manufactured by Enraf-Nonius in the Netherlands using designs made by the ESO mechanics group. The concept and design had been successfully tested on a prototype in the fall of 1987. Two gratings are mounted back to back in the grating holder of which the angular position is servo-controlled. Selection of the central wavelength will be remotely controlled as well as flipping the grating holder 180 degrees to select the other grating.

For precise positioning we selected the Heidenhain ROD 905 incremental encoder which is the most accurate encoder currently available. It has a radial grating with 36,000 lines/revolution and (by using 100 × subdividing electronics) a measuring step size of 0.36 arcsec. Although this could be marginally sufficient to achieve the +/− 0.5 to +/− 1 arcsec stability that is required for the complete unit, the ESO electronics group developed a new servo technique which locks on a zero-crossing of the basic sinewave. This so-called "phase-locked servo loop" has an electronic stability of +/− 0.1 arcsec. The tests measure the mechanical flexure of the unit in the orientations in which it will be used at the telescope as EMMI turns to follow the field rotation.

Five gratings are currently on order, three blue and two red ones. They are blazed at 400 and 550 nm for the blue and red arms of EMMI, respectively and provide resolving powers of up to 4,000 assuming a one arcsec wide slit. In a later stage, gratings with larger groove densities will be purchased that yield R up to 10,000 as well as an echelle for the red arm with R = 24,000.

The integration of the EMMI spectrograph in Garching will commence in the fall of 1988 and tests will continue during the first months of 1989. In the second part of that year the instrument will come into operation at the NTT.

H. DEKKER, ESO

MIDAS Memo

ESO Image Processing Group

1. Application Developments

The table file system is being enhanced with a number of astrometric functions which will make it possible to perform full astrometric reductions in MIDAS. They include transformations between different coordinate systems, correction for epoch and equinox differences, and general astrometric reduction programmes.

Reduction procedures for data from the Infrared Array Camera (IRAC) are being developed in collaboration with A. Moneti. Besides extensive use of the existing CCD package, some new programmes were made to optimize the extraction of data utilizing the special characteristics of IR array detectors.

A new context implementing relational algebra on tables has been included. This context, developed in collaboration with the IFCAI in Palermo, is an experiment to extend the functionality of the table system.

2. Work Stations

To relieve the situation of interactive image processing with MIDAS both in Garching and at La Silla, a decision was made to purchase 5 work stations out of which 3 will be placed at La Silla. These work stations will be used in single user mode for interactive usage of MIDAS and linked to the main computer facilities through a Local Area Network using TCP/IP protocols.

During the spring of 1988 more than 20 different UNIX systems were benchmarked with the portable MIDAS. A detailed report of these tests will be given in the next issue of the *Messenger*. On the basis of these results and offers received, the systems were ranked according to their price-to-performance ratio. Three single user work stations (i.e. SUN 4/110, PCS Cadmus-RC, and Bull DPX 5000-10) formed the best group with almost the same high performance per cost unit estimated over a 5-year period including maintenance. Work stations from IBM, HP, and Apollo-Domain could not be included in the evaluation due to formal issues. Due to the ESO requirement of maintenance at La Silla and a slightly better price/performance at the time of the tender, it was decided to purchase SUN 4/110 systems. It should be noted that the differences between the three systems were very minor and that slightly different criteria such as local conditions or usage for other applications than MIDAS may change the ranking. Further, both price and performance of work stations change rapidly with time altering the relative ranking (e.g. PCS improved the I/O performance of the Cadmus-RC system after the decision by modifying a driver).

3. Floppy Disk Formats

There has been a growing need for interchange of data between the ESO main computer facilities and PC-compatible systems. To accommodate this, an Olivetti M 290 (PC-AT compatible) and a PS/2 Model 30 were installed and connected to the ESO Local Area Network using TCP/IP protocols. These systems make it possible to read 3.5" and 5.25" floppy disks formatted in an IBM compatible format. Writing can be done on 720 kbyte and 1.44 Mbyte 3.5" floppy disks or on 1.2 Mbyte PC-AT 5.25" disks. Standard ASCII files can be exchanged without problems whereas other formats may be difficult due to different binary and record formats. The Image Processing Group will not be able to assist people in converting non standard files.

4. Portable MIDAS

The first official version of the portable MIDAS will be the 88NOV release which will be frozen on November 1st, 1988. This version will include the vast majority of applications available in the current VMS version. A few application packages may not be fully debugged and ready for the 88NOV release. This may include ROMAFOT and a new version of the long slit reduction package.

To make the transition easier, sites will be able to request both the portable version of MIDAS and/or a slightly upgraded version of the old VAX/VMS version of 88JAN. The MIDAS Request Forms will be sent out to all present MIDAS sites during October. Other sites may ask for the release through the MIDAS Hot-Line.

5. Measuring Machine Facility

The GRANT measuring machine was disconnected on August 1st and is no longer offered to users. Institutes interested in taking over this machine may contact ESO.

The new control system of the OPTRONICS went into operation in July. At this moment, it offers facilities to perform manual measurements of objects but will be upgraded later this year with options for scanning. However, it will not be possible to use this option efficiently before the central Measuring Machine Facility computer is replaced in the beginning of 1989.

6. MIDAS Hot-Line Service

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

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

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

"Remote" Control of the 1.52-m Telescope!

Until recently, astronomers working with the 1.52-m spectrographic telescope had to sit at the control desk *in* the telescope dome. During long, cold and perhaps windy winter nights this could be extremely painful. Now, following improvements in the mechanical functions of the telescope and a computerized positioning system, the control desk has been moved to an adjacent room (the former dark-room, no longer used for photography). Although a few functions still have to be done manually in the dome, these will also be "remotely" controlled in the future. I and other visiting astronomers at this telescope highly appreciate this new facility of the faithful old 1.52-m telescope.

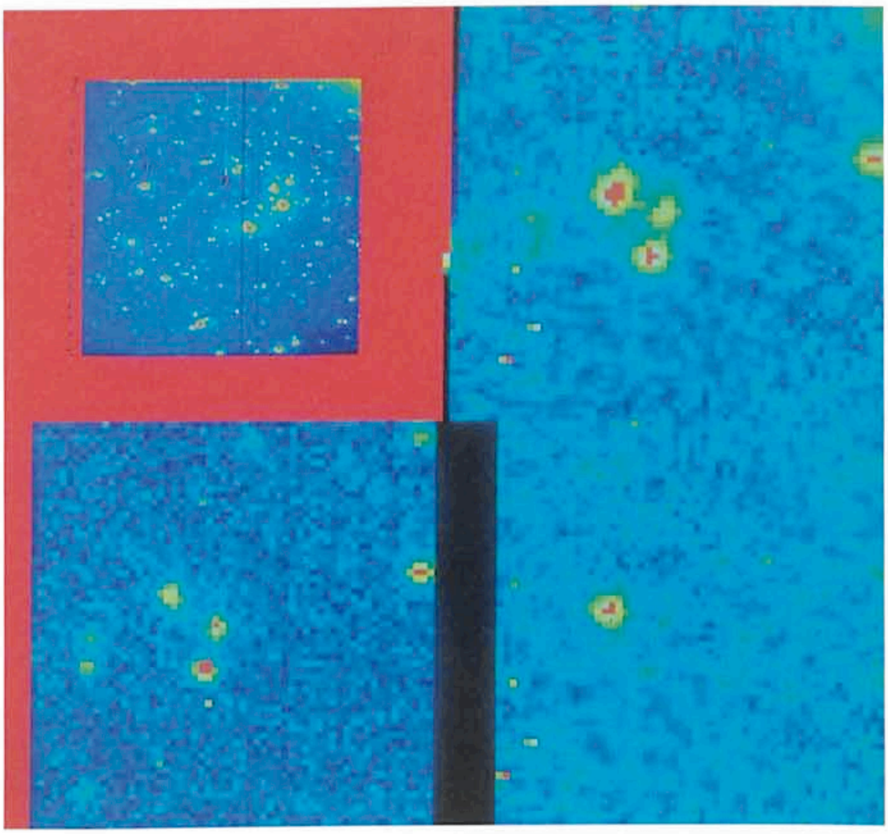
B. STENHOLM

The new control room of the 1.52-m telescope. Night assistant Luis Ramirez P. at the guiding console, while astronomer Matthias Dietrich, Göttingen, is checking the results. ▶

A Supernova in AC 118 (z = 0.31)

The search for distant supernovae on the Danish 1.54-m has been described in the *Messenger,* **47,** 46. In February 1988, L. Hansen detected a faint event (V ≈ 23.3) in a cluster J1836.14 RC of redshift z = 0.28. Now a much brighter event has been found by H.U. Nørgaard-Nielsen on August 8–9, 1988, in an inconspicuous galaxy in the galaxy cluster AC 118 (redshift z = 0.31).

In the figure, the image of August 8–9 is compared to an earlier one obtained in 1986. The upper left frame shows the compressed 1986 image of AC 118, and below is an enlargement of part of the image near the eastern rim. The upper right shows the same area for the August 8–9 image. The NE object of the three near the centre has brightened considerably. The lower right shows the difference between the two images, and the event stands out clearly. The supernova is displaced by 0.″5 E and 0.″7 S compared to the quiescent galaxy. The magnitude is V ≈ 22.3. The event is interpreted as a type I supernova. Subsequent observations have shown a gradual decrease in brightness.



Latest News: SEST Observes SN 1987 A!

Just before this *Messenger* issue went to press, R. Chini, A. Götz, C. G. T. Haslam, E. Kreysa, and P. G. Mezger, Max-Planck-Institut für Radioastronomie, Bonn, announced the detection of SN 1987 A with the SEST on Sept. 7–9 at 1.3 mm, equipped with a MPIfR bolometer. At the optical position they found an average flux density of 29 ± 4 mJy, integrated over a beam of about 30 arcsec. Possible contamination by underlying emission from the LMC was excluded by observing two adjacent positions 30 arcsec north and south of SN 1987 A where no signal was found above a limit of 4 mJy.

My Visit to La Silla

The Director General of ESO, Harry van der Laan, invited me to La Silla as consultant during the realuminization and the optical trimming of the ESO Schmidt telescope. I was very happy with this invitation because it gave me an opportunity not only to spend some time at the Schmidt, but also to meet with many friends in Chile. At La Silla I had the good luck to meet Richard West who suggested to me to write a short contribution for the *Messenger* about my stay in Chile which I have done with pleasure.

At the airport Tobalaba in Santiago, leaving for the mountain, I met already some of my old colleagues, Daniel Hofstadt and his wife Sonja, Wolfgang and Suze Eckert, Erich Schumann, Labrin, Leon and the French astronomer Mr. Spite. Travelling from the Pelícano airport to La Silla in a comfortabel car, my thoughts went back to 1964 when the trip from Pelícano to La Silla took us five and a half hours on horseback.

The skyline of La Silla has considerably changed with the installation of the SEST and the NTT building. It looks rather funny to see the tremendous NTT construction rotating! I missed the Swiss telescope and discovered it later close to my dormitory. I think the Swiss astronomers must enjoy its closeness to the hotel.

It was very nice to work again with Hans Schuster, Guido and Oscar Pizarro at the Schmidt telecope. The overhaul, done by the technical staff, went smooth. The only handicap was the weather. It took rather long to collect the necessary plates for the different tests. We succeeded in doing a rather good trimming of the telescope. A few results may be of interest.

The collimation error of the mirror is just under 0.2 arcsec. The plate-tilt is not more then 15 arcsec, corresponding to a theoretical image diameter of 0.2 arcsec at a radius of 100 mm assuming perfect focussing at the late centre. A simulated two-hour exposure, exposing only during the first and the last five minutes, gave a perfect coincidence of the two exposures, proving that there exists no differential fluxure between guider and camera. The telescope elevation at −45° declination deviates less than 0.3 arcsec from the theoretical refracted pole position. The azimuth deviation is 3.5 arcsec. These values were measured from two pole exposures of 5 minutes with fifty minutes interval.

Furthermore, the objective prism and the supernova search device (*The Messenger* **19,** 29, December 1979) were tested.

During my stay at La Silla I went for the first time with Erich Schumann to Coquimbo and La Serena to see how the food purchases are done. I was quite surprised about the impressive amount of food which is weekly transported to the mountain. One hardly realizes how much work is involved before dinner is served.

Finally, I would like to thank everybody who made my stay at La Silla such a pleasant one. *A. MULLER*

Editor's note: André Muller was one of the first astronomers to join the European Southern Observatory and to participate in the site testing at Zeekoegat in South Africa. In June 1964 he became the first superintendent in Chile. Among many other tasks he was responsible for the improvement of the Schmidt telescope. In 1983, at the age of 65 years, he retired from ESO and is now living near Eindhoven in the Netherlands.

New ESO Publications

The Proceedings of the NOAO-ESO Conference on

High-Resolution Imaging by Interferometry – Ground-Based Interferometry at Visible and Infrared Wavelengths

held from 15 to 18 March 1988, are now in the printing press and will be available by the end of September.

The Proceedings, which are divided in two volumes, contain a total of 1143 pages and are sold at a price of DM 95.–. This price includes packing and postage (surface mail) and has to be prepaid.

Payments have to be made to the ESO bank account 2102002 with Commerzbank München or by cheque, addressed to the attention of

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

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

The Proceedings of the ESO Conference on

Very Large Telescopes and Their Instrumentation

(21–25 March 1988)

are now being edited and it is expected that they will be available at the end of October. They will also be published in two volumes and may be obtained at the same price and the same conditions as the above-mentioned Proceedings.

Los editores sienten comunicar que debido a algunas noticias de último minuto el texto en español ha sido postergado para el próximo número.

Contents

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where thirteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. A 3.5-m New Technology Telescope (NTT) will become operational in late 1988 and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.

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

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