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The NTT Provides the Deepest Look Into Space

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The ESO New Technology Telescope on La Silla has again proven its extraordinary abilities. It has now produced the "deepest" view into the distant regions of the Universe ever obtained with ground- or space-based telescopes.

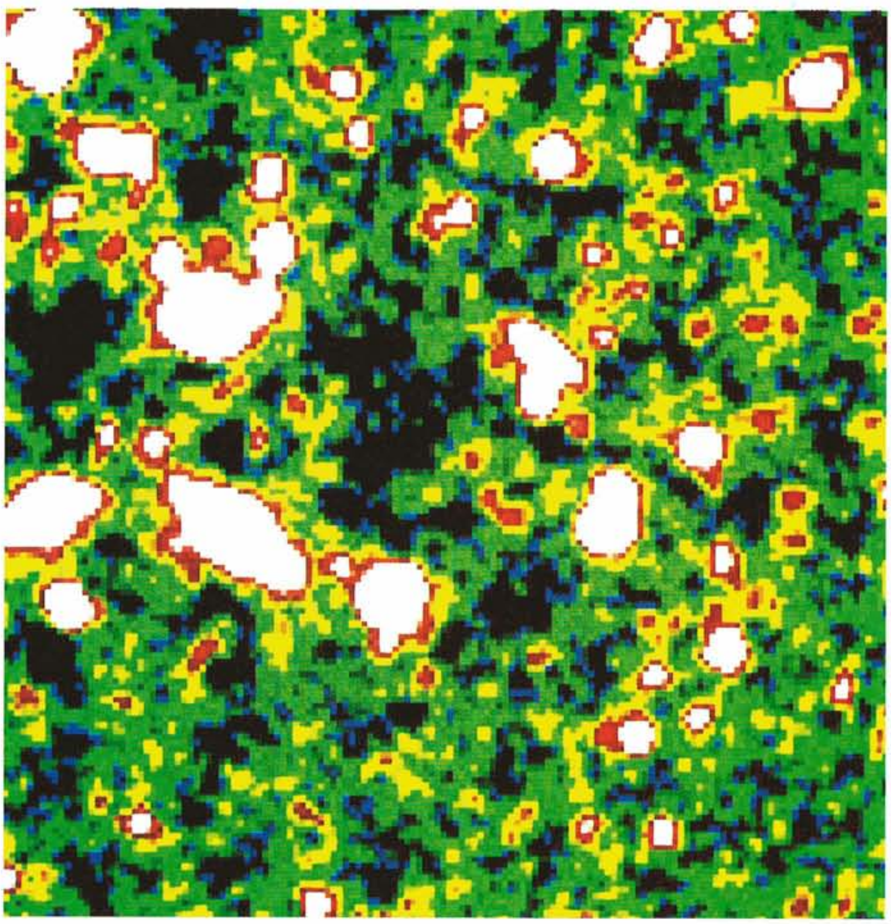

Figure 1: *This picture is a reproduction of a 1.1 × 1.1 arcmin portion of a composite image of forty-one 10-minute exposures in the V band of a field at high galactic latitude in the constellation of Sextans (R.A. 10^h 45^m; Decl. -0° 14′).*

The individual images were obtained with the EMMI imager/spectrograph at the Nasmyth focus of the ESO 3.5-m New Technology Telescope using a 1000 × 1000 pixel Thomson CCD. This combination gave a full field of 7.6 × 7.6 arcmin and a pixel size of 0.44 arcsec. The average seeing during these exposures was 1.0 arcsec.

The telescope was offset between the individual exposures so that the sky background could be used to flat-field the frame. This procedure also removed the effects of cosmic rays and blemishes in the CCD.

More than 97 % of the objects seen in this sub-field are galaxies. For the brighter galaxies, there is good agreement between the galaxy counts of Tyson (1988, Astron. J., ***96,*** *1) and the NTT counts for the brighter galaxies. However, the limiting magnitude for this image is ~ 1 mag fainter than for previous work. A magnitude sequence of a few of the galaxies is shown on the accompanying map on page 2.*

This V-image represents the deepest image that has ever been published.

The new picture reaches magnitude 29 and shows enormous numbers of extremely faint and remote galaxies whose images almost completely fill the field of view.

A Magnitude Sequence in the NTT Picture

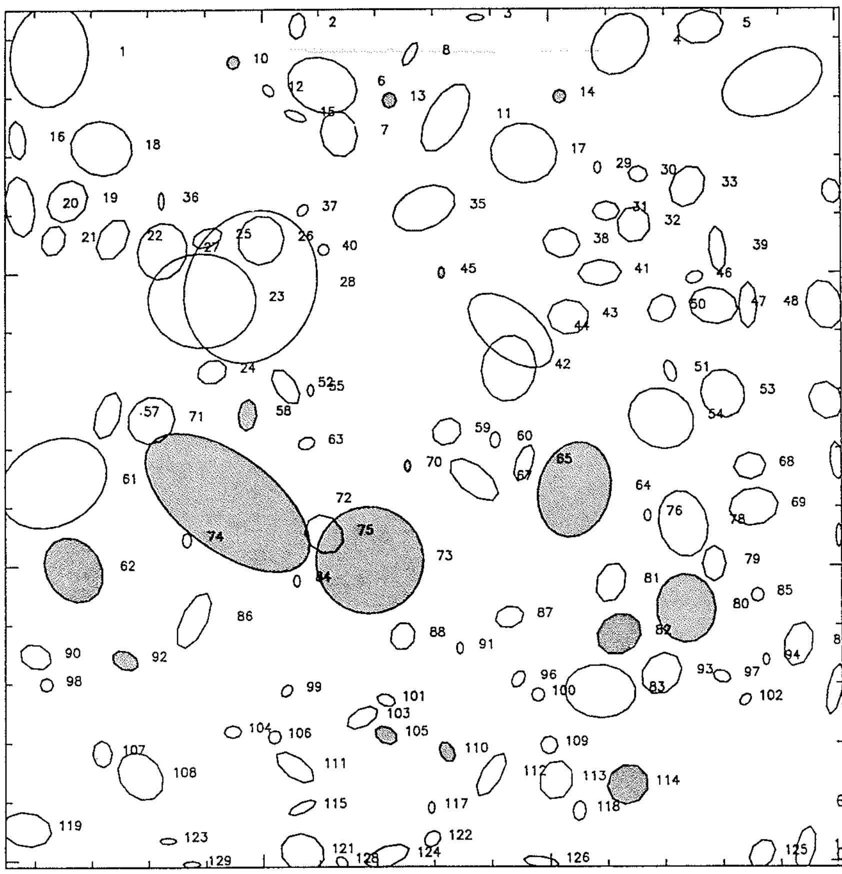

Figure 2: *This map identifies some of the galaxies which are seen in the deep NTT frame on the front page. The computer-drawn ellipses reflect their sizes and shapes. Note that the identifying numbers are located to the right of the objects they refer to.*

The following sequence of measured V-magnitudes illustrates the extraordinary depth of this picture: V = 20.3 (galaxy no. 72), 21.1 (73), 21.5 (64), 23.0 (62), 23.4 (80), 24.9 (114), 26.3 (58), 26.8 (92), 27.5 (105), 27.7 (110), 28.0 (13), 28.4 (10), 29.0 (70), 29.1 (45).

The Observations

Beginning in March 1991, and together with Yuzuru Yoshii of the National Astronomical Observatory in Tokyo and Joseph Silk of University of California, Berkeley, we have embarked upon an observing programme with the NTT aimed at detecting and measuring extremely faint galaxies.

To avoid problems with bright objects in the field, we pointed the NTT towards an "empty field" in Sextans. Previous observations had shown that no objects brighter than about magnitude 20 were visible in this direction. As will be seen, this first attempt has been highly successful.

Using a Thomson high-quality CCD detector in the ESO Multi-Mode Instrument (EMMI) at one of the NTT Nasmyth foci, Bruce Peterson took forty-one exposures of this field, totalling 6 hours 50 minutes. The individual pictures were registered and co-added to produce a combined image of which a small part (about 2% of the total area) is reproduced on the photo on the front page of this issue of *The Messenger.*

Characteristics of the Picture

It has been known for some time that on very deep sky exposures, most recorded objects fainter than about magnitude 24 are galaxies, rather than individual stars. In simple terms, this is because, as we look further and further out in space, we see more and more galaxies, while there is only a limited number of foreground stars in the Milky Way.

More than 97% of the objects in the frame are galaxies. The brightest ones, of about magnitude 21–25, can clearly be seen to have different shapes and can be accordingly classified. Thanks to the good angular resolution, it is possible to see that some of the fainter images are more or less elongated. This may be due to the galaxy type or to the inclination.

Calibration exposures were made on the same nights and we determined that the limiting magnitude of the frame is fainter than magnitude 29. This is more than one magnitude, i.e. at least 2.5 times, fainter than any other image obtained so far by any optical telescope, on the ground as well as in space. We have indicated a magnitude sequence on the drawing.

The frame shows enormous numbers of faint galaxies whose images to a large extent overlap each other. As a matter of fact, it is not even certain that there is any place where we are able to see the sky background. Already this simple observation is of great cosmological significance: the number of galaxies still appears to be increasing at these very faint magnitudes. It seems that we have not yet reached a point where we begin to look through the system of galaxies, as we can look through the stars in the Milky Way system.

A single frame, however, cannot with certainty discern between relatively nearby dwarf galaxies, very distant "normal" galaxies, or extremely remote superluminous galaxies. If some of the faintest images here seen belong to dwarf galaxies like the Magellanic Clouds, then their redshifts are likely to be 0.5 to 0.7, corresponding to look-back times of 38–48% of the age of the Universe. Those which are normal galaxies like the Milky Way will have redshifts of the order of 3–3.5 and the look-back time would be 88–91%. However, if any of them are brighter than the Milky Way Galaxy, then their distances would be even larger.

Follow-up Observations

A number of follow-up observations are now being undertaken.

First of all, reasonably accurate colours of most of the observed galaxies will be measured. With the NTT, this will be possible for those which are brighter than magnitude 28. An R-frame similar to the V-frame shown here has already been obtained; a comparison may enable us to cast some light on the ages of the galaxies observed.

The NTT will also be able to obtain spectra of the galaxies brighter than about magnitude 24. This will make possible the measurement of their redshifts, i.e. their velocities and cosmological distances.

The differentiation between relatively nearby dwarf galaxies and much more distant normal galaxies will also be possible by means of continued observations of the same sky field. Dwarf galaxies at redshift 0.5 would be close enough for individual supernovae to be observed in large numbers. Contrarily, supernovae in normal galaxies at redshift 3 or more would be too faint to be observed. A comparison of pictures obtained at different times will tell whether short-lived supernovae are seen or not, and therefore immediately give important information about the nature of the objects seen.

This NTT picture has given us a tantalizing, first glimpse of what can be done with the new and improved observational means which are now at our disposal. It has given us a unique look into regions of the Universe, so remote in space and time that they have never before been explored.

This is the type of work that will be at the frontline of optical observational cosmology during the coming years.

HST – the First Year

R. FOSBURY, ST-ECF

At the end of April, the Hubble Space Telescope completed its first year in orbit. With a projected lifetime, however, of some fifteen years, the observational programme of the spacecraft is just beginning. After the announcement in June 1990 of the spherical aberration in the primary mirror, the first assessment by astronomers tended to relegate the observatory to the role of a "large IUE with some UV imaging".

Now that the science verification phase of the commissioning process is nearing completion and the Guaranteed Time and General Observer programmes have started, it is a good time to assess what we have learned so far and try to paint a somewhat more realistic picture of the current capabilities of the instruments as they will be until the optical correctors are installed late in 1993 (current estimate).

In our eagerness to examine and assess the first real observations with the cameras and the spectrographs, it is perhaps too easy to overlook the tremendous complexity of the spacecraft and the ground operation and so to underestimate the achievement that the by now regular observing schedule represents. In the early months of the year, many of the pointing and target acquisition problems were overcome and by April, when revised pointing control software was installed in the on-board computers, the rate of successful completion of planned observations had become encouragingly high.

An engineering assessment of the spacecraft reveals both good news and some cause for concern. The new NiH2 batteries, specified at a late stage in the project, are performing well and the solar arrays are exceeding expectations in their power output. This means that the extra power can be used to minimize the thermal cycling of the scientific instruments and so help to extend their lifetime. Also, the thermal behaviour of the spacecraft as a whole is excellent and imposes no additional operational restrictions on the observing programmes. Communications with the ground, both direct and via the TDRS system, are no problem with a bit-error-rate some thousand times better than the minimum specification. The data management is also operating well, although a failed memory unit (one of six, four of which are currently used) caused the HST to enter a deep sleep – "hardware sunpoint safemode" state – recently. A five-day recovery process was completed just in time to intercept the observing schedule for some GHRS observations of the flare star AD Leo coordinated with a variety of ground- and space-based observatories.

After an equivocal start, the pointing performance has been improved to a level where most target acquisitions are successful. The spacecraft motions induced by the solar arrays during terminator transitions mean that the "jitter" does not meet specifications although large parts of the orbit are extremely quiet (~ 5 milliarcseconds rms). Noisy periods, which would degrade certain observations, can be rendered benign

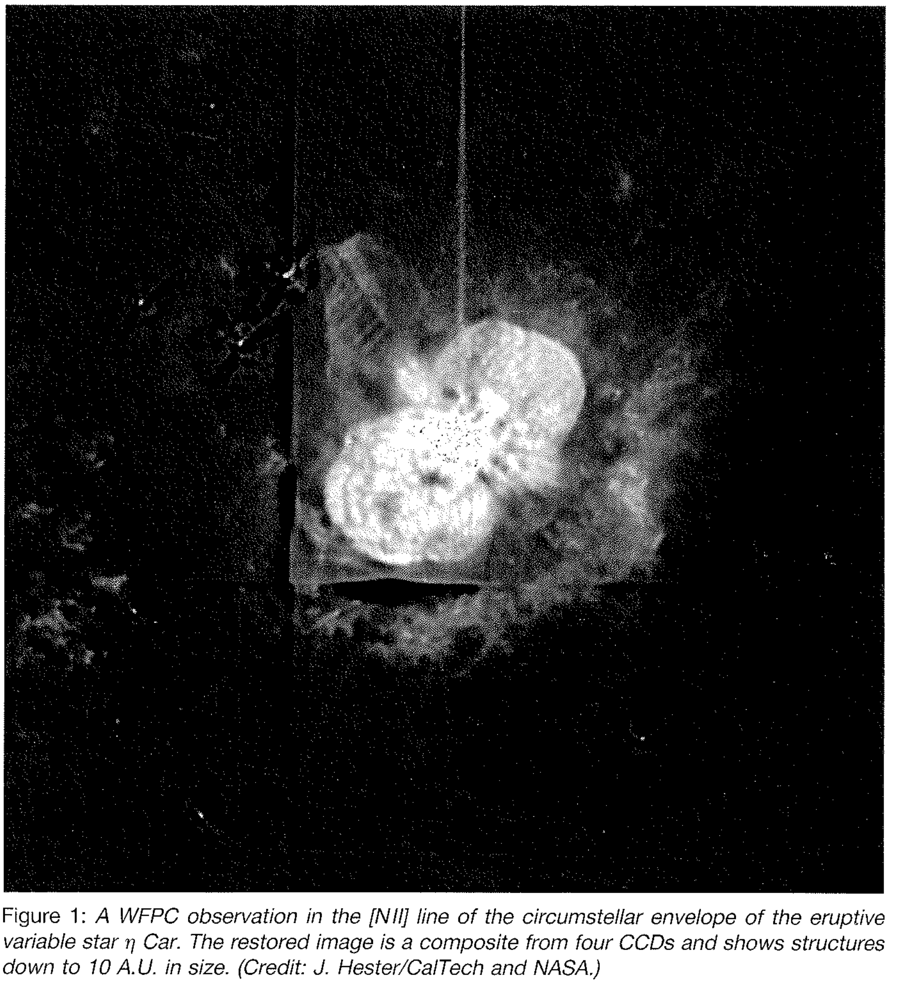

Figure 1: *A WFPC observation in the [NII] line of the circumstellar envelope of the eruptive variable star η Car. The restored image is a composite from four CCDs and shows structures down to 10 A.U. in size. (Credit: J. Hester/CalTech and NASA.)*

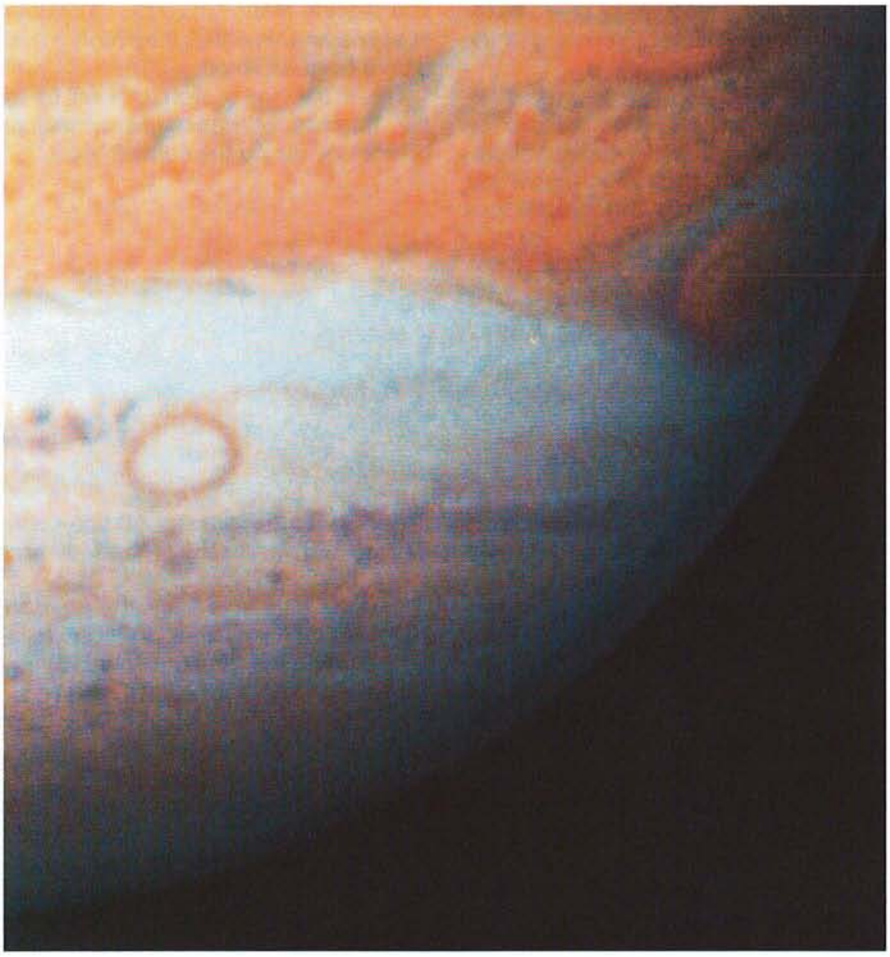

Figure 2: *The first HST WFPC observation of Jupiter. This "true colour" composite has about the same resolution as the pictures taken by Voyager five days before encounter in 1979. The banded structure at the limb is caused by the planet's rotation during the six-minute sequence of red, green and blue filter observations. (Credit: NASA.)*

by building suitable schedules. The Fine Guidance Sensors (FGS) which provide the errors to the pointing control system in one of two alternative modes – Coarse Track and Fine Lock – are affected by the spherical aberration but this is somewhat offset for the Fine Lock observations by the much lower than expected rate of spoiled acquisitions due to the unknown multiplicity of guide stars. Now that software has been provided for anticipating velocity aberration due to the orbital motion of HST, short observations under gyro control only can be made with good enough stability for some purposes and greatly reduced acquisition overhead. This will enable observers to apply for programmes of short "snapshot" mode observations which will fill unavoidable gaps in the schedule and increase the overall utilization of the observatory. One of the six gyros failed at the end of 1990. Four of the remainder are used by the control system.

The optical performance of the telescope has now been characterized with sufficient accuracy to enable the specification of corrective optics for WFPC II and for COSTAR – the scheme to replace the HSP with corrective optics for FOC, FOS and GHRS (see ST-ECF Newsletter #15, pp. 22, 23). The measurements made on the original test equipment used in the figuring of the primary mirror and in-orbit observations agree well and, incidentally, give a horrifically graphic picture of the blunder in the mirror testing which resulted in the infamous "HST point spread function". At the moment, the process of collimating the telescope remains incomplete, primarily because the two cameras and the FGS have somewhat differing requirements.

The individual scientific instruments are working well. The WFPC suffers some UV (< 3000 Å) problems due to contamination – probably from the lanoline used to lubricate the rivets in the instrument structure! The interaction of spherical aberration with the Cassegrain repeater optics in the camera produces a position-dependent PSF which complicates the processes of photometry and image restoration. The FOC is nominal. The FOS, and to a lesser extent the GHRS, suffer from magnetically induced image motion. This can, with the exception of the FOS red-side spectropolarimetry, be corrected using revised software. The FOS spectral response below 1500 Å decreases below expectation and below that of the GHRS, probably due to contamination of the surface of a grazing incidence mirror. The HSP is rather seriously affected by the combination of spherical aberration and spacecraft jitter and has not yet progressed very far through its science verification programme.

A workshop at the STScI in Baltimore in the middle of May gave the participants a mature review of the performance of the observatory and a good perspective of the early scientific results from the science verification observations and the beginning of the GTO and GO programme. Contrary to some of the earlier assessments, based more on the overall size of the PSF than on its detailed characteristics, the imaging performance of the cameras is qualitatively different from even the best ground-based telescopes. With the MTF extending almost to the diffraction limit, the resolution of sources with a limited dynamic range, e.g. planetary surfaces, is spectacular. The comparison of the (restored) 2200 Å image of the M87 jet shows it to be essentially identical with the 0.1 arcsec resolution VLA map obtained at a wavelength some one hundred thousand times longer. The WFPC emission-line image of η Car shows a wealth of structure down to 10 A.U. dimensions including a jet at right angles to the previously supposed direction of bi-polar outflow. Other circumstellar observations obtained during the first year were of the emission-line ring around Supernova 1987A and the twisted jet in R Aqr. The multi-line studies of the Orion nebula and, most recently, the Cygnus loop demonstrate the ability of the WFPC to resolve ionization structures in these nearby objects with consummate ease.

UV images of the cores of globular clusters are yielding some surprising results. The core of M15 shows no light cusp and indeed has a radius of 2 arcsec; the radial light distribution does not fit equilibrium models. The core of 47 Tuc in UV light – after accounting for the filter red-leaks – shows a central concentration of blue stragglers (a phenomenon noted by Sandage in 1953), one of which falls within the X-ray source error box.

For small, isolated sources, the spectrographs are affected only by the reduced throughput of the small apertures. One of the most exciting new results came from observations of the absorption spectrum of the nearby quasar 3C273 made with both the FOS and the GHRS. In addition to lines from the Galactic halo and at the redshift of the Virgo cluster, there are nearly an order of magnitude more Lyman-α systems than expected from the behaviour of the forest above $z \sim 2$. Indeed, with a velocity resolution of 3.5 km/s, the GHRS is proving to be a superb interstellar medium machine with lines down to mÅ equivalent width being seen in the UV spectra of bright stars (ξ Per, β Pic and Capella). As an interesting aside, atmospheric OI lines can be seen and used to provide an accurate internal wavelength calibration. Studies of exotic elements in χ Lup and chromospheric features in α Tau were presented. The current sophistication in the modelling of the atmospheres and winds of hot stars was demonstrated by the successful fitting of the P Cyg profiles in Melnick 42, a 100 $M_\odot$ in the 30 Dor nebula.

Within the Solar System, the HST provides the opportunity to carry out extensive planetary campaigns, something not afforded by the fly-by missions. Mars can be studied for long periods with a surface resolution similar to or exceeding that obtained under exceptional circumstances from the ground only at opposition. The atmospheres of Jupiter and Saturn can be seen at a resolution similar to that of the Voyager approach sequences and, of course, the ultraviolet part of the spectrum is available for the first time.

Some of the data discussed at the workshop are already in the public domain and available from the ST-ECF archive in Garching. All of the science verification data will become public soon after the end of the SV phase later this summer.

The "Discovery" of Paranal

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Introduction

Early morning on April 10, 1983 an expedition consisting of Mr. Bachmann, Ms. Demierre, Dr. Muller, Mr. Schuster, Mr. Torres and myself left La Silla to explore some northern sites in Chile. The next day we visited the Paranal area for a first inspection. After subsequent discussions with the *Intendente* in Antofagasta and a visit to the areas of S. Pedro de Atacama, we returned by plane to have another look at Paranal and its surroundings. Soon thereafter, under the leadership of Dr. Ardeberg, an observing station was set up at Paranal that provided the data based on which some seven years later the decision could be taken to locate the VLT there. It may be of some interest to describe the reasons why Paranal could be considered a promising site so early on.

At the beginning of the eighties plans for the VLT were still in a preliminary stage. It was clear, however, that infrared observations would constitute an important part of the raison d'être of the VLT; the choice of 8-m unit telescopes was, in part, dictated by the wish not to be diffraction limited at 20 microns wavelength. Since infrared observations from the ground are hindered mainly by water vapour in the earth's atmosphere, a very dry site was needed. Water vapour will absorb wherever it is located, and what matters is therefore not the local humidity but the integrated amount of water vapour in the atmosphere above the site. It is usually expressed in mm of precipitable water – the amount of rain that would fall if all the water vapour rained out. Sites with less than 1 mm of H_2O are comparatively very good sites for IR observations, sites with more than 3 mm rather poor. The local humidity has only a limited relation to the integrated amount of water vapour. If it is locally very humid, the integrated

Figure 1: *The first ESO expedition to Paranal (from left to right: H.-E. Schuster, A. Muller, G. Bachmann, and the author; photograph Ms. U. Demierre).*

[1]Professor Lodewijk Woltjer was Director General of ESO from 1975 to 1987.

Figure 2: *Paranal stands isolated and has the shape of a cone, two features of vital importance for the air flow over and around the mountain.*

amount of H_2O is generally high, but above some dry sites there may be a more humid layer higher up. Thus, in looking for high-quality sites, one should begin by looking for very dry sites, but subsequently measure the integrated amount of H_2O; this may be done with an instrument that monitors the intensity of the infrared emission bands emitted by water molecules. Two such instruments were bought by ESO from Kitt Peak National Observatory about a decade ago.

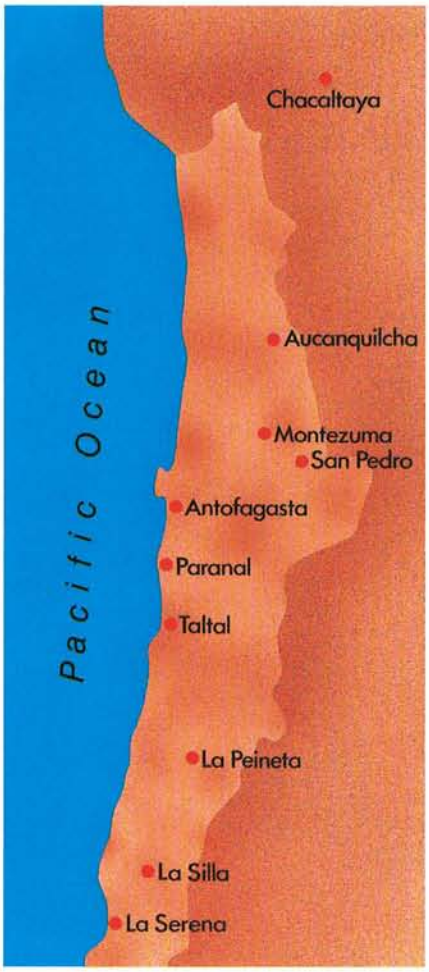

Figure 3: *Identification of sites in Chile.*

Low water vapour content was, of course, not the only condition. The VLT site should also meet the traditional criteria of low cloudiness and low atmospheric turbulence.

What was Known in 1983?

The site surveys conducted by AURA, ESO and CARSO had indicated that some of the world's best sites were located in Chile, inland from La Serena and somewhat further north. Some studies had also been conducted at La Peineta, east of Copiapó, where the number of clear nights was somewhat larger than at Tololo/La Silla, but with stronger winds. There was some reluctance to go so far north, because it was believed that the Magellanic Clouds would be the most important objects for study; even at La Silla the Small Cloud would be at best 43° from the zenith, and further north the situation would be still less favourable. In the meantime it has become clear that, though important, the Magellanic Clouds account for only a small percentage of the total observing time at the large telescopes, because the southern sky is so rich in other interesting objects. By 1980, some water vapour measurements had been made at La Silla and at Tololo which indicated that these were fair, but certainly not excellent infrared sites.

Long before these site surveys were made, the Smithsonian Institution had operated the "Montezuma station" (2700 m) just south of Calama in northern Chile. C.G. Abbot who for almost fifty years directed the Smithsonian Astrophysical Observatory was engaged in a programme to measure the "solar constant", the intensity of the solar radiation and its possible variations with time. Since an important part of the solar radiation is emitted in the near infrared, searches were made for the driest spots on earth (1). The best place at moderate altitude was found to be Mt. St. Katherine in the Sinaï desert, where from 1934 to 1937 observations were made. Finally "war, excessive isolation and the tendency to intestinal sickness there" caused the end of the activities. In the southern hemisphere, South West Africa (now Namibia) was rather disappointing, but more favourable conditions were found in northern Chile. Observations of the sun were obtained at Montezuma during some two decades beginning in 1923. Abbot found that the winter water vapour content averaged below 3 mm, with many days below 1 mm. Unfortunately the variations of the "solar constant" found by Abbot appear to have been spurious since satellite data indicate much smaller variations. Although the precise calibration of the water vapour measurements is perhaps uncertain, it is clear that Montezuma is an exceptionally dry site, as was amply confirmed by

Ardeberg's measurements in northern Chile half a century later. It is interesting to note also that C.P. Butler of the Smithsonian observed in 1935 for a few days at Mt. Aucanquilcha, nearly 6000 m, and found the solar radiation to be stronger there than anywhere else on the earth's surface (2). The same mountain was later included in the ESO site survey by Ardeberg.

Afterwards, when it had become clear that high-precision measurements of the "solar constant" are unlikely to be made from the surface of the earth, interest in dry sites diminished until the advent of IR astronomy led to its revival. During 1975–1976, J.W. Warner made a 12-month series of measurements at Chacaltaya (3) a cosmic-ray research station at 5360 m near La Paz. Monthly averages of H_2O were mainly in the range 2–3 mm, perhaps somewhat disappointing for such a high site. The tentative conclusions that could be drawn from all these data were that very dry sites might be found well to the north of La Silla, but that going too far to the north into Peru was likely to be counterproductive.

Precipitation has some relation to humidity. Here the situation was clear: to the north of La Silla rainfall declines to very low values, while to the east in the higher Andes and to the far north (Chacaltaya) it increases. Rainfall has an interesting temporal pattern in Chile: at La Silla and Copiapó it rains in winter, but in the far north the little rain that falls comes in summer, a pattern continuing into Peru. This would tend to suggest that the La Silla precipitation comes from disturbances to the south, while disturbances to the north cause the precipitation in the very north of Chile. It might then perhaps be expected that the atmosphere would be relatively undisturbed in the region in between. In the desert, however, the strong daily heating would still cause much turbulence, except close to the coast, where it might be suppressed by the cool breeze from the ocean. In general, island or coastal sites seem to have more favourable conditions for astronomical "seeing" than sites further inland.

Finally, cloudiness is an important parameter. It was known that cloudiness diminished going from La Silla to Copiapó. Day-time cloudiness at Montezuma appeared to be of the order of 30 %, while at Chacaltaya it was already substantially higher. Everyone who has visited La Silla in summer will have seen the towering clouds above the mountains to the east, some of which must still be present during part of the night. A study of satellite data by Ardeberg confirmed these findings: cloudiness is lowest in the northern Chilean deserts, but increases in Peru (4).

From all these rather fragmentary data it seemed that it would be worthwhile to look for high coastal sites substantially to the north of La Silla but within Chile. Some evening looking at the map of Chile, I realized that there was only one place with mountains in excess of 2500 m coming close to the coast, namely the area around Paranal. The only mention I have found of this area in the astronomical literature is by J. Stock, who made the Tololo site surveys (5): "There are a number of mountains of sufficient elevation south of the town of Antofagasta and very close to the coast. The abrupt rise from the Pacific Ocean on one side, and a large flat plain, more than 1000 m lower, on the other side, give these mountains rather special conditions. High stability, that is, good seeing, is expected for night-time conditions. Furthermore, the extremely low humidity makes this area very suitable for astronomical work in the infrared. Since this area is absolutely arid, water supply for an observatory will be difficult and costly. Underground currents may exist, but most likely at a prohibitive distance and depth." It is curious to note this preoccupation with water, which also played such an important role in ESO's site selection. The Chileans had discovered long before that water can be transported. In any case, it seemed worthwhile to have a look at the Paranal area.

To Paranal

On maps of northern Chile, many roads are indicated. Not all of them exist and even if they do they need not be passable. The road passing a few km east of Paranal being the old Panamericana, we at least had a reasonable confidence that we could get there. Accordingly we first went to Taltal and spent the night at the *hosteria* there. Food was difficult to obtain, but fortunately the owner – a retired seaman and part-time gold miner – was barbecuing a pig for some friends. The next morning we set out along the coast under a somber cloudy sky. Fifty km further north at Paposo, the old frontier town (with Bolivia), we turned inland, and a steep climb began. We came into the clouds at about a thousand metres altitude. Suddenly, after going up a bit further, the clouds gave way to a spectacularly clear, deep blue sky. At La Silla, when one looks near the sun, the blue usually turns milky because of scattering of the sunlight, but here it remained unchanged until as close to the sun as one dared to look. At the same time, the last trace of vegetation disappeared as we entered the most absolute desert we had ever seen. Not a trace of life was there: no birds, no insects, nothing at all. Nor did we meet any car on the more than 100 km road that brought us through the Paranal area. To the east, the Vicuña McKenna mountains shimmered in the heat of the sun, but towards the ocean the atmosphere looked more stable. Our vehicles were insufficient to actually go up to Paranal, and so we moved on to Antofagasta. Our first view, however, had already been sufficiently impressive that we paid a visit to the *Intendente* of the province to obtain his agreement for some ESO activities there. At the time this was particularly necessary, since the mounting of strange equipment

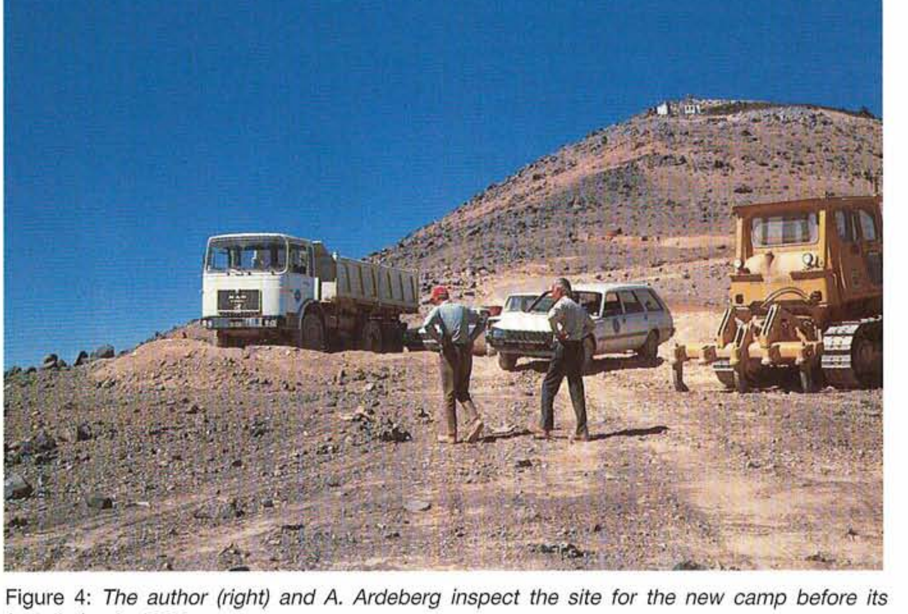

Figure 4: *The author (right) and A. Ardeberg inspect the site for the new camp before its installation in 1987.*

close to the coast in the middle of nowhere by some foreigners could easily have been misinterpreted. Subsequently, we passed by Montezuma and visited S. Pedro de Atacama to see the area further to the east. It did not seem easy to find there fully free standing mountains with heights of less than 4000 m – about the highest possible for normal work without special provisions for oxygen.

We planned to fly back from S. Pedro via Paranal, and then over some inland mountains near the Salar de Punta Negra. Accordingly a plane was chartered which landed on the airstrip of S. Pedro, but it got stuck in the sand. All of us had to push to get the plane to a harder part of the surface, and when finally we were taking off, not all passengers looked very happy. Since the pilot had deliberately taken only a small amount of fuel, the plane managed to take to the air and half an hour later we landed at Antofagasta. The subsequent flight over Paranal was interesting. Flying over the narrow strip of mountains between the old Panamericana and the ocean, the atmosphere was absolutely stable, but as soon as we came east of the road, strong turbulence was felt. The view was spectacular with the blue ocean and white low clouds on one side and the steep cliffs and absolute desert on the other. After circling Paranal a few times, we continued the flight southward, still more convinced that measurements should begin there as soon as possible. A few months later Dr. Ardeberg had the observing station installed and manned by Mr. Gomez and son, who measured the H_2O content every two hours around the clock and, of course, also made observations of cloudiness and other meteorological parameters.

A site may be very dry and the sky very transparent and free of clouds; however, if the "seeing" conditions are not very good, it is all in vain. Fortunately, the seeing monitor installed by Dr. Sarazin some years later showed that also as far as atmospheric turbulence is concerned, Paranal is excellent, in fact better than La Silla.

The Future

Paranal has now been chosen as the site for the VLT. This gives a unique chance to rationally construct a new observatory which may look rather different from La Silla with a smaller resident staff and a more intensive direct communication to Europe. It will be particularly important to place at and around Paranal only telescopes and instruments that use the essential characteristics of the site, and especially during the installation phase of the VLT to avoid the plethora of small telescopes which have made the La Silla operation rather heavy.

Paranal is probably the observatory site with the lowest cloudiness in the world and also among the best in "seeing" and water vapour content. Are there still better sites to be discovered? Some astronomers think that the central area of the antarctic plateau – closer to the pole than the region of strong winds – may be particularly suitable because of its very low humidity. Since the sun is never far below the horizon, the number of hours of darkness is rather small and the site seems appropriate only for IR and sub-mm observations. The cost per hour of observation would be very high, and it is clear that only special-purpose instruments could justify this cost. On a longer time scale the lunar base currently under study may offer unique possibilities for astronomy at all wavelengths. None of this, however, is likely to endanger the role of Paranal as one of the world's leading observatories for the next half century.

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ESO Awards VLT Contracts to Dutch and Danish Firms

The decision to place the world's largest telescope, the ESO 16-metre equivalent Very Large Telescope (VLT) on the Paranal mountain in the Chilean Atacama desert, taken by the ESO Council on 4 December 1990, has now been followed up by an important next step. During a small ceremony on April 26, 1991 at the ESO Headquarters in Garching, two major contracts were signed which will together define the future shape of the VLT Observatory and its infrastructure.

Following a call for tenders which was responded to by a large number of engineering companies in the ESO member countries, ESO awarded contracts to INTERBETON of The Hague, the Netherlands, and COWIconsult of Copenhagen, Denmark. The contracts were signed by Mr. A.J.M. Boersma, Area Director (INTERBETON), and Mr. K. Østergaard Hansen, Executive Director (COWIconsult), and Professor H. van der Laan, Director General of ESO.

INTERBETON will carry out the levelling and landscaping of the Paranal mountain, so that it can accommodate the entire array of 8-metre and auxiliary telescopes as well as associated buildings that together make up the VLT Observatory. About 23 metres will be cut off the Paranal peak by blasting and ripping, leaving a flat area of about 20,000 m^2 at 2640 m altitude. In July

From left to right: Mr. K. Østergaard Hansen, Executive Director of COWIconsult; Prof. H.v.d. Laan, Director General of ESO; Mr. A.J.M. Boersma, Area Director of INTERBETON.

1991, INTERBETON will establish a base camp for the temporary housing of its personnel in the hostile desert surroundings, and the actual blasting will start in September 1991. It is expected that this work will be terminated in February or March 1992, after the removal of no less than 250,000 m^3 of rock and gravel.

COWIconcult will perform an in-depth engineering design study of all the structures and buildings which will later be erected at Paranal as well as of the optimal lay-out of the necessary access roads and also the entire infrastructure. The Paranal site is one of the most pristine in the world and ESO is placing great emphasis on the need to preserve it in a condition that is as close to the original as possible. The COWIconsult study will therefore include the innovative use of alternative sources of energy, for instance wind turbines and photovoltaic solar cells for providing electricity and thermal solar cells to heat the buildings. Water tanks must be provided to store the water which will be trucked from Antofagasta to this absolutely dry, remote location. This study will take about 12 months, following which the actual construction work will begin in the second half of 1992.

The Editor

ESO'S EARLY HISTORY, 1953–1975

XI. Policy, Payments and a Bit of Politics*

A. BLAAUW, Kapteyn Laboratory, Groningen, the Netherlands

"German astronomers would be very happy if in the long run not only the [ESO] Administration, but also scientific activities could be located in our country".

From a statement by the German astronomical Council delegate in December 1973.

Introduction

The present article concludes my account of ESO's early history. We first followed the developments leading to the signing and ratification of the ESO Convention in 1962 and 1964, and the simultaneous searches for sites, first in South Africa and later in Chile; next the first phase of constructions in Chile concluded with the dedication ceremonies on La Silla in March 1969, and then first scientific activities. We saw that by the time of the dedications first thoughts were given by Directorate and Scientific Programmes Committee to developments of ESO beyond the Initial Programme of the Convention, but that their follow-up was stifled by the growing concern about the completion of the 3.6-m and the Schmidt telescopes. Subsequent progress in these two telescope projects was described in the last three articles.

In dealing with these latter subjects, I entered into the period of my own Directorate of the Organization. As a matter of principle I did not want to cover that period except for those items for which developments were well under way in preceding years and hence would naturally ask for an account of their follow-up, as was the case with the 3.6-m and Schmidt telescopes. Thus, my account did not cover a wide range of developments following the 1969 dedications, such as: the scientific work by ESO staff in Chile and by visiting astronomers; the large construction programmes carried out in Chile; the more detailed account on the work of the TP Division; and the steadily progressing effort of the ESO Administration and Finance Committee in establishing the framework of rules and arrangements governing staff positions.

This concluding article will again deal with two subjects that rooted in ESO's earliest days. First, we take up some matters of general policy that were on and off the subject of, sometimes rather pithy, discussion. Next we shall deal briefly with an important aspect that so far was hardly touched: the financial one – what it all cost and how it was paid for.

MATTERS OF POLICY

Two matters of policy ran, since the earliest days, as a continuous thread through the deliberations of Directorate and Council: a) the question, to what extent ESO should have a nucleus of research-oriented astronomical staff, and b) the problem of ESO's geographical dispersion, particularly the dispersion in Chile. Although the two subjects are interrelated, let me deal with them consecutively.

A. ESO, A Centre for Research?

In article VII I quoted the opening statement by the advisory committee that in 1965 submitted to Council recommendations on the way the Observatory should operate: *"Whereas the role of the Observatory as an astronomical institute in its own right – – – should be of great importance, the facilities should particularly be available to serve the national interests of the member states".* We recognize here two conceptions between which the Organization swung since then, a role as *"observatoire de mission"* and one as a research institute in its own right. I referred to this ambiguity earlier, in article VI in connection with the creation of the Santiago Headquarters.

In 1968, as described in article VII, the newly created Scientific Programmes Committee proposed the creation of an ESO Centre in Europe, to serve a double purpose: offering a meeting ground for astronomers, and a place where auxiliary measuring equipment could be developed, to be used in conjunction with the observational work on La Silla. As we have seen, this suggestion as well as others of the SPC met little response when early in 1969 the problem of the realization of ESO's main telescopes began to dominate Council deliberations. However, the proposal contained elements that in the following years would recur with increasing urgency in discussions between Directorate and Scientific Policy Committee on the one hand, and Council on the other hand.

The matter was expressly brought up in part II of document Cou-60 of December 1969 (to the first part of which I referred in article IX), written in preparation for the new policy to be adopted for the realization of the 3.6-m telescope and resulting in preference for the collaboration with CERN. With the prospect of the strong technical group to be built up at CERN that would absorb anyhow the small but growing technical group at Hamburg-Bergedorf, and with the threatening dispersion of ESO's establishments in Europe (on top of that in Chile), it seemed attractive to move to the vicinity of this technical group also the other services of Hamburg and es-

* Previous articles in this series appeared in the *Messenger* Nos. 54 to 63.

The ESO Guesthouse in Santiago from the air
The Guesthouse was bought in the year 1964 as a pied-à-terre in Santiago and served in the early years for both the administrative offices and for lodging visitors from Europe. In the early 1970's it was contemplated to sell the Guesthouse and incorporate its function for visitors into the Vitacura Headquarters building. The idea was not, however, pursued any further.
From photograph in the EHPA.

tablish there the ESO Centre suggested in earlier proposals. Naturally, there was the difficulty that Switzerland was not yet a member of ESO, but efforts to achieve this were under way. An obvious advantage of such a move would have been the opportunity for natural interaction between the three astronomical groups: that in Europe involved with the visiting astronomers programme, the astronomical staff at the TP Division, and astronomers from Chile visiting Europe. Also, favourable conditions would be created for further pursuing the Scientific Programmes Committee's proposals for a new generation of telescopes referred to earlier.

As was reported in article IX, Council in December 1969 encouraged the further exploration of collaboration with CERN for the large telescope project and this eventually led to the creation of the TP Division. The question of the ESO Centre was, however, referred to a special advisory committee Council intended to create for dealing with matters of general policy [1]. As we saw in article IX, the French delegation at that time stressed the importance of first of all concentrating all efforts on the construction of the large telescope. Reluctance with regard to the coupling of the telescope project and a "Centre" was more specifically heard from the side of the German delegation: *"The central ESO institute is some sort of ghost going around. --- As long as --- a study is not available, we have to separate the two questions: --- the large telescope and the central institute"* [2].

The Scientific Policy Committee Created

The special advisory committee just mentioned, to be called Scientific Policy Committee, was created in the Council meeting of June 1971 and meant to advise Council on matters brought up by Council as well as such it might take up on its own initiative [3]. The Council meeting of December 1, 1971 appointed its membership: Ludwig Biermann, Jean-Claude Pecker and Bengt Strömgren, with the latter as its President. The acronym SPC would henceforth refer to this new committee, and the former SPC became Observing Programmes Committee (OPC). President of this latter became Pol Swings. The meetings of both committees up to the end of 1974 are listed in the table on page 25 of *The Messenger* No. 60 (article VII). This new SPC, with its small membership, soon became a welcome sounding-board for the Director General when it came to matters of general policy.

Meanwhile, the matter of the ESO Centre had remained more or less dormant in 1970 and 1971. These were not only the years in which the TP Division took up its task; the ESO Directorate also was confronted with increasingly serious economic problems in Chile that required a variety of measures in the personnel sphere [4].

A Research-Oriented Group at ESO?

The question of the Centre was taken up by the (new) SPC in its meetings of April and October 1972, at the last one on the basis of a proposal submitted by the Directorate: "Preparation for the Optimum Use of the 3.6-m Telescope" [5]. In the course of that year, with the work of the TP Division in progress, it had appeared desirable to take first steps towards ensuring that the astronomical community in the member states would be prepared for making full use of the large telescope, once this would become operational. It was not obvious that this would be the case. For instance, research with the large telescope might be expected to concentrate mostly on extragalactic problems, i.e. the study of stellar systems outside the Milky Way system, whereas around the year 1970 research on our own system, the Galaxy, dominated observational work [6]. The proposal received strong support from the SPC in its October 1972 meeting and could be summarized as follows [7]:

"1) ESO aims at creating without delay a small group of astronomers with the task

– a. to help orienting research in the ESO member-states towards those programmes, to which the 3.6-m telescope may be applied with its optimal efficiency;

– b. to help orienting the development of auxiliary instrumentation towards the application of these programmes;

2) The group should have a small nucleus of permanent or semi-permanent members, and for the remainder consist of a rotating membership (visiting scientists)."

The group was meant to be located preferably at the TP Division; it was proposed that budged provisions be made for three first appointees, and that it should be guided by a senior astronomer of outstanding qualification [8].

The Committee of Council in its meeting of October 31, 1972 was in majority favourable to these ideas and amended the proposal in the sense that leadership of the group might be combined with the still vacant position of Deputy to the Director General which had been created in connection with the retirement of Ramberg at the end of 1971 [9], and a correspondingly amended proposal was submitted to Council [10]. The amended proposition seemed particularly interesting because by that time an astronomer of outstanding qualification had, in private, expressed to the Director General interest in this leadership. However, contrary to expectations raised at Committee of Council, the Council meeting of November 1972 held in Chile acted reluctantly. It authorized the Director General to approach the person concerned about the intended association with ESO, but rejected creation of the research-oriented group [11]. As a result, interest on the part of the person concerned faded.

The Workshop Proposal

The question of the orientation of research with the 3.6-m telescope was again on the agendas of the SPC meeting of March 28, 1973, and of Committee of Council on the day following. This had been preceded by consultation of the President of the SPC and the Director General with a prominent astronomer in the member state from where much of the resistance appeared to stem, the German Federal Republic, and this had led to an alternative suggestion: instead of creating the research-oriented group within ESO, ESO might *"– – – organize a succession of Workshops, each of about 6 months duration, with participation of astronomers from astronomical institutes of the ESO countries, who would be on leave of absence from their home institutes for the duration of the Workshop. – – – "* [12]. Although it was realized that in this way the most urgent task Directorate and SPC had in mind, working out a programme for the auxiliary equipment for the 3.6-m telescope, would not be taken up as expediently as in the original proposal, Committee of Council recommended the Workshop proposal to be worked out in detail by the Directorate, especially for its financial implications.

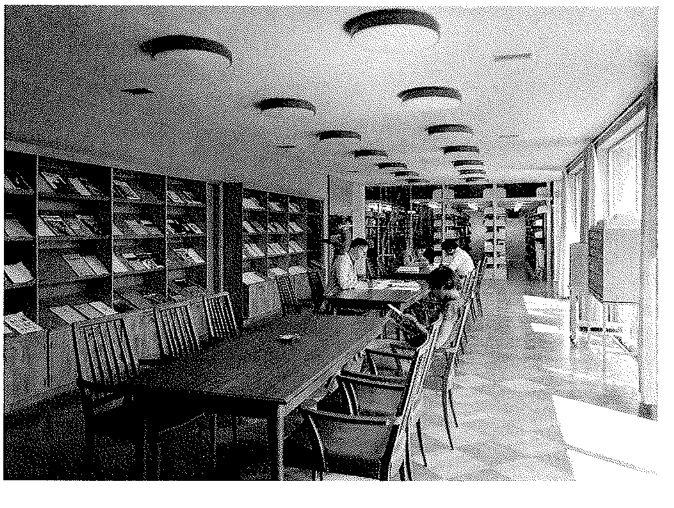
A second meeting of Committee of Council followed soon, on May 18, 1973 in preparation for the June Council meeting. The fact that, in this case, two meetings of this Committee preceded the Council meeting reflects the concern about developments felt by the Directorate as well as by the SPC. This concern found its expression in a rather extensive document, Cou-142, prepared by the Directorate: "Notes Concerning some Imminent Problems and Related Matters" of May 10, 1973 [13]. With the termination of the current terms of appointment of the Director in Chile (per June 1974) and of the Director General (per January 1975) in sight, the document reviewed, more broadly than had been done before, developments within ESO that required early adjustment or clarification. It paid special attention to certain aspects of the Office of the General Directorate and to ESO's geographic and organizational structure, including the suggestion that part of the astronomical activities in Chile might be incorporated in the establishment in Europe.

Most of the extensive discussion in the Council Meeting of June 5 and 6, 1973 was devoted to these problems, both on the basis of an extensive report of the Chairman of the SPC, B. Strömgren, and in reaction to the above-mentioned document, Cou-142. There was uneasiness about the Workshop proposal. However, with the prospect of a review of ESO's entire structure, no final conclusion was reached and the Directorate was requested to submit to Council *"– – – proposals and possibly alternative proposals on the future role of ESO in encouraging and organizing cooperation in research in the Member States, and in promoting the development and construction of the auxiliary instrumentation – – – "*; this study *"– – – to be used for the preparation of decisions on the future structure of the Organization. – – – ".*

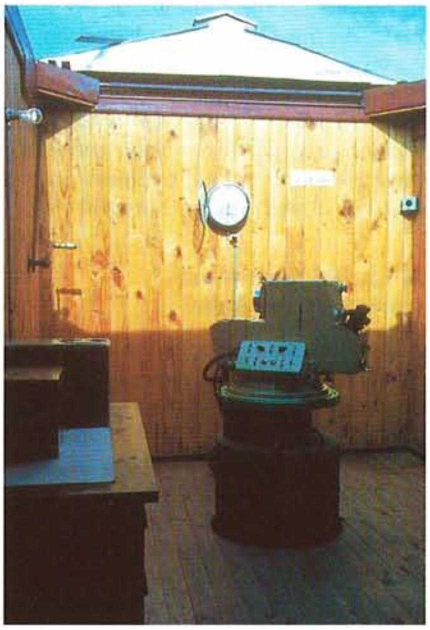
At this meeting, the SPC was strengthened by the appointment of Lodewijk Woltjer as its fourth member, and broad consultation with astronomers in the member states was encouraged [14].

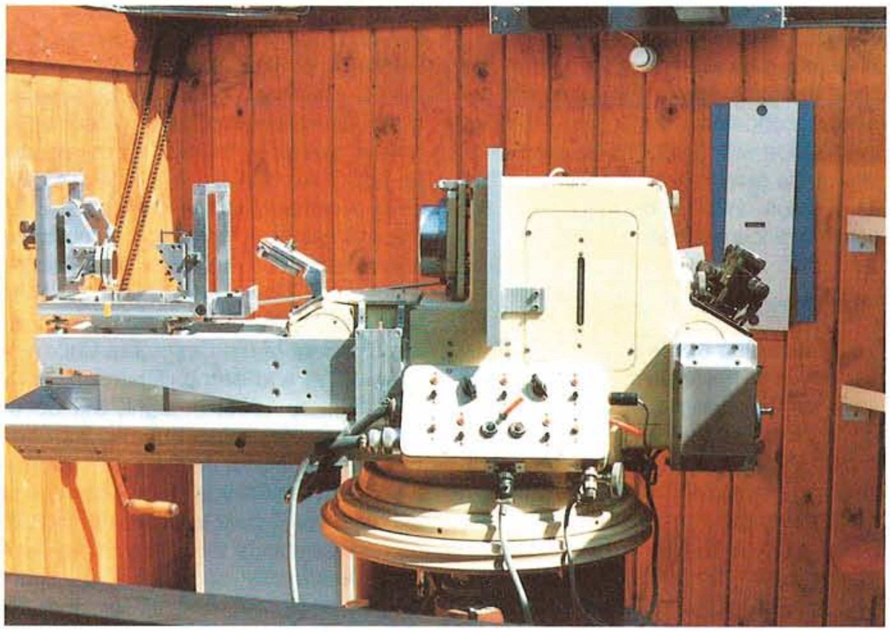
A Formal Statement from German Side

Besides the above necessarily very condensed account on these deliberations on general policy in the middle of 1973 (in fact, too condensed to reflect the range and depth of the discussions), we must record an initiative that would turn out to have far-reaching consequences for ESO. It was at this Council Meeting of June 1973 (as well as at the preceding meeting of Committee of Council), that a remarkable formal statement was read by the German delegate. After referring to the *"observatoire de mission"* concept favoured from German side, the statement, apart from other items, expressed the opinion that with the completion of the 3.6-m telescope ESO's activities would be mainly in Chile, including the office of the Director General. However, as to the services then left in Europe, it said *" – – – if ESO feels the necessity to put its European office at Hamburg in a stronger position, – – – I am authorized to state: My government is ready to give all its support to hosting ESO in the Federal Republic of Germany under optimal conditions, thus promoting the European cooperation which is one of our principal aims – – – " [15].* At the meeting of Committee of Council preceding this Council meeting, the President of the SPC, Strömgren, had shown particular interest in this



ESO Headquarters in Santiago
After the dedications in Chile in 1969, the Headquarters in Santiago housed the administrative services and assumed an increasingly important role in ESO's activities in Chile. In these photographs: at left: the Headquarters building seen from the entrance gate; at right: the reading room in the library with in the foreground, at left and right, astronomers François and Monique Spite.
From photographs in the EHPA.





The ESO Astrolabe at Cerro Calan Observatory

Since its installation, at the end of 1965, at Cerro Calan Observatory of the University of Chile, the Astrolabe has been in regular operation. Under the supervision of C. Anguita and F. Noël it observed, among other objects, the stars in the FK4 Catalogue which embodied the fundamental reference system of stellar positions, and it contributed important improvements to this system. The collaborative agreement between Cerro Calan and ESO dates from April 29, 1965; by this agreement, the desire expressed in the ESO Convention for ESO contributing to positional astronomy was fulfilled. The above photographs show: at left, the astrolabe in its removable covers, and at right, after the covers have been taken away. The photograph below shows Cerro Calan Observatory, in the outskirts of Santiago, with the Astrolabe housing in the lower right. These photographs were kindly made available by Dr. F. Noël.

statement and expressed the hope that the proposition might be studied in depth in connection with the problems presented in Doc. Cou-142 [16].

Response by Directorate and SPC, Doc. Cou-150

In response to Council's request the Directorate submitted by the end of 1973 an extensive recommendation, Doc. Cou-150. Annexed to it were "Considerations by the Director General" as well as supporting reports on behalf of the SPC and the Instrumentation Committee, and Notes by the Director in Chile. The SPC had thoroughly discussed the items raised in document Cou-142 at its meeting of September 14; it had invited for this, apart from its membership (Strömgren, Biermann, Pecker und Woltjer) also the Chairman of the IC, J. Borgman, and B. Gregory, former Director General of CERN and now Director of CNRS, and R. Lüst, President of the Max-Planck-Gesellschaft.

Among its main items document Cou-150 supported the Workshop Programme, however for the organization and follow-up it recommended establishing a small group of ESO staff astronomers that would also incorporate the Visiting Astronomers Service (the organization of the observational programmes in Chile), and that should closely collaborate with the TP Division. Furthermore, it strongly recommended [17]:

"I. To consolidate the activities of ESO in Europe by removing the present activities at Hamburg to Geneva during the 5-years period [required for the completion of the work of the TP Division]:

II. To review before the end of this 5-years period – preferably within the next 2 years – the question of the location of the consolidated headquarters in Europe on the basis of ESO's scientific purposes."

Council's Resolution December 1973; the German Offer

Thorough deliberations of Council in its meeting of December 13-14, 1973, partly in closed session, resulted in a long and detailed formal resolution [18]. It supported the Workshop Programme but wished it to be executed by Visiting

Scientists on leave of absence from (preferably) European institutes instead of the proposed nucleus of ESO staff. It did, however, recognize the importance of simplification of the structure of ESO and in this connection *"Gratefully acknowledge[d] the possibility offered by the German Government to establish the Headquarters as well as other facilities of the Organization in the neighbourhood of German astronomical and technological establishments ---* ". It requested the Director General to *"study the offer of the German Government as well as any other proposals which might emanate from Member States for the Organization's Headquarters and other facilities in Europe."*, and *"to make proposals for a provisional transfer of his office, or part of it, to the site of the TP Division --- "*.

The German offer referred to in this resolution had meanwhile become more explicit than half a year earlier. A statement by the German astronomical Council delegate reported positive reactions among German astronomers (including the Rat Westdeutscher Sternwarten) with regard to the recommendations in document Cou-150, but added: *"German astronomers would be very happy if in the long run not only the [ESO] Administration, but also scientific activities could be located in our country"*, and specifically mentioned the possibility of an establishment in conjunction with the astrophysical institutes at Garching near München. More explicit statements were presented by both the Government delegate on Council and a representative of the Foreign Ministry of the Federal Republic, who especially for this item joined the German delegation. According to the former *"--- it was necessary to distribute research organizations fairly throughout Europe, --- avoiding a concentration of efforts in one place ---* ", reasons why *"the German delegation had been instructed to say that part of the proposal presented was difficult for the German Government to accept."* The representative from the Foreign Ministry, after referring to the effect of the choice of a site on public opinion, added *"--- all the more so when so few international organizations are located on [our] territory"*, and concluded with *"My Government, therefore, would be grateful if ESO were to accept the offer of a suitable site in Germany."*

The Political Aspect

Clearly, for the German delegation the question of the location of the future centre of ESO had grown to include more than just the interest of ESO itself: it had a political aspect. Whereas nearly all European organizations had their headquarters outside the GFR, notably in Geneva, Paris, Brussels, Rome, etc., there were very few within the GFR notwithstanding the fact that the GFR was one of the main financial contributers. With ESO's administrative headquarters and some related services having been in the GFR since their creation, it had become a concern at government level not to let ESO also drift to other territory. With astronomy at large gradually entering the era of "big science", ESO, too, unavoidably entered the domain of political attention.

The Year 1974: the Centre in Sight

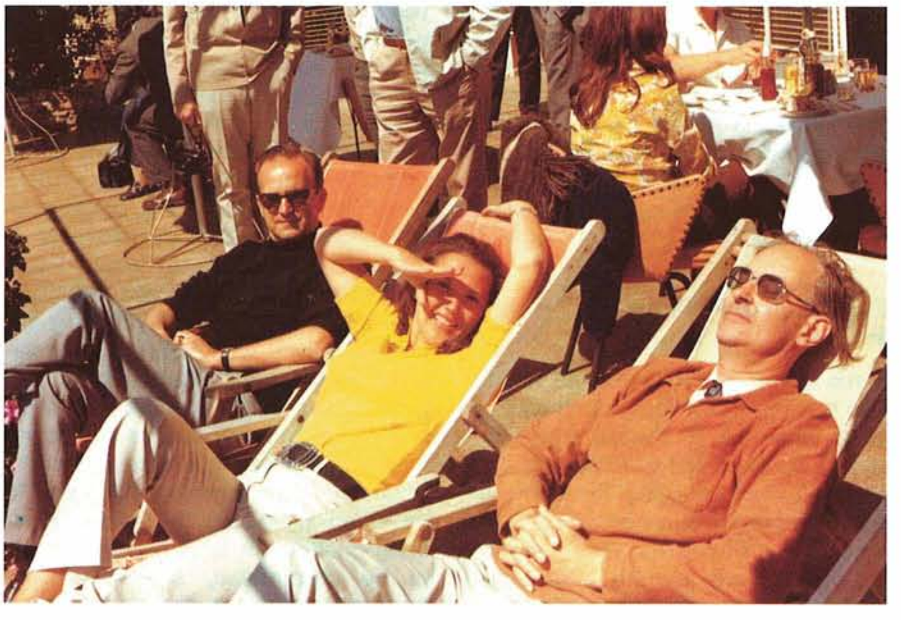
During the year 1974, a variety of measures in Chile absorbed a good deal of the managerial capacity of the ESO Directorate. An interim report on the implementation of the Council resolution, presented at the June 1974 meeting of Council, revealed that no alternative offers for sites for the European Headquarters were to be anticipated from Denmark, Sweden and the Netherlands, and the German offer had been the subject of consultation between the Directorate, the SPC and the Max-Planck-Gesellschaft. A study of the temporary transfer of Hamburg facilities to Geneva was under way [19]. A promising step towards orientation of research with the 3.6-m Telescope, had been the successful ESO/SRC/CERN conference on research programmes, held at CERN on May 27-31, 1974 [20].

Naturally, by this time, mid-1974, many of the measures had to be viewed in anticipation of the succession in the General Directorate per 1 January 1975. Meanwhile, two important future developments began to stand out: a temporary enhancement of the role of the TP Division by the incorporation of services so far located at the Hamburg Office, and the prospect of the creation of a comprehensive and representative Headquarters near Munich.

By the end of the year, the views of the new Director General, Lodewijk Woltjer, had firmly put their stamp on further planning, as is apparent from the following quotation from the minutes of the meeting of Committee of Council of November 1, 1974 *"--- B. As to the creation of an astronomical Centre in Europe, which had been made a condition by Professor Woltjer for his acceptance of the position of Director General, --- a course of action would seem to be acceptable --- which would comprise the following: 1) In the frame of the 1975 budget, --- to start recruiting a nucleus team for the astronomical centre. ---* ". The Centre was envisaged to be established temporarily on the premises of CERN [21].

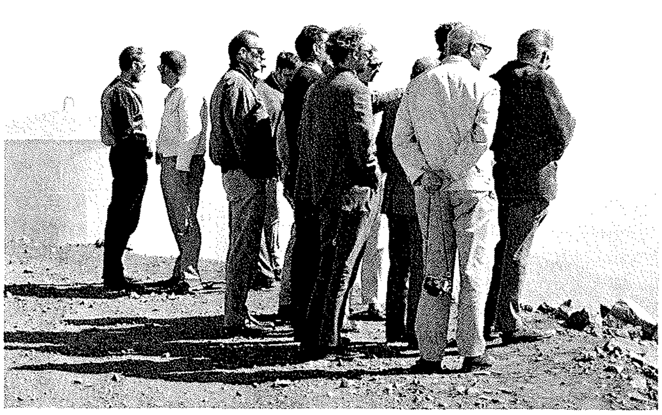
B. ESO's Geographical Dispersion

From the time when, in March 1969, the dedications in Chile concluded the first phase of constructions and the Headquarters in the Vitacura suburb of



Bus Stop at Los Vilos

Early October 1971 the ESO Finance Committee held its (21st) meeting in Chile (its second one in that country). As was customary in those days, the trip from Santiago to La Serena was made by bus, with a lunch stop at Los Vilos or Pichidangui in flowery surroundings at the coast. Shown here, during a moment of post-lunch relaxing, from left to right: C. Zelle (President Finance Committee), Hedwig Geier (Secretary of Director General), and the author.



Finance Committee in Chile
In October 1971 Finance Committee made itself acquainted with developments on La Silla, in La Serena and in Santiago. In these photographs, taken on La Silla, from left to right:
Left photograph: Miss H. Geier (Secr. of Dir. Gen.), H. Grage (DK), C. Zelle (GFR; partly hidden behind Grage), B. Samuelsson (S), A. Blaauw (Dir. Gen.), H. Dumont (F), P.A. Berniard (F).
Right photograph: M. de Groot and H.-E. Schuster (ESO astronomers), and in the front row C. Zelle (GFR), H. Dumont (F), H. Grage (DK), P.J. Fierst van Wijnandsbergen (NL), B.E. Westerlund (ESO Dir. Chile).
From photographs in EHPA.

Santiago assumed its functions, the La Serena Office became of secondary importance but it remained indispensable as a base for the La Silla operations. Besides these three Chile components, there were the Guesthouse, also in Santiago not far from the Headquarters, and at the base of La Silla the Pelícano complex of storehouse and services, in use since the very first construction activities for La Silla. Visitors from abroad wondered at this multitude of settlements, and it is not surprising that members of Council and Finance Committee on the occasion of their visits to Chile critically enquired whether not the situation implied inefficient use of manpower and finances. We have seen in article VII that, indeed, in 1969 this was one of the items of review by the Working Group of Funke, Alline and Scheidemann; however, the Group refrained from recommending changes.

Extension of Facilities in Chile

The question of the structure in Chile was brought to the foreground again in 1972, when the TP Division's activities had to be extended to Chile: the construction of the building and dome for the telescope, and related auxiliary and support constructions (for instance, lodging facilities for the construction workers). In addition to this, an extensive (and expensive) programme lay ahead for providing facilities required for the operational phase with its increased observational activity. A comprehensive scheme, drafted in collaboration between the TP Division, the Directorate in Chile and the General Directorate was submitted to FC and Council in April 1972 [22].

This scheme foresaw, besides constructions in La Serena and on La Silla, also extension of the Headquarters in Santiago, but Council in its meeting in June 1972 considered that this could not be separated from the long-range policy for the establishments in Chile: *"whereas from the beginning it was decided to create in Santiago the Headquarters --- and this policy of Council was maintained for almost 15 years, in recent times the question arose whether, indeed, there are not disadvantages in having these establishments so far from La Silla and whether not the operation of the Observatory is hampered by the remoteness of the facilities in Santiago. ---* " [23]. Decisions on the building programme were postponed until, in November of the same year, Council would judge matters in situ during its visit to Chile.

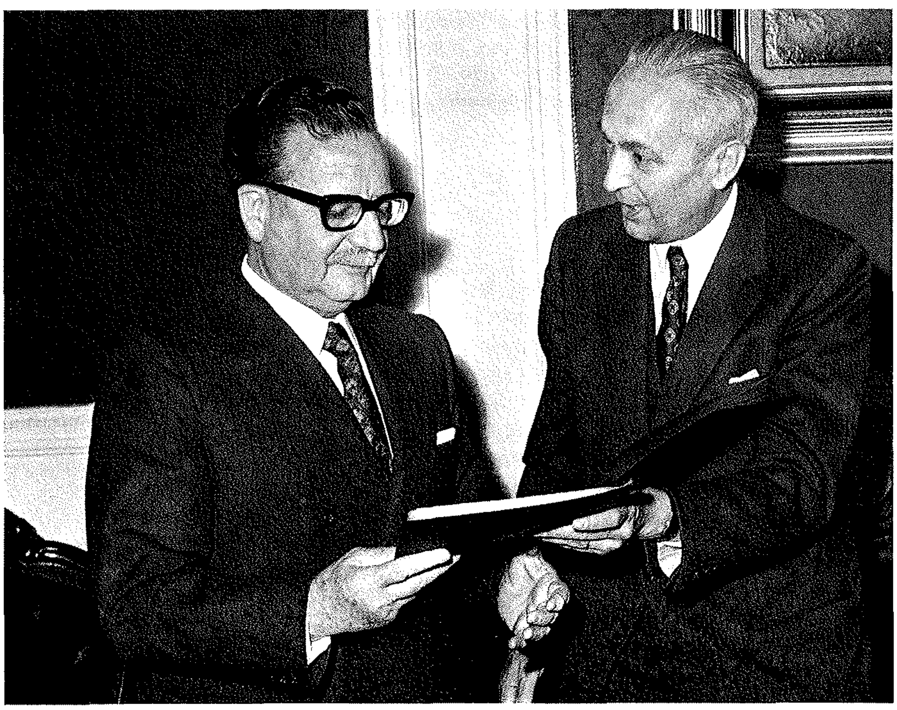
At this November, 1972 meeting important moves were made indeed toward the extension of facilities in Chile. In La Serena, land was to be purchased next to ESO's Las Cisternas compound for the construction of more housing of ESO staff and a technical office was to be added; in the La Silla – Pelícano area, living quarters for local personnel were to be constructed, and workshops, storehouses and service stations were to be moved to La Silla. The proposed extension of the Santiago Headquarters, however, was not granted and it was contemplated to sell the Guesthouse and have it incorporated in the Headquarters establishment at Vitacura. Transfer of the Headquarters or part of it to La Serena was not favoured for the time being, in view of the increased activities now expected in the La Serena area [24]. Also, at this time, in the context of proposals for the ESO Centre, serious consideration was given to the proposition that part of the Vitacura services be moved to Europe [25].

Moving "Vitacura" to La Serena?

An important next step was, a year later, the recommendation by the Director General and the SPC of November 1973, in Document Cou-150 to which we referred before. With regard to the integration within Chile it recommended to further investigate *"the advantages (respectively disadvantages) and financial implications of a move of the Vitacura establishment to La Serena, in order that by the time the 3.6-m telescope comes into operation (medio 1976) the optimal geographic structure in Chile may be attained"* [26].

Naturally such a move would have far-reaching consequences for the work and the living conditions of ESO's staff in Chile. The views of ESO's Director in Chile, B.E. Westerlund, presented in the preparation of Cou-150, were included as Annex IV to this document. As a result of his balanced weighing of the advantages and disadvantages of a move, Westerlund concluded: *"Summarizing today (27.10.1973) my feelings on Santiago versus La Serena I conclude that if ESO makes an effort to solve [problems concerning schooling, medical assistance and cultural environ-*

Visit to President Allende
On the occasion of Council's visit to Chile, in November 1972, a delegation from ESO paid a visit to the President of the Republic of Chile. The top photograph shows President Salvador Allende talking to, from left to right: A. Alline, President of the ESO Council; A. Blaauw, Director General of ESO; C. Zelle, President of Finance Committee; B.E. Westerlund, Director of ESO for Chile; and (seen from behind) B. Strömgren, President of Scientific Policy Committee. Bottom photograph: A. Alline presenting President Allende with a collection of pictures of ESO.



ment], most staff will see a move with calm. If it is worth from an economical and PR view, I do not know. With "normal" time returning to Chile in the future, I doubt it." These latter words remind us of the facts that economic conditions in Chile in the course of the past years had strongly deteriorated, that six weeks before Westerlund wrote this letter the coup d'Etat had taken place, and future conditions in Chile seemed unpredictable.

The Council meeting of December 1973 requested the Directorate to prepare specific proposals for restructuring in Chile and redistribution of tasks between Chile and Europe [27].

The Year 1974: Restructuring in Sight

Restructuring in Chile was pursued in 1974 but at a slow pace due to the special circumstances that developed in this country, and also because views of the new Director General would more and more have to be taken into account. The minutes of the Council meeting in June of this year reported: *"Regarding a transfer of the Vitacura facilities, studies were under way with a view to finding an adequate alternative site at La Serena. Certain contacts had been made with the local government official concerned (Intendente) during the spring of 1974. Any further negotiations would be conducted probably on the Foreign Ministry level. There would be the question of construction costs and of social implications, including the provision of school and medical facilities. --- For*

La Silla on Chilean Post Stamp

On April 25, 1973 Chile issued a post stamp depicting the 1-m Photometric Telescope with part of La Silla in the background. On the artist's sketch we recognize the flattened top on which the 3.6-m Telescope was to be erected and, in front of it, the Schmidt telescope building and part of that of the GPO. Photographed from a leaflet describing the Observatory, issued by the Dirección Nacional de Correos y Telecomunicaciones de Chile, and carrying the First-day-of-issue stamp. (Property of the author.)

the further improvement of communications, particularly in circumstances where rapid transport was required, an air-strip was being constructed at Pelícano under a recent Council decision. – – – " [28].

Giving final shape to restructuring in Chile would be the task for the new Director General. Drastic measures were in the air, including considerable reduction of the role of the Vitacura Headquarters.

THE FINANCIAL STORY

Reviewing finances, we distinguish three phases: the pre-Convention period, beginning early 1954 when it was proposed to create ESO and ending early 1964 after the signing and ratification of the Convention, the next one concluding with the dedications in Chile in 1969, and the third one ending in more or less open-ended way in the middle 1970's with the completion of the 3.6-m Telescope Project.

The Pre-Convention Period, 1954–1963

These early years called for improvization. With the Convention still pending, there was no internationally agreed obligation for the governments to provide financial means for preparatory work that could be taken up right away: site tests in South Africa and planning for the instrumentation and first design studies. One wished to go ahead, and fortunately so, for, as we have seen, it took nearly ten years before the Convention was ratified.

Under the supervision of the ESO Committee (the predecessor of the ESO Council), budget estimates were drafted and the funds required were obtained in different ways in the various countries. In the Netherlands and Sweden, the government-sponsored science foundations supported the ESO project on a year-to-year basis, and in other countries ministries of science or their equivalent collaborated; the ESO archives do not clearly reveal their exact nature. The efforts were co-ordinated and administration was carried by the provisional treasurer J.H. Bannier.

For fixing the shares of the five participating countries after, in an early stage, Great Britain had withdrawn, the following key was used: the Federal Republic and France would pay one third each, with the remaining one third to be shared by Belgium, the Netherlands and Sweden proportionately to their Gross National Incomes (which at that epoch were virtually equal). The system was flexible enough for one or more of the partners to help out with an advance if financial problems arose in one of the other states, and in the years 1958 and 1959, when no financial contributions could be expected from internally disturbed France (see article I), these were bridged by a temporary arrangement by which Germany paid 49% and the other partners about 17% each [29].

Naturally, the lack of financial guarantee was a serious drawback, but on the other hand, the situation left room for improvization. Budget estimates made and agreed upon in advance of the fiscal year could fairly easily be adjusted later if developments required so, and in such cases the ESO Committee benefitted much from the authority which members of the Committee carried in their consultation with government officials at home. As a consequence, establishing now the amount of the early contributions from the financial documents left in the ESO Archives is done more by means of *a posteriori* reports than by looking at the advance budget plannings.

About Dollars and Deutschmarks

The currency in which the budget estimates and, hence, the contributions of the member states were expressed during the first two decades (in fact until 1973) was the US Dollar, with the exception of a brief period in the very beginning when the English Pound figured. The choice of the dollar was a natural one: cost estimates of instrumentation were mostly based on American experience, the dollar tended to be stable and the choice was not biassed towards any of the ESO partners. Yet, for the presentation in this article I shall use the Deutschmark, the currency in which ESO budgets nowadays are defined. This gives a better feeling of costs and contributions when compared to those of modern European operations.

For the conversion factors of Dollars into Deutschmarks over the years I used tables provided by the ESO Administration [30]. Until 1970 the rate was about 4 DM per Dollar, during the 1970's it gradually diminished to 1.8 DM per Dollar and rose again in subsequent years. However, using this currency is not enough for the desired comparison; we also must take into account the inflation over the years, i.e. the gradual change (decrease) of the purchasing power of the DM. Where this is done here, it is based on inflation tables also provided by ESO [31]. To give an idea of its importance: in the second half of the 1960's the purchasing power of the DM was about 1.8 times larger than by the time (1976) the 3.6-m Telescope became operational, and it was 2.7 times larger than it is at present (1990). The inflation of the DM has been very smooth; it is illustrated at the bottom of Figure C.

In what follows I shall use the following notations:

– DM for Deutschmark converted from dollars at the rate valid at the epoch concerned;

– dm for Deutschmark adjusted to present day level taking into account the inflation.

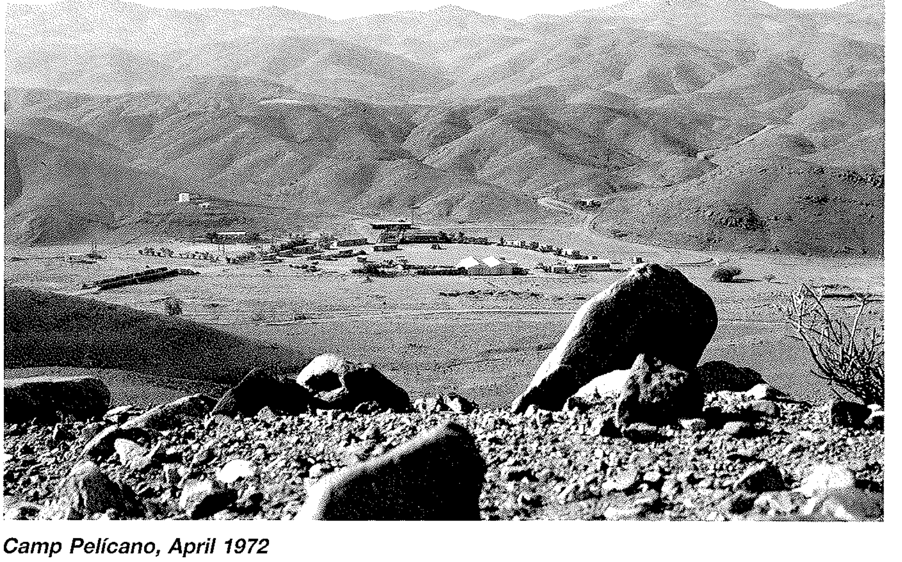
The principal source of information used for the present compilation are the reports of the external auditors of ESO. These are agencies, designated in turn from the member states, with the assignment to scrutinize from impartial point of view the financial administration of the Organization. Sometimes their reports also, bring up matters of management. These quite valuable reports form part of the files of the Head of Administration [32]. For the period preceding the ratification of the Convention, for which auditor's reports are not always available, part of the data was derived from the minutes of the meetings of the ESO Committee [33].

Early Annual Contributions and Project Costs

We first illustrate the development of the total of the early annual contributions of the member states; see Figure A. Here, no corrections for inflation have been applied yet. We see that from 1955 to 1963 the contributions grew from about 100.000 DM to 2 million DM. Integrated over the years ending with 1963 we find a total of 6.8 million DM (17 million dm). During these early years contributions were used partly for the site testing expeditions and for the research programmes carried out in the context of these tests and described in article II: the Tübingen photometric work and the Marseilles radial velocity project with the GPO telescope. However, a sizeable unspent balance was also built up before the beginning of the post-Convention years; by the end of 1964 it amounted to about 9 million DM (about 22 million dm), including the grant of one million dollar of the Ford Foundation (see article I) which was transferred to ESO in 1964, corresponding to 4.0 million DM (9.4 dm).

Early Cost Estimates

Starting point for the early long-range financial planning were, naturally, estimates of the total investment costs required for the establishment of the Observatory, accompanied by predictions of the ultimate running costs. In article I, I quoted the figures mentioned at the June 21, 1953 meeting of the ESO Committee: capital investments of $ 2.5 million (DM 10.5 million) and annual running costs of $ 100.000 (DM 420.000), as well as the revised figures of January 1954: $ 3.5 million (DM 14.7 million) for capital investments and $ 126.000 (DM 530.000) for running costs. In subsequent years the estimates of the capital investments increased and reached a value of $ 5 million (DM 21 million, dm 56 million) around the years 1957 to 1960, a figure we encountered already in connection with the grant of one million dollars from the Ford Foundation described in



Camp Pelícano, April 1972
In the context of the restructuring of ESO in Chile, part of the logistic services that had developed at Camp Pelícano from the earliest construction stages on La Silla, were moved to La Silla, but the Camp continued to be the entrance gate to the Observatory. A comparison with the photograph taken in Januar 1966, shown on page 29 of the Messenger *No. 58 (article V), shows the development over six years. On the nearest side we recognize the two large storage buildings.*
Photograph in EHPA.

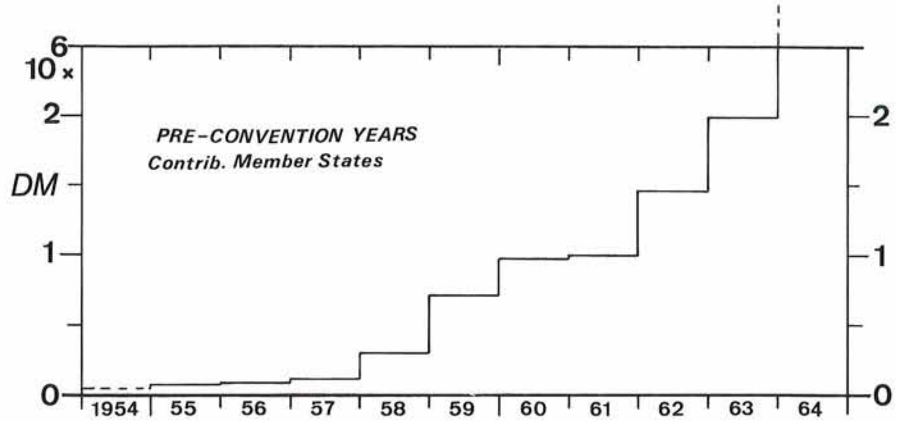


Figure A: *The total of the annual financial contributions of the prospective member states over the period from conception of ESO till the ratifications in 1964. The principal expenses to be defrayed from these contributions were the site testing expeditions in South Africa and the connected observational programmes with the Marseilles GPO and the Tübingen photometric telescope.*

article I, and at that moment equivalent to the average share of one of the five potential member states. This estimate of $ 5 million figured prominantly in negotiations with government agencies in the years of struggling for getting the Convention signed; in fact so prominently that years later, when it had been amply exceeded, certain government delegates could take naughty pleasure in bringing it back to astronomers' recollection . . .

The $ 5 million estimate was based on the following components:

an up-to-date estimate of the costs of the Lick 120-inch telescope	$ 3.500.00
an up-to-date estimate of the costs of a copy of the Palomar Schmidt	600.000
meridian circle and auxiliary instruments	100.000
workshops, buildings, houses	100.000
roads, power, water	100.000
unspecified	600.000
	$ 5.000.000

and on erection of the Observatory in South Africa. It figured, for instance, in the discussions in the EC meetings of April 1957 [34] and October 1958 [35]. It was estimated that the payments would be spread over 5 years once constructions could be started.

The Post-Convention Years

This time schedule of five years probably was still more or less what Heckmann had in mind when in his First Annual Report after ratification of the Convention, over the year 1964, he esti-

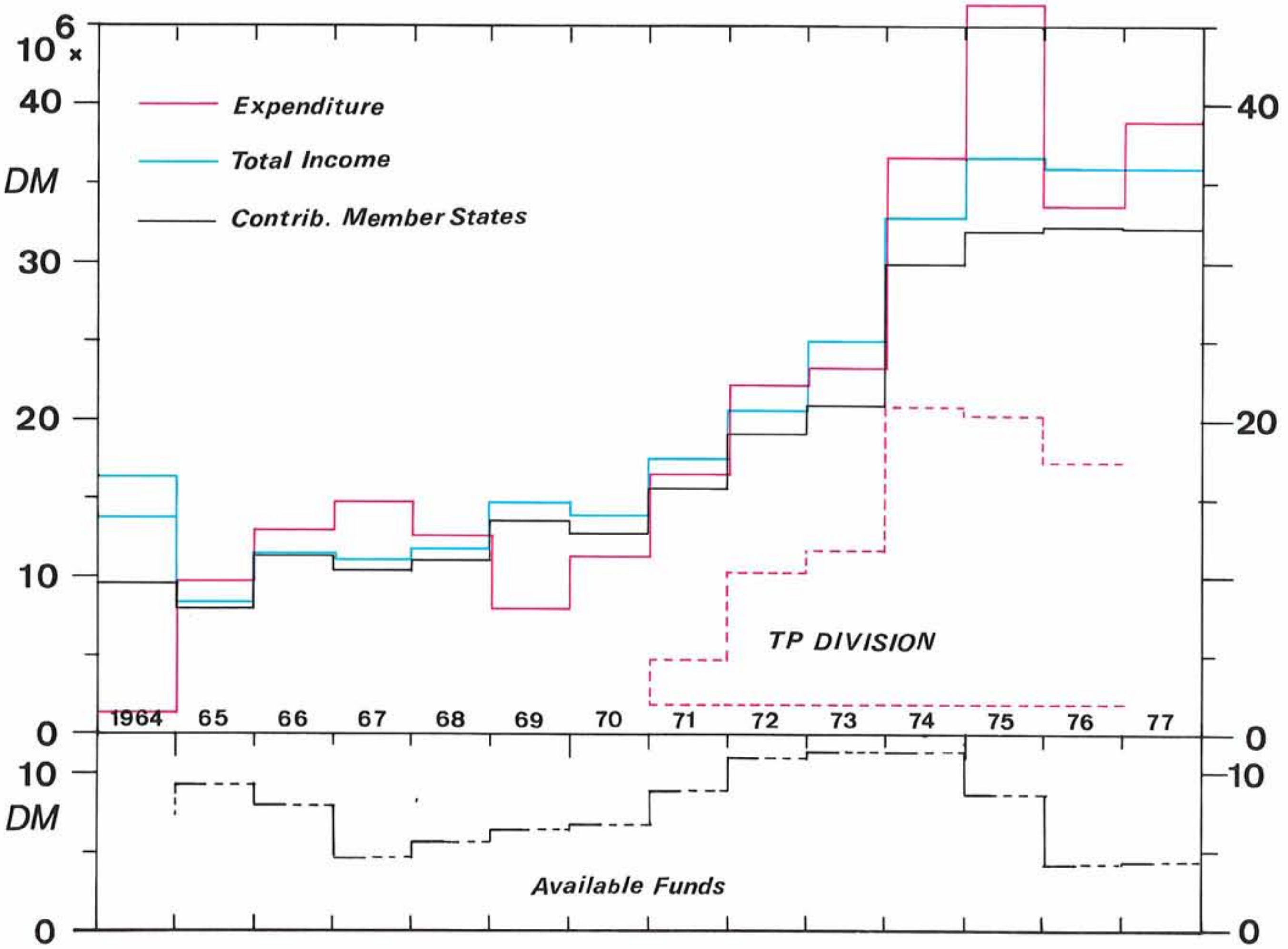


Figure B, top part: Black line: *The annual contribution of the member states over the first 14 years following the ratifications.* Blue line: *The annual contributions increased with additional sources of income including interest from unspent balances ("Available Funds").* Red line: *Expenditures; The dashed part represents the share of the TP Division in the years 1971 and later. Bottom part: Development of Available Funds (expressed in Million DM).*

mated that up to the end of 1970 the total capital investment would amount to about $ 12.824.000 to which part of $ 2.166.000 for Overhead expenses would have to be added, hence about $ 14 million altogether i.e. dm 132 million. At that time, plans for the major instrumentation had changed radically; not a copy of the Lick telescope but the more powerful and considerably modified 3.6-m Telescope was planned, and also the Schmidt design had been modified. Of course, the principal component of the budget was the 3.6-m Telescope. Its costs, including building and dome was in 1962 estimated to be $ 7.400.000 but a revised figure at the November, 1966 meeting of the FC became about $ 1.2 million higher (mostly due to inflation), hence about $ 8.6 million [36], i.e. 76 million dm.

Finally, at the end of the 1960's, an estimate of the total cost of the 3.6-m Telescope Project was contained in the report Cou-59 referred to in article IX. It was compiled by the Technical Director J. Ramberg in preparation for the December 1969 Council meeting at the time when the new course for the realization of the telescope was under consideration. A breakdown into the main components of Ramberg's estimate follows:

For the Telescope:	
further design and development	$ 1.000.000
the optics	1.715.000
the mechanical parts	1.450.000
electric and electronic components	1.100.000
aluminizing plant	210.000
freight and assembling	750.000
For the building	2.500.000
For the dome	1.200.000
	$ 9.925.000

corresponding to DM 39 million or dm 82 million.

In comparison to the pre-Convention estimates, another radical change resulted from the switch from South Africa to Chile, where construction costs, including those connected with water supply, power installations, and road constructions would have to be much higher than had been foreseen for South Africa.

The Annual Contributions from 1964

In Figure B, the black line shows the joint annual contributions starting from 1964, the year in which the Convention was ratified. They are in DM, not yet adjusted for inflation. The blue line shows the annual contributions increased by additional sources of income, such as interest gained over unspent funds and increases or losses resulting from parity changes between the various currencies in which ESO held its bank accounts, and also the entrance fee of Denmark (spread over the years 1967, 1968 and 1970). The red line shows the expenditures. Unlike the principle I adopted for the earlier articles, to describe only developments reaching into the early 1970's, in the present context we follow developments into the late 1970's.

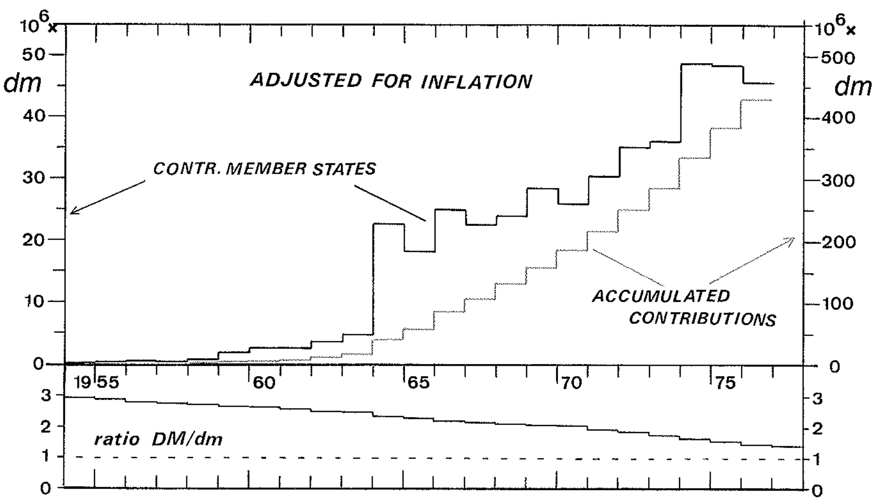


Figure C: Top part. The black line *shows the annual contribution of the member states over the first two decades since 1954, adjusted for inflation (i.e. expressed in the purchasing power of the Deutschmark of 1990). The* blue line *shows the accumulated contribution, i.e. the total of the contributions up to and including the year indicated at the bottom of the figure, and also adjusted for inflation; this line has been derived from the black one.* Bottom part. *This line shows the gradual change of the ratio between the purchasing power of the Deutschmark at the year indicated, and that in 1990. These ratios were used for obtaining the top part of the figure.*

Conflicting Interests and the Bannier Procedure

We note, in Figure B, the smooth gradual increase of the contributions up to around 1975, in contrast to the stronger fluctuations in the curve of the expenditures. Such strong fluctuations are typical for a project in its construction phase (in this case the work of the TP Division), but they entail conflicting interests. On the one hand, that of the project management that wishes to realize it expediently and therefore needs to dispose of a considerable sum over a limited period. On the other hand, that of the funding agencies, in this case the governments of the member states, who dislike strong fluctuations in their budgets. Moreover, it is customary for government budgeting to avoid commitments beyond the next budget year although, of course, there must be room for long-term projects.

In order to avoid the undesirable shock effect that steep rises in the ESO budget might have, a system was adopted around the year 1970, introduced earlier at CERN and known by the name of its initiator: the [J. H.] Bannier procedure. It requested the organization not only to submit its budget proposal for the coming year, but also to deposit at the funding ministries a well-founded estimate for the year following and an approximate one for the third year. The system has helped paving the way for the rapid growth of the ESO budget in the early 1970's.

First Post-Convention Years, 1964–1969

Soon after the Convention had been signed the construction programme in Chile, described in articles V and VI, began to absorb considerable financial means. Accordingly, the annual contributions had to increase, but part of the expenses could be defrayed from the reserves that had been accumulated before 1965. By the time of the completion of the first phase, marked by the dedications on La Silla in March 1969, expenditures went down. This had not been foreseen originally, for at that time it should have been the turn for construction costs of the 3.6-m Telescope and the Schmidt, however, as we have seen in articles VII and IX, these were delayed. This explains the dip in the expenses for the years 1969 and 1970.

Yet, in that period the annual contributions continued to grow. This was partly due to late realization that progress in the telescope constructions would be below expectation, but it also reflected the expectation that soon considerable expenses for these projects would be due anyhow. Thus, reserves were built up again around the year 1970 that came useful at later dates. The bottom part of Figure B shows how these reserves (called Available Funds in the external auditors' reports) developed in the course of time. Naturally, it was tempting for the financing authorities to use these reserves for reducing next years' contributions. Moreover, for an organization like ESO to put considerable funds on a profitable savings account meets little sympathy on the side of the funding agencies. Luckily, ESO Council and Finance Committee were tolerant in this matter.

The Years 1971–76; The TP Division

The early 1970's saw the creation of the TP Division for the realization of the 3.6-m Telescope, and one of its first tasks was reliable budget planning. As a consequence, the required annual contributions rose steeply to a level that in the years 1974 and 1975 amounted to more than twice that around the year 1970. The documentation mentioned before allows singling out the financing of the TP Division from the remaining expenses. This leads to the presentation in Figure B. The dashed red contours outline the share of the Division and illustrate that it was responsible for the rapid increase of income and expenses in the early 1970's. Roughly speaking, TP Division expenses through 1976 concerned the 3.6-m Telescope with its building and dome, whereas in subsequent years emphasis shifted to auxiliary instrumentation as part of the regular running costs, and hence annual contributions and expenses then levelled off. Over the period 1971 to 1976 (the year of completion of the 3.6-m Telescope), the integrated expenditure of the TP Division amounted to DM 74 million. We saw that Ramberg's estimate of the year 1969 amounted to DM 39 million; adjusting this to 1975 for inflation would give about DM 52 million.

Overall Developments Since 1954

In Figure C the black line shows the overall development of the annual contributions over the first two decades from 1954, and this time all figures are in dm, i.e. adjusted to the 1990 purchasing power of the Deutschmark; the amounts are marked along the left-hand scale. We see that after 1964 there was a decade of approximately linear increase of the contributions followed by an extra growth around the completion of the large telescope, and subsequently levelling off when ESO's full operational stage had been reached.

The blue line shows the accumulated contributions, also in dm, and to be read along the right-hand scale. We infer that by the time the 3.6-m Telescope became operational, ESO had spent altogether about 400 million dm. Of these, the expenditure by the TP Division had been about 113 million dm, i.e. about 28%. A somewhat larger amount, about 150 million dm, 38%, had been spent up to 1970 when ESO's first phase had been concluded with the dedications on La Silla. 34%, or about one third, had been spent after 1969 on the operations and new construction programmes in Chile and on the services (including that for the Visiting Astronomers) at the (provisional) Headquarters in Hamburg-Bergedorf.

References and Notes

Abbreviations used:
EHA = ESO Historical Archives.
FHA = Files Head of Administration at ESO.
EHPA = ESO Historical Photographs Archives.

[1] FHA Doc. Cou-62, Minutes 14th Cou Meeting, p.16.
[2] See Ref. [1], p.10.
[3] FHA Doc. Cou-96, Minutes 17th Cou Meeting, p.31.
[4] See, for instance, the minutes of Cou and FC over the years 1971–1973.
[5] This proposal served for discussion in closed session at the 2nd meeting of the SPC and is not in the FHA. Its contents is reported in the minutes of this meeting, Doc. SPC-2 in FHA.
[6] See, for instance, the compilation "Publications based on observational work at the ESO Observatory La Silla", of Nov. 1974, Doc. OPC-20 in FHA-Sc.Act.
[7] Minutes of this meeting with attached report of Chairman SPC to C. of Cou., Doc. Cou-121rev. in FHA.
[8] See Doc. Cou-126 of Oct. 20, 1972 in FHA.
[9] FHA Doc. Cou-127, Minutes of C. of Cou.
[10] FHA Doc. Cou-126rev.
[11] FHA Doc. Cou-131, Summary 20th meeting of Council; see also discussion of this topic in minutes 21st Cou meeting, Doc. Cou-149.
[12] Report Chairman SPC and Minutes C. of Cou., Docs. Cou-145 and Cou-136 in FHA.
[13] FHA Doc. Cou-142.
[14] FHA Doc. Cou-149, Minutes 21st Cou. meeting.
[15] See Ref. [9].
[16] FHA Doc. Cou-147, Minutes 8th meeting C. of Cou., p.9.
[17] FHA Doc. Cou-150, p.7.
[18] FHA Doc. Cou-162, Minutes 22nd Cou. meeting, p. 21–23.
[19] FHA Doc. Cou-175, Minutes 23rd Cou. meeting.
[20] Proceedings of the ESO/SRC/CERN Conference on Research Programmes for the New Large Telescopes, Ed., A. Reiz, 1974.
[21] FHA Doc. Cou-179, Minutes 12th meeting C. of Cou., p.2
[22] FHA Doc. FC-246 and Cou-115.
[23] FHA Doc. Cou-119, Minutes 19th Cou. meeting, p.11.
[24] FHA Docs Cou-131 and Cou-135, Summary of Conclusions and Minutes 20th Cou. meeting.
[25] FHA Doc. Cou-142 and discussion by president SPC in C. of Cou. in May 1973, see Doc. Cou-147.
[26] FHA Doc. Cou-150, p.8.
[27] FHA Doc. Cou-162.
[28] FHA Doc. Cou-175.
[29] EHA-I.B.8.
[30] Monatsberichte Deutsche Bundesbank, Statistische Beihefte, Mai 1989, No. 2.
[31] Statistisches Bundesamt, Fachserie 17, Reihe 7, Preise und Preisindizes . . . (November 1990).
[32] Minutes 2nd meeting Provisional Finance Comm. in FHA.
[33] Docs FC-44,45 in FHA.
[34] EHA-I.A.1.5. and I.B.3.
[35] EHA-I.A.2.17. and I.B.7.
[36] Minutes of the 9th meeting of F.C., Doc. FC-102 in FHA.

Visiting Professor in Astronomy – 1991/92

Under the recent Portugal-ESO Agreement, there is the possibility of financing a lecturership at the University of Porto.
Host Institution: Centro de Astrofísica – Universidade do Porto
Field: Astronomy/Astrophysics
Period: 6 to 8 weeks, starting from the middle of October 1991 or beginning of May 1992.
Titles of the courses to be taught: Extragalactic Astronomy, Galactic Astronomy, Interstellar Medium, Stellar Astronomy; other possibilities may be acceptable.
Qualifications: Ph. D., preferably with some teaching experience in Astronomy/ Astrophysics. Preference will be given to people with interest in observational Astronomy, in particular with experience of using the ESO facilities.

For further information please contact:

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Observations of the Mutual Phenomena of Jupiter: The Volcanic Hot Spots on Io

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P. BOUCHET, O. HAINAUT, H. LINDGREN, E. MATAMOROS, A. SMETTE, and R. VEGA, ESO-La Silla

I. Io, the Odd Satellite

The anomalous nature of Io (i.e. its multihued surface, high albedo, red colour, and absence of H_2O ices) was recognized in the early 60's (Moroz, 1961). A decade later, a brightness temperature of ~ 128 K was measured at 20 μm, which corresponds to the equilibrium temperature expected for a slowly rotating body of Io's albedo at its distance from the sun. However, quite surprisingly, measurements at 11 μm and 8.4 μm gave values of 138 K and 149 K, respectively. Sinton (1973) invoked the presence of an NH_3 atmosphere to account for these dissimilar results, but this explanation was later on ruled out by near-infrared spectroscopy (Fink et al., 1976). Also, eclipse observations revealed that Io cooled down to 102 K at 20 μm at the end of a total eclipse, but only to 125 K at 11 μm (Morrison, 1977). Furthermore, an intense brightening was observed at 5 μm at an orbital phase angle of 68°: the emission mechanism was not understood, but was thought to be probably due to an interaction with Jupiter's magnetosphere (Witteborn et al., 1979). Several photometric monitoring campaigns were then undertaken, in order to shed some light on Io's mysteries: they led to think that its variability was depending on wavelength, but no satisfactory explanation for such a property could be given (see for instance, Sinton et al., 1983 for a summary of the photometric characteristics).

Then, the 2 Voyager spacecraft arrived in Io's vicinity and unveiled part of the mystery: during the encounters, nine variable plumes (60–300 km high, with velocities of 0.5–1 km/s), ten major hot spots, and a transient SO_2 atmosphere were detected, above active vents on a young, craterless volcanic terrain, with numerous dark calderas and surface flows, which indicated vigorous, sustained eruptive activity. The volcanoes led to new thermophysical parameters, and provided a link among much of the accumulated disparate ground-based data on Io: the hot spots (whose radiation is not modified during an eclipse) produce the outbursts which are observed in the near-infrared (especially at 5 μm), and affect the photometry more at 11 μm than at 20 μm. Also, the volcanic activity is responsible for the anomalous dehydration of the surface, and accounts for the unexpected concentration of sulfur and sulfur compounds. Moreover, it can explain the apparent ionian source of sulfur and oxygen ions to the Jovian plasma torus.

This volcanism has been understood as resulting from internal heating of Io by a very large tidal dissipation (Peale et al., 1979), with an additional energy source in the Joule heating by tremendous electrical currents (Ness et al., 1979; Gold, 1979). However, as quoted by Johnson et al. (1984), *"since the 2 Voyager encounters, better characterization of the continuing volcanic activity on Io has remained a major challenge for planetary astronomers".*

II. The Infrared Spectrum

The major part of Io is in instantaneous thermal equilibrium with the absorbed sunlight (the temperature being highest at the subsolar point, and lowest at the limb). The remaining part of the surface (in areas scattered over the disk) are the hot spots at different temperatures: (~ 300 K for LOKI; ~ 600 K for PELE, which are the most prominent hot spots observed by Voyager). Sinton (1981) has shown that the energy coming from the hot spots is of non solar origin (the total non solar power is ~ 6 ± 1 × 10^{13} W, or ~ 2 W m^{-2}).

Then, the spectrum can be represented by 3 components, coming from:

- the reflected sunlight (1–4 μm)
- the thermal emission from the hot spots (4–12 μm)
- the thermal emission from the passive, insolation-heated, surface of Io at ~ 129 K, in the far IR.

Io's spectral radiance and its components as a function of wavelength is shown in Figure 1 (after Johnson et al., 1984).

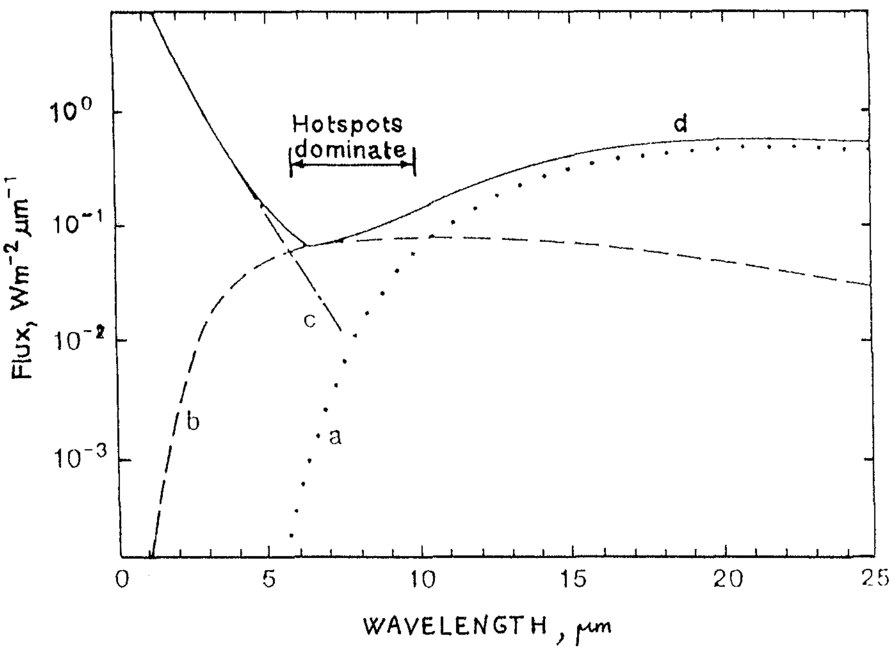

Figure 1: *Io's spectral radiance and its components as a function of wavelength: (curve a) thermal emission from the passive surface of Io (taken as an average disk temperature of 129 K); (curve b) thermal emission from the hot spots (disk centred at longitude 300° W calculated from observed Voyager hot spots); (curve c) reflected sunlight; and (curve d) the sum of the components. This figure comes from Johnson et al., 1984.*

III. The Ground-based Observations

To characterize Ionian volcanism both temporally and spatially, measurements must be made at all longitudes and latitudes, and continued for a long period of time. As the spacecraft thermal measurements are restricted to March 1979 and cover only ~ 30% of Io's surface, most of our information on volcanic activity and the magnitude of the heat flow has been provided by ground-based IR observations. Several types of experiments have been carried out:

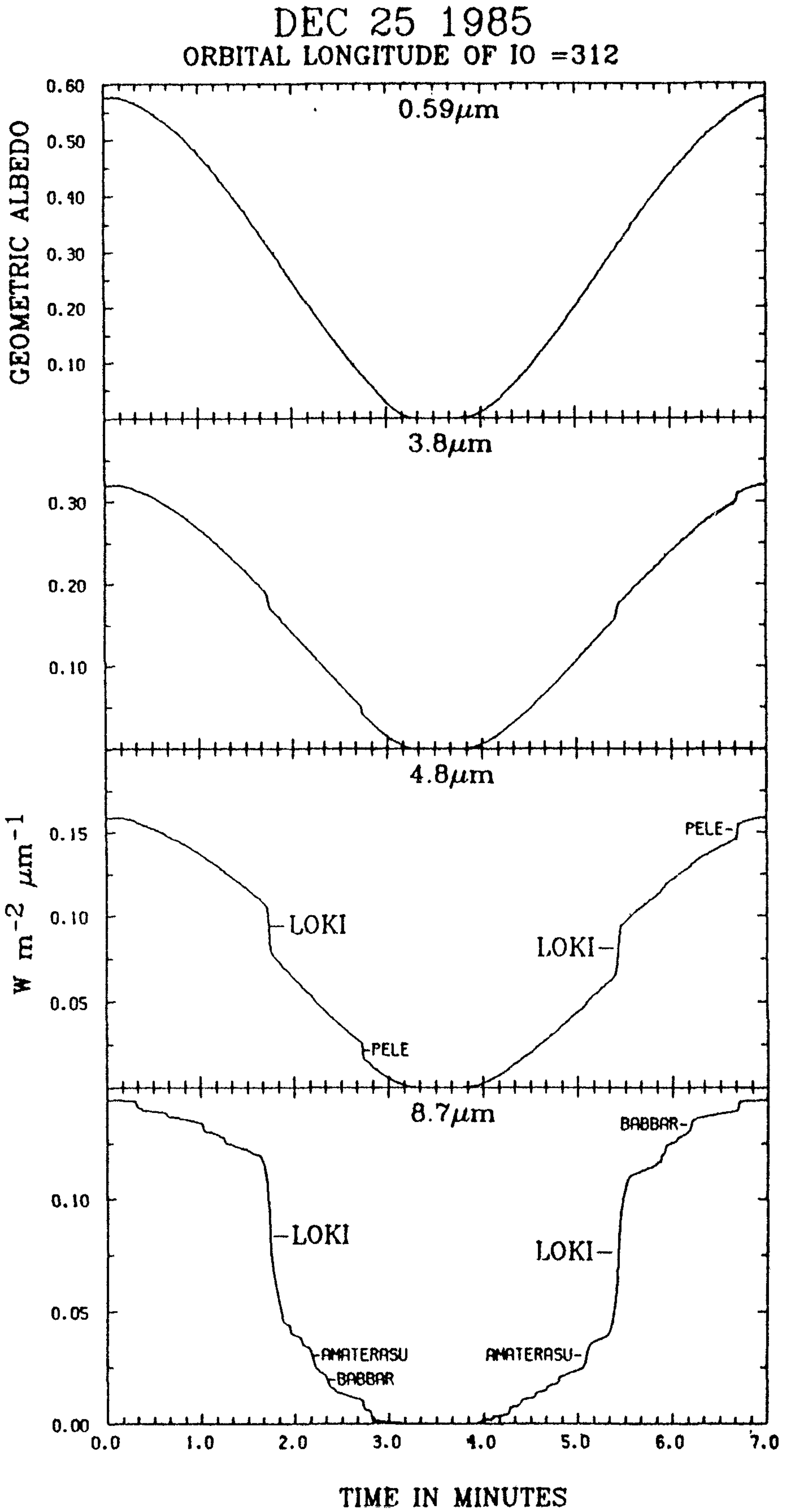

Figure 2: *Global model for the temporal occultation profiles (for December 1985) plotted against geometric albedo (0.59 µm) and against infrared fluxes. Major slope breaks due to beginning and ending occultations of hot spots are labeled (after McEwen et al., 1986).*

A. Eclipses

As a substantial fraction of the emitted radiation during an eclipse arises from hot spots, such events are propitious for studying the volcanic activity. However, eclipses are always restricted to the same hemisphere (270° W < L < 360° W). Furthermore, an adequate fitting of the cooling and heating curves requires complicated, vertically and horizontally inhomogeneous models, with two different albedo regimes. Therefore, the resulting positioning of the hot spots is far from accurate. Nevertheless, with this technique, Morrison and Telesco (1980) showed that the hot spot spectra can be matched by components with temperatures of 200–600 K covering ~ 1–2% of the surface. Also, Sinton et al. (1980) detected hot spots at ~ 560 K with a combined area of 5×10^{-5} of Io's disk.

B. Photometry (2.2, 3.8, 5, 8.7, 10 and 20 µm)

Photometric monitoring has confirmed that Io is a passive object reflecting sunlight at 2.2 µm, while it is variable at 3.8 and 5 µm due to emission from volcanic activity. Short-lived (several hours to one day) high-temperature sources have been detected: they are small and intermittent, and do not contribute much to the heat flow from Io (eight outbursts have been detected at T ~ 700 K, the temperature dropping markedly in the first hour or two down to ~ 300 K, and the derived area expanding from ~ 100 km^2 to ~ 5×10^4 km^2, with velocities of ~ 100 km/h). The most important result from the photometry has been to show that the IR emission arising from the volcanic hot spots on Io is strongly concentrated in a few locations (a greater brightness at 3.8 and 5 µm has also been observed on the trailing hemisphere*). It is not known yet if that implies more activity or a higher albedo which could be due to differences of surface composition.

C. Polarimetry at 4.8 µm

A disk-integrated linear polarization of ~ 1.6% has been measured. The de-

* The leading hemisphere is centred at 90° W and the trailing hemisphere at 270° W; this terminology refers to the hemisphere centred on the direction parallel (leading) or antiparallel (trailing) to the orbital velocity vector of a synchronously rotating satellite.

gree and position angle vary with Io's rotation in a manner characteristic of emission from a small number of hot spots. Data are fitted by a 3 hot spots model: Loki, Pele, and another one, unknown by Voyager (Goguen and Sinton, 1985). The position of Loki, as determined by this technique is 228° ± 3° W and 20° ± 2° N, with a temperature of T ~ 450 K and an area A ~ 3060 km^2.

D. Speckle Interferometry at 4.8 μm

With the speckle technique, it has been possible to resolve the disk and to detect an emission from a hot spot in the Loki region (60% of the total flux). The spot was located at 301° ± 6° W and 10° ± 6° N, with T ~ 400 K and A ~ 11,400 km^2 (Howell and McGinn, 1985).

In conclusion, although ground-based IR observations have yielded an estimate of the global heat flow from the hot spots (Morrison and Telesco, 1980; Johnson, 1984), there are two major uncertainties in (i) the positioning of the hot spots and (ii) their latitudinal distribution, as high-latitude features are underrepresented when viewed from earth: if the known sources are the only major volcanic centres, then current global heat-flow estimates must be revised downward. It turns out, then, that heat flow from unobserved longitudes, hot spots at high latitudes, and conducted heat flow must still be measured.

IV. The Mutual Events

The occultations of Io by Jupiter (very common) are not useful because of the atmosphere of the planet. When the Earth and the Sun cross through the orbital plane of the Galilean satellites (every ~ 6 years), a series of occultations and eclipses of one satellite by another may occur ("mutual phenomena"). In 1991, Io will be mostly occulted by Europa, whose albedo is 0.02–0.04 and which is not emissive in the near IR; this is highly favourable. Moreover, the relative velocity between Io and Europa during the occultations will be optimum. These occultations will then provide rare opportunities to achieve a spatial resolution that exceeds the diffraction limit of the telescope and which is unreachable with any other technique: speckle and polarimetry give accuracies of a few 100 km, while occultation with a 4-m class telescope allows spatial resolution of hot spots on the scale of a few tens of kilometres (to be compared to the diameter ~ 200 km of Loki).

In a first step, the observations of these mutual phenomena in the visible range of the spectrum should improve our knowledge of the dynamics of the motions of the Galilean satellites, allowing, for instance, the research of weak non-gravitational effects which are suspected but not yet detected, and therefore not included in the current theory (in particular the secular acceleration of Io). It has to be stressed that the current theory is based on observations whose accuracy is not better than 400 km. Yet, space exploration imperatively requires a more accurate positioning of the Galilean satellites! Then, in a second step, these observations combined with infrared ones should help determine the location and temperature distribution of Loki, the source(s) of excess emission in all the regions, the distribution of small, high-temperature sources, and the albedo changes of the scale of those that occurred between the Voyagers encounters.

The technique used for the observations, and the achievable results are described in the pioneering work of Go-

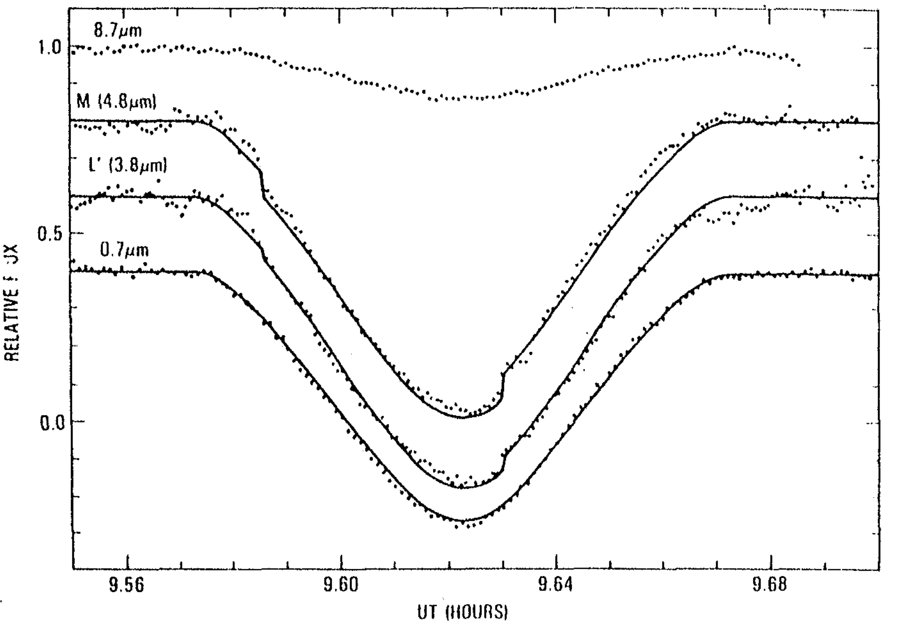

Figure 3: *Data (3 sec average/point) and global model (curves) for the occultation by Callisto on July 10, 1985. All curves have unit value before and after the occultation, but an integral number of offsets of 0.2 have been subtracted for clarity (after Goguen et al. 1988).*

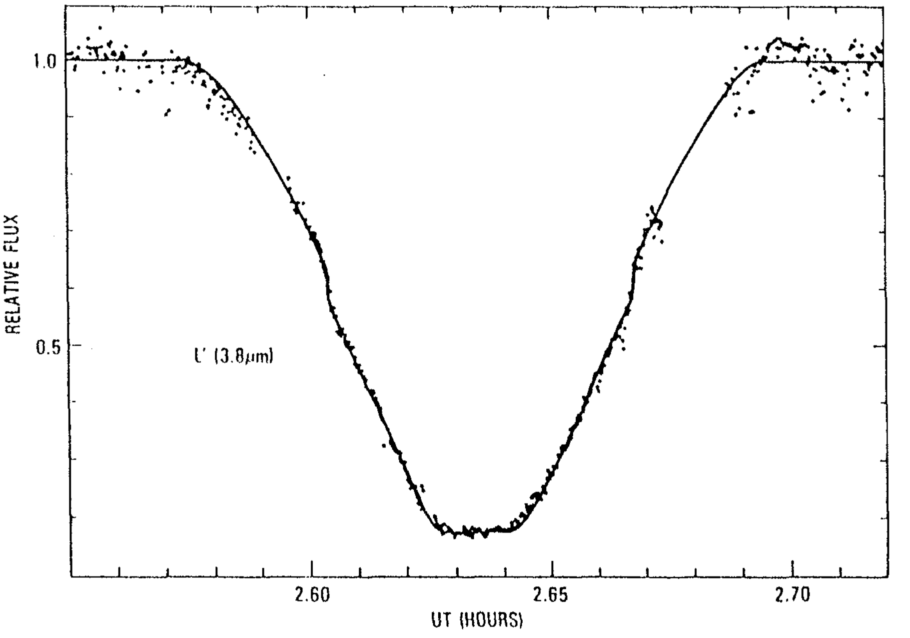

Figure 4: *Data (1 sec average/point) and global model (line) for the occultation by Callisto on December 25, 1985, obtained with the CFHT at 3.8 μm. Missing data segments and variable noise are caused by detector saturation as a result of fog in the field of view. The vertical offset near 2.603 and 2.607 hr UT are the disappearance and reappearance of the Loki region, which was included in the global model (after Goguen et al., 1988).*

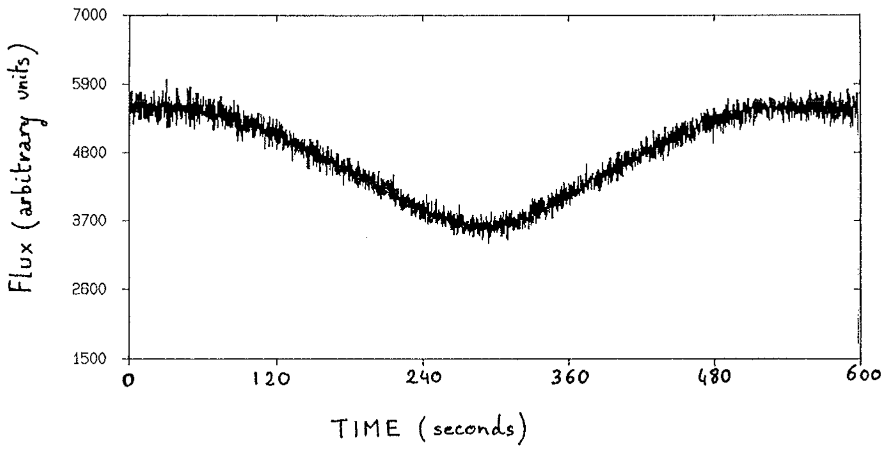

Figure 5: *Light curve obtained through the V filter during the occultation of Io by Callisto on February 15, 1991, with the ESO 50-cm telescope.*

guen et al. (1988): the combined flux of the occulting satellite and the unocculted portion of Io is tracked through a ~ 10 arcsec aperture (as Io is ~ 1 arcsec on the sky, a typical occultation lasts ~ 6 minutes but events of a few hours duration can also occur). The velocity of the occulting satellite is ~ 20 km/s at Io, and then a sampling of 0.1 seconds yields a spatial resolution of a few kms. The disappearance of a significant hot spot behind the occulting satellite limb results in a decrease in flux that lasts until the hot spot reappears. Observations are carried out at wavelengths from 3 to 10 μm: measurements at two wavelengths of the fluxes from a hot spot determine both T_{eff} and the solid angle it subtends, and then its area (the duration of the hot spot occultation gives an independent estimate of its size, if the hot spot is sufficiently large and bright). It has to be emphasized that the observations need to be obtained with a fairly high signal-to-noise ratio, which at these wavelengths can only be achieved with large telescopes (4-metre class).

Modeling the expected temporal profiles requires not only good ephemerides for the geometry of each event (the major uncertainty being the "impact parameter", which is known with an accuracy of ~ 400 km only), but also the knowledge of the albedo distribution and the photometric behaviour in the IR, which are both unknown. Furthermore, if the model were to omit the effect of hot-spot occultation on the light curves, the derived satellite positions would be affected. Therefore, a global model of the complete distribution of the hot spots is first constructed on the basis of the light curves obtained in the visible and the correlation between hot spots and low-albedo features seen in the Voyager images, assuming uniform normal reflectivities. Such a model is illustrated in Figure 2, which shows the temporal occultation profiles for December 25, 1985 as a function of wavelength, as computed by McEwen et al. (1986). Using this occultation technique, Goguen et al. (1988) have shown that the mean error in the apparent relative position of the occulting satellite is ~ 178 km. These authors have resolved Loki (with a diameter of 200 km, centred at 308° ± 1° W and 20° ± 3° N), and discovered a new spot (of ~ 20 km diameter) on the leading hemisphere: Figures 3 and 4 illustrate their notable results.

V. Results

Each event is visible only from a restricted geographical area, and therefore an international campaign had to be organized in order to make the best possible profit of these mutual phenomena. The remoteness of La Silla with respect to the other major observatories involved in this campaign makes ESO an indispensable partner in this network.

Observing time has been allocated at the ESO 50-cm telescope, to follow 13 events in the visible during period 46 and 12 during period 47. These events observable at La Silla are mostly not observable from other sites (Arlot and Rocher, 1989). On a total of 19 already passed occultations, 13 have been well observed and very nice light curves have been recorded, as can be seen in Figure 5 which displays the February 20, 1991 results. Unfortunately, the harvest concerning IR light curves is far from being as rich! Five nights only have been allocated to this programme with the ESO 1-m telescope. Observations at 5 and 8 μm had therefore to be disregarded, and it was expected that the signal-to-noise ratio of the light curves obtained at 3.8 μm be too poor to yield any significant new results concerning Io's hot spots. However, we have been trying to perform these observations, in order to confirm the feasibility of such a programme and to check the capabilities of the ESO infrared photometers. For several reasons (bad weather or too high an airmass) only two occultations could be recorded. The light curve obtained on February 20, 1991 is shown in Figure 6: although the signal-to-noise ratio is far from ideal, it can be seen from this figure that the shape of the light curve is not the expected one, if the surface of the satellite were uniform. That result gives a clear account of (i) the power of this technique, and (ii) the quality of the data which could have

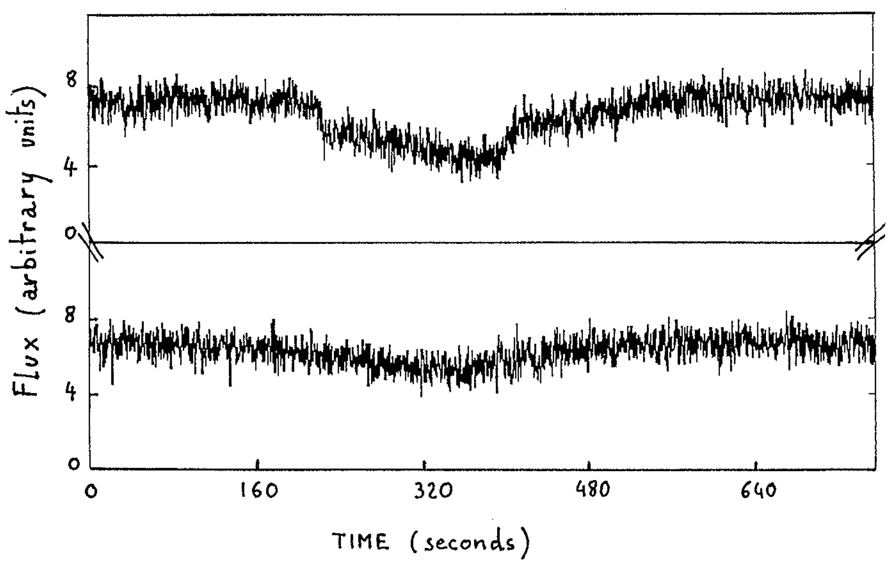

Figure 6: *Light curves obtained through the L filter (3.8 μm) during the event of February 20, 1991, with the ESO 1-m telescope: upper curve, the occultation of Io by Callisto (note the asymmetric profile); lower curve, the following (a few minutes after the occultation) eclipse of Io by Callisto.*

been obtained with the ESO 3.6-m telescope instead of the 1-m.

The high-quality results obtained in the visible at La Silla will now be combined with the results obtained from other observatories. This will lead to new position ephemerides for the Galilean satellites. There is no doubt that ESO will have played a major role in this realization.

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Splitting the Zodiacal Light

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1. Introduction

In view of the progress in the field of astronomy, in particular the ever-increasing accuracy of measurement and the development of high-resolution optics, it is an amazing fact that some of the largest phenomena in the sky have not yet been correctly described. This realization came as a surprise to us, a group of German amateur astronomers.

Some time ago, scientists of the Astronomical Institute of the University of Bochum, Germany, drew our attention to various unsettled problems concerning the inclination of the zodiacal light against the ecliptic plane. Already the first person who described this phenomenon, the well-known French-Italian astronomer Giovanni Domenico Cassini, noted an inclination of 3° against the orbit of the Earth (1). Visual, photographical and photometric observations in our century gave other results and were quite inconsistent (2). In the meantime, the Infrared Astronomical Satellite (IRAS) has shown that the zodiacal light bridge consists of individual bands within 10° of the Ecliptic. These substructures can be connected to the large number of asteroids with similar orbital parameters, leading to frequent collisions and thus to inhomogeneous concentrations of the dust (3).

2. New Observations

To obtain new and better observational results, we installed our cameras at places with low light pollution and made deep photographs of the Ecliptic. This work started in 1984 at the observatory at Jungfraujoch in Switzerland in the High Alps and ended in March 1989 at the ESO La Silla observatory.

We employed a fisheye lens (2.8/16 mm) which has a field of view of 180° over 43 mm image diagonal and which is very useful to render large- and low-contrast phenomena. As film served the T-MAX 400 emulsion from Kodak, which was forced to 1600 ISO while preserving its gradation. In this way we kept the exposure times short enough to avoid any smearing-out of the regions near the horizon, which would otherwise have exposed themselves on delicate structures in the zodiacal light. The camera was pointed to the antisolar direction and the lens was stopped down one step to have a more homogeneous illumination on the negative. Since one of our aims was to examine the position and structure of the gegenschein, the pictures were taken at times when the

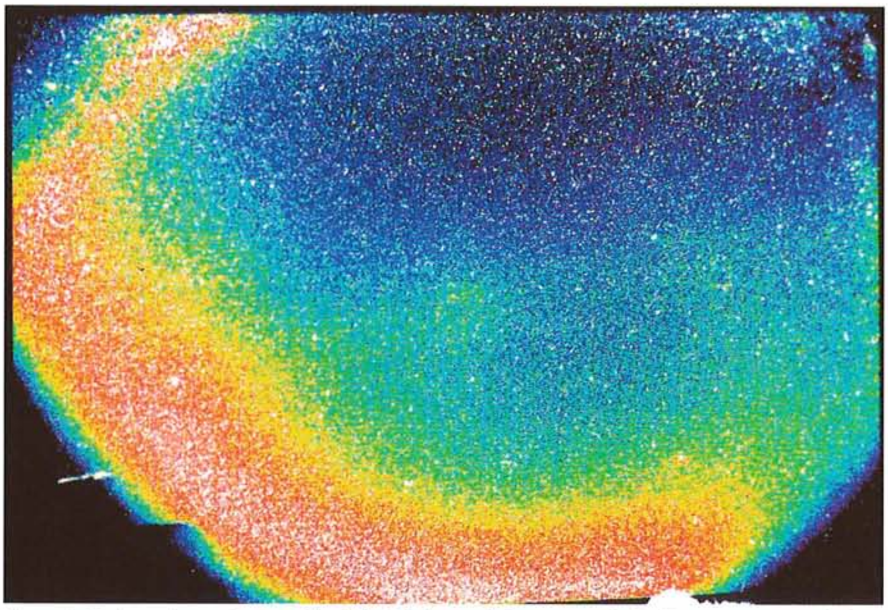

Figure 1: *False-colour picture of the light bridge and the gegenschein. Due to a strong airglow, the areas of the Ecliptic near the horizon are overexposed and the zodiacal light bridge shows a low contrast. Exposure: 60 min on March 14, 1989, 6:03 UT; objective: 4.0/16 mm.*

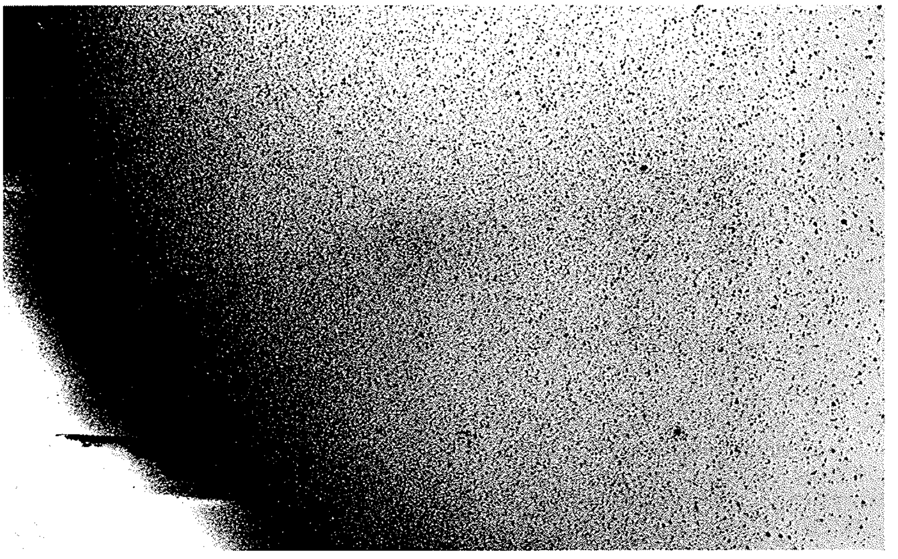

Figure 2: *Contrast-enhanced picture of the same photograph as Figure 1. Two bright stars have been marked to facilitate the orientation. Especially west of the gegenschein a separation of the light bridge is noticeable.*

antisolar point was at high galactic latitudes and the Milky Way did not interfere too much. Because of this, the zodiacal light bridge could be observed over a large extension along the ecliptic. Unfortunately, at the time of our observations (March 14, 1989) there was a strong airglow due to high solar activity close to its maximum, and the areas of the Ecliptic near the horizon were overexposed and the zodiacal light bridge had a low contrast.

The negatives obtained were either digitized and processed to false-colour images (Fig. 1) or contact-copied to increase the contrast (Fig. 2). Further techniques, like the correction of inhomogeneous illumination by the optics or subtraction of the stars, has not yet been performed. Especially the subtraction of stars would have been a good means to avoid any deceiving of the eye by star chains. In another step the scale of the picture was determined and the positions of the two bands appearing within the light bridge were marked, taking care that they did not influence the judgement of the pictures themselves. This procedure was repeated with three different pictures with various scales to improve the accuracy of measurement. Furthermore, the degree of error could be determined.

3. Results

All measurements over an ecliptical length of 70° in the region $140° \leq \lambda \leq 210°$ showed a separation of $6° \pm 1°$ of the bands within the zodiacal light bridge; this could also be established for the field of the gegenschein. Within the accuracy the bands are parallel to each other although one has the impression that they might diverge in the direction of increasing λ. The Southern band coincides with the Ecliptic and is more prominent, probably because it contains more dust. The deviation of the inclination will be studied with another set of exposures.

How far these bands agree with those observed by IRAS at different times and wavelengths remains to be seen, but it is at least possible by earthbound observations to see structures within the zodiacal light and to measure them. In particular, it will also be possible to make long-term observations which will throw more light on the constancy of this phenomenon. Other, still open questions are the inclination of the bands to the ecliptic, their intensity and how far they correlate with the distribution of the asteroids.

Here we only demonstrated that with a quite modest equipment new results can be obtained in this field of astronomy. Surely, the excellent conditions on La Silla contributed to this.

4. Acknowledgements

I am indebted to Prof. W. Schlosser, Bochum, for his suggestion to embark upon this subject and for his continuing support. Thanks are also due to the Director General of ESO, Prof. H. van der Laan, and also to Prof. L. Woltjer and Dr. R. West for permission to realize the observing campaign from La Silla. I also want to thank Prof. H. Debrunner, Bern, who gave me the opportunity to make observations from the Jungfraujoch observatory. My gratitude goes also to P. Riepe, Bochum, for the critical revision of the manuscript.

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Fundamental Stellar Quantities of Early-type Stars

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1. Background and Motivation

Absolute dimensions (masses, radii, luminosities) of massive stars are well known only for a few early-type stars, which comprise about 30 OB binaries of spectral types earlier than B5 and less than 10 O-type systems, while no reliable data at all are available for stars with $M > 40\ M_\odot$. However, especially for massive stars improvements in the theoretical treatment of the internal structure and stellar evolution have been reported during the last few years. Such new findings include convective core overshooting and continuous stellar wind mass loss with important implications for the stellar structure and temporal evolution of single and double stars.

There is an urgent need for an increase in the amount of high-precision

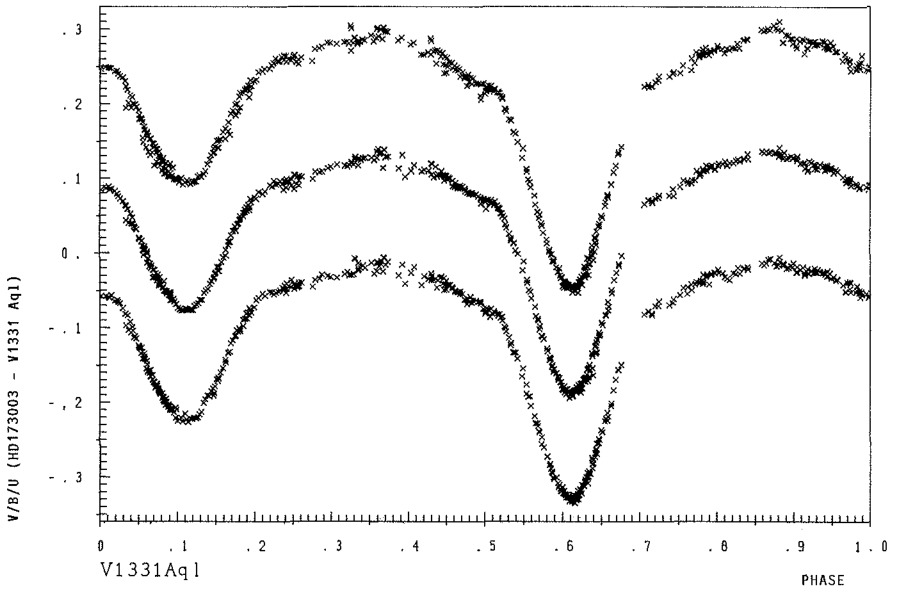

Figure 1: *UBV light curves of V1331 Aql obtained with the ESO 0.50-m telescope between June 15–29, 1990; individual measurements (U top, B middle, V bottom) are differential magnitudes in the sense: comparison (HD 173003) minus V1331 Aql. Ephemeris used is: hel. JD 2442610.0581 + 1$^{d}_{.}$3641953 E.*

absolute parameters of early-type stars to provide a statistically significant basis for a comparison of the actually observed properties with the revised evolutionary scenario. However, the absolute number of OB stars is relatively small, and there is an even greater deficit of "clean", undisturbed OB binary systems, which are by far the most important source of our knowledge of absolute dimensions. Most of these double-lined eclipsing binaries are close systems exhibiting a variety of interaction processes like tidal deformation, mass transfer and mass loss with immediate effects on the eclipse light curves and radial velocities.

Hence a programme has been initiated to analyse also complex systems with the main aim to derive fundamental stellar quantities and orbital elements as precisely as possible, and to enlarge the data base to be compared with stellar structure and evolution theory for massive stars.

2. Light Curve Solutions of Interacting Close Binaries

The various interaction processes in close early-type systems cause appreciable complications of the light curves. Frequently also a finite amount of third light (in triple or multiple systems and OB associations) introduces additional parameter correlations, which usually prevent convergent and unique solutions with classical methods. Therefore, flexible solution procedures are required, which take these complicating effects into account and make use of refined numerical methods.

The Wilson-Devinney approach based on the Roche model can handle tidal and rotational distortion, reflection effect as well as limb and gravity darkening in a satisfactory physical way. For hot luminous stars radiation pressure has to be considered as an additional important factor, which modifies the shape of the potential field. We furthermore use the nonlinear simplex parameter optimization procedure (Kallrath and Linnell, 1987), which is superior to the conventional differential corrections method in several respects.

The so-called *simplex* is a geometrical figure defined in the n-dimensional space of adjustable parameters, which can perform various operations like reflection, contraction, etc. The light-function values are calculated for each of the (n+1) vertices of the simplex, and the movement through the free parameter space is determined by a comparison of the corresponding sums of squared re-

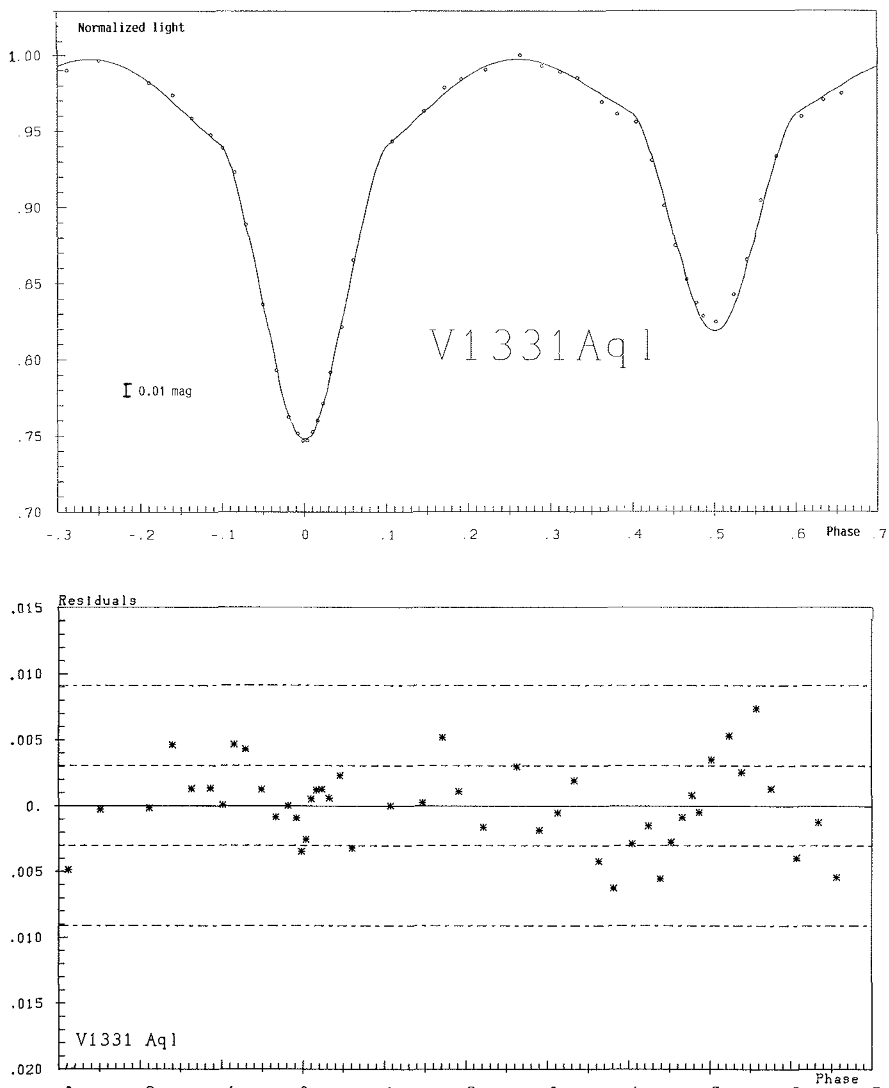

Figure 2: *V curve solution for V1331 Aql (top); dots are normal points, for which residuals are shown at bottom; solid line is mean value of residuals (very nearly zero), dashed lines give 1σ and 3σ belts.*

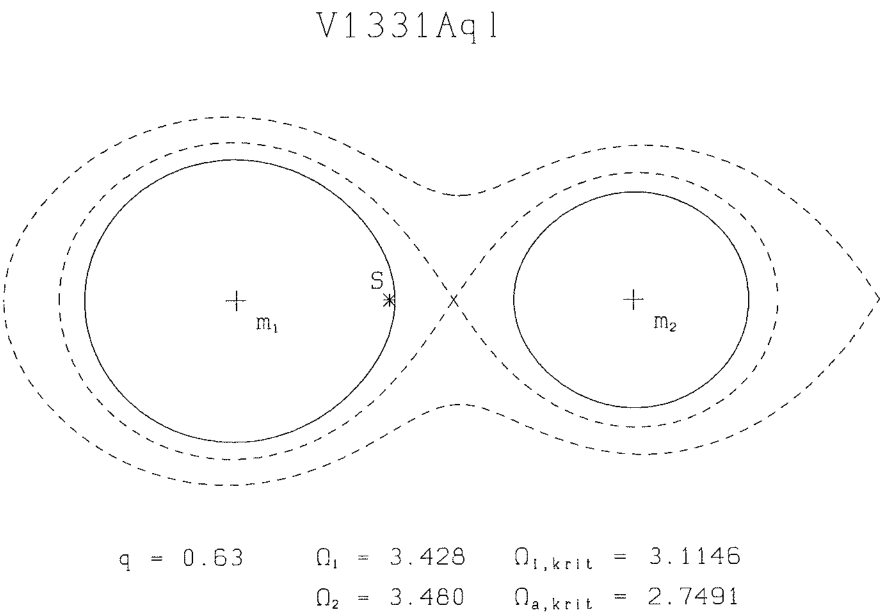

Figure 3: *Meridional intersection of the close detached system V1331 Aql; shown are both components together with inner and outer critical Roche surfaces.*

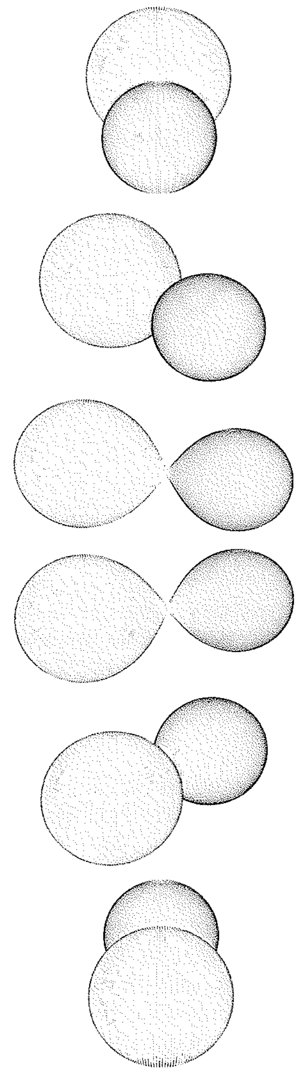

Figure 4: *Aspects of the massive contact system LY Aur (O9.5III + O9.5III, P = $4^{d}.003$) at orbital phases 0, 0.1, 0.2, 0.3, 0.4, and 0.5 (top to bottom).*

siduals. The simplex will eventually contract towards a locus in the parameter space at which best coincidence between observed and calculated light curves is achieved. The simplex algorithm exhibits a particularly good convergence behaviour, even for cases where the start parameter set is far apart from the final solution, and for systems with strong parameter correlations due to light-curve distortions and the presence of third light.

Our experience shows that the application of this modified Wilson-Devinney approach combined with a careful treatment of the spectroscopic information and other limiting boundary conditions can yield consistent system solutions and sufficiently accurate stellar parameters in many hitherto contradictory or unexplored cases.

3. A Few Recent Solutions

Table 1 summarizes photometric solutions and absolute dimensions of four recently analysed OB-type binaries, which should all be counted as difficult cases to complex light curves or third-light contributions.

V1331 Aquilae

This close eclipsing binary is of type B1V and has an orbital period of 1.364 days. Only scarce photoelectric measurements have been reported, and were solved with the classical Russell-Merrill method and Wood's WINK code in only one case. New UBV light curves were obtained with the ESO 0.50-m telescope between June 15–29, 1990. More than 500 individual measurements in each filter are shown in Figure 1.

Preliminary solutions converge to several possible values of the mass ratio q (= M_1/M_2), ranging between about 0.6 to 0.8, with nearly equally good fit quality. In all cases the system configuration is detached. The luminosity of the secondary is about three times lower than that of the primary, and its temperature turns out to be around 19,000 K (assuming 25,400 K for the primary). Both components are apparently not far from ZAMS. According to the spectral types, the masses amount to about 13 and 8 $M_\odot$, and the value of q should be close to 0.6. A very similar value of q = 0.63 resulted from our simultaneous solution of the UBV light curves. The V curve solution, together with residuals of normal points, and the derived system configuration are shown in Figures 2 and 3. Third light was a free parameter in all solutions, but converged towards neglectable amount. The final decision

Table 1: *System parameters of early-type binaries*

	V1331 Aql	AH Cep	IU Aur	LY Aur
T_1 (K)	25400	31500	32000	32100
T_2 (K)	19130	29990	28200	28800
i (deg)	70.3	70.5[1]	88.3[1]	89.0
Separation A ($R_\odot$)		19.8	18.7	38.7
R_1 ($R_\odot$)[2]	0.37 A	6.4	6.5	17.9
R_2 ($R_\odot$)[2]	0.28 A	6.0	6.5	14.7
M_1 ($M_\odot$)	13:[3]	17.7	15.9	30.0
M_2 ($M_\odot$)	8:[3]	15.6	10.8	18.6
log ($L_1/L_\odot$)	4.2:[3]	4.58	4.62	5.51
log ($L_2/L_\odot$)	3.4:[3]	4.52	4.40	5.32
l_3	0%	5%	20%	10%

[1] for epoch 1984; [2] mean Roche radius; [3] ZAMS values.

about the mass ratio must be delayed until a spectroscopic determination of q will be available. It is planned to collect the necessary rv data in July 1991 at the ESO 1.52-m telescope (with ECHELEC).

It should be noted that in a review of early-type binaries by Hilditch and Bell (1987) two objects with very similar parameters appear: V Puppis (B1V, P = $1\overset{\mathrm{d}}{.}495$) and TX Aurigae (B1V, P = $1\overset{\mathrm{d}}{.}210$); these are semi-detached systems, with secondaries filling their Roche lobes. The detached system V1331 Aquilae therefore seems to be an important addition to the sample of the earliest binaries. In the following, a few more complex interacting binaries are briefly described, for which recent solutions were derived in the scope of this programme.

AH Cephei

AH Cephei (B0V + B0.5V, P = $1\overset{\mathrm{d}}{.}775$) is an early-type close detached system. Light curves from two widely separated epochs (1930 and 1984) with clearly different depths of eclipse minima were analysed. The derived time variation of the orbital inclination suggests the presence of a third body in the system, which manifests itself not only by light-time effect, but also by the precession of the orbital plane of the eclipsing binary. This finding is further confirmed by a fraction of third light of about 5 per cent, as is evident from the solution of the light curves. Besides IU Aurigae, AH Cephei is a unique example for a triple system, where the presence of a physical third component is not only proved by the light-time effect or third light, but also by a time change of the orbital inclination (Drechsel et al., 1989).

IU Aurigae

IU Aurigae (B0Vp + B0.5, P = $1\overset{\mathrm{d}}{.}811$) is a semi-detached system with the secondary filling its critical Roche volume. As in the case of AH Cephei, IU Aurigae is a rare case for which the presence of a third body can be confirmed beyond any doubt by light-time effect, third light of about 20 per cent, and in addition by the time variation of the orbital inclination due to the precessional motion of the binary orbit triggered by the third body (Mayer and Drechsel, 1987).

LY Aurigae

LY Aurigae (O9.5III + O9.5III, P = $4\overset{\mathrm{d}}{.}003$) is a massive contact system. A close visual field star with an angular separation of 0.5 arcseconds contributes appreciable third light to the total flux. This might be one reason for partly contradictory previous results concerning the mass ratio and system configuration. The recently obtained light-curve solution yields a third-light contribution of 10 per cent and a mass ratio of about 0.6, which is compatible with the spectroscopic value (Drechsel et al., 1989).

4. Future Prospects

We have shown that the sample of absolute dimensions known for very early stars can be enhanced by inclusion of interacting close binaries with hitherto unexplored or uncertain system parameters. The current programme not only aims at the measurement and solution of eclipse light curves, but will also complement radial-velocity data necessary for independent spectroscopic determinations of mass ratios, which are necessary for reliable photometric results. An essential subject of future investigation will be an adequate treatment of radiation pressure effects, which have already been shown (Drechsel et al., 1991) to be of major importance for the shape and configuration of early-type close binary stars.

Even at the end of the pre-VLT era and certainly also in the future, bright stars are far from being exhaustively explored. For good reasons, large instruments are not available for such objects, while medium- to small-size telescopes are still able to provide a wealth of important new data – especially if they are located at such marvellous sites like La Silla.

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Hunting the Brown Dwarf

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1. What are "Brown Dwarfs"?

During the seven last years there has been a considerable interest developing in view of the discovery and observations of presumed sub-stellar objects, also named "brown dwarfs". This illustrative term denotes a class of objects that appears naturally in the theory of star formation: recent models predict that the collapse and fragmentation of a molecular cloud should produce clumps down to 0.02 solar masses. Between this lower limit and 0.07 solar masses, the fragment is not massive enough to ignite nuclear reactions inside its core and ends as a "failed star", faintly shining in the infrared due to the release of gravitational energy associated with its progressive contraction. Observations of some members of this new class of celestial bodies would of course be of the highest importance for the theory of very low mass star formation, and models have been proposed which aim at predicting the photometric and spectrophotometric characteristics of brown dwarfs and their evolution with respect to their birth mass and age.

Another reason for the revival of this observational activity is of course to be found in several breakthroughs achieved in astronomical instrumentation, specifically at infrared wavelengths, which opened the door to the possible direct detection of at least the brightest, i.e. the youngest, brown dwarfs: high efficiency infrared arrays and diffraction-limited imaging techniques in the IR are prime weapons in this hunting.

2. First Attempts

The first observers to spot something were McCarthy et al. (1985). They used infrared speckle interferometry to detect brown dwarf companions possibly or-

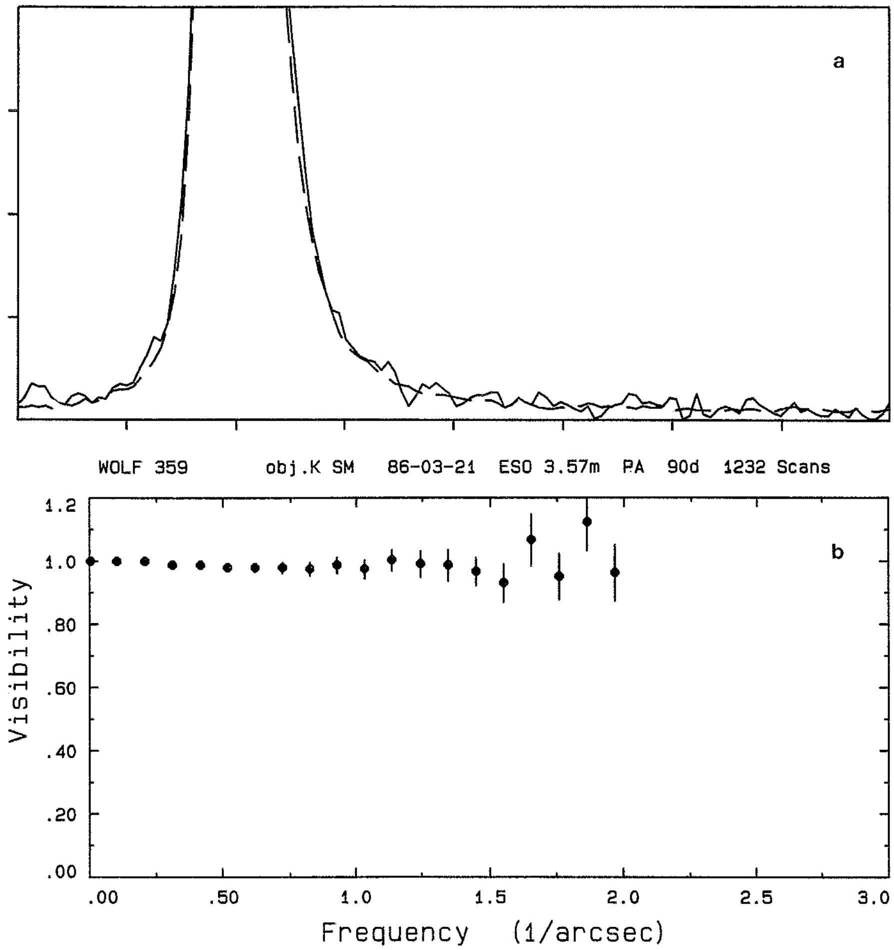

Figure 1: *Long-exposure image and visibility of Wolf 359 at 2.2 microns.*
1.a: Superimposed East-West profiles of the source and of a reference star (dashed line) enlarged 20 times with respect to peak value. The total scan amplitude is 18.4 second of arc. The r.m.s. noise value measured on the sky (right half of the scan) corresponds to a magnitude K = 13.2.
1.b: Corresponding visibility showing that the image core is not resolved: any companion with K<11 and at a separation larger than 0.5″ would produce a detectable sinusoidal modulation of the visibility.

biting the nearest red dwarfs in the northern hemisphere. The reason to search for brown dwarfs in binary systems is that, unlike Lewis Carroll's Snark that can be recognized thanks to "five unmistakable marks", one, and only one, parameter allows yet to confirm the sub-stellar nature of an candidate brown dwarf, namely its mass. The reason to use speckle-interferometry, a technique achieving imagery at diffraction-limited angular resolution, is that it gives access within a distance of 10 parsecs to separations of the order of 1 A.U., and therefore to binary systems with typical periods of a few years.

3. Observations at La Silla

Following these tracks, we have started in 1986 a programme of observation of the closest southern hemisphere stars with the infrared speckle system available at the La Silla 3.6-m telescope, in order to complement the on-going northern hemisphere survey. Among others, our target list included some famous sources, such as Proxima Centauri, Barnard and Kaptein's stars, as well as some extreme low-luminosity stars such as Ross 154, Wolf 359 and some Van Biesbroeck's stars (VB4 and VB5).

Alas! Our first observations turned out to be rather disappointing: not only not a single new sub-stellar companion appeared in our visibility curves (see Fig. 1), but VB8B itself, the unique candidate specimen of the class, proved to be only a mere artifact, caused by a tenuous calibration problem (Perrier and Mariotti, 1987): the number of detected brown dwarfs was reduced from 1 to 0!

Further observations in 1987 and 1988 did not allow us to invert this unfortunate result. In the meantime, several discoveries of new candidates were reported, but up to now none of them is clearly confirmed as sub-stellar, because an unambiguous determination of the mass is always lacking.

A by-product of our first observation campaign has been, however, to lead to new separation measurements of several low-mass red-dwarf binaries, including the determination of the masses and orbital parameters of Gliese 570B (Mariotti et al., 1990), a binary system independently discovered as a spectroscopic SB2 system by Duquennoy and Mayor (1988). Indeed, infrared speckle interferometry turned out to be an extremely powerful technique when applied to the observations of binaries previously detected or suspected because of their radial-velocity variations:

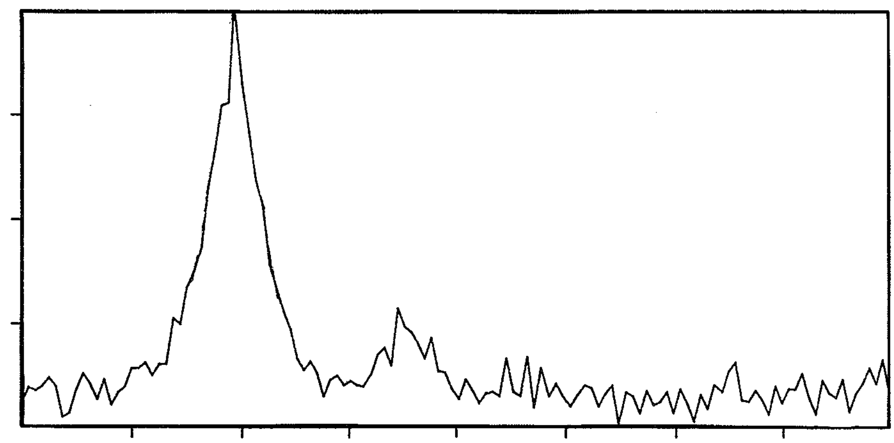

Figure 2: *A sub-stellar companion of Gliese 440?*
In January 1990, we detected a very faint and red object a few seconds of arc away from Gl 440, one of the closest white dwarfs with a distance of 5 pc. Further observations in March 1991 revealed that the separation of the two objects has increased by about 2 seconds, i.e. exactly the amount and the direction due to the proper motion of Gl 400: the "companion" is hence not a brown dwarf, but rather a background "normal" red star lying for a while on the line of sight. The figure displays the Jan. 90 image profile at 1.6 microns: scan direction is E-W, intervals between ticks are 1.5 second of arc.

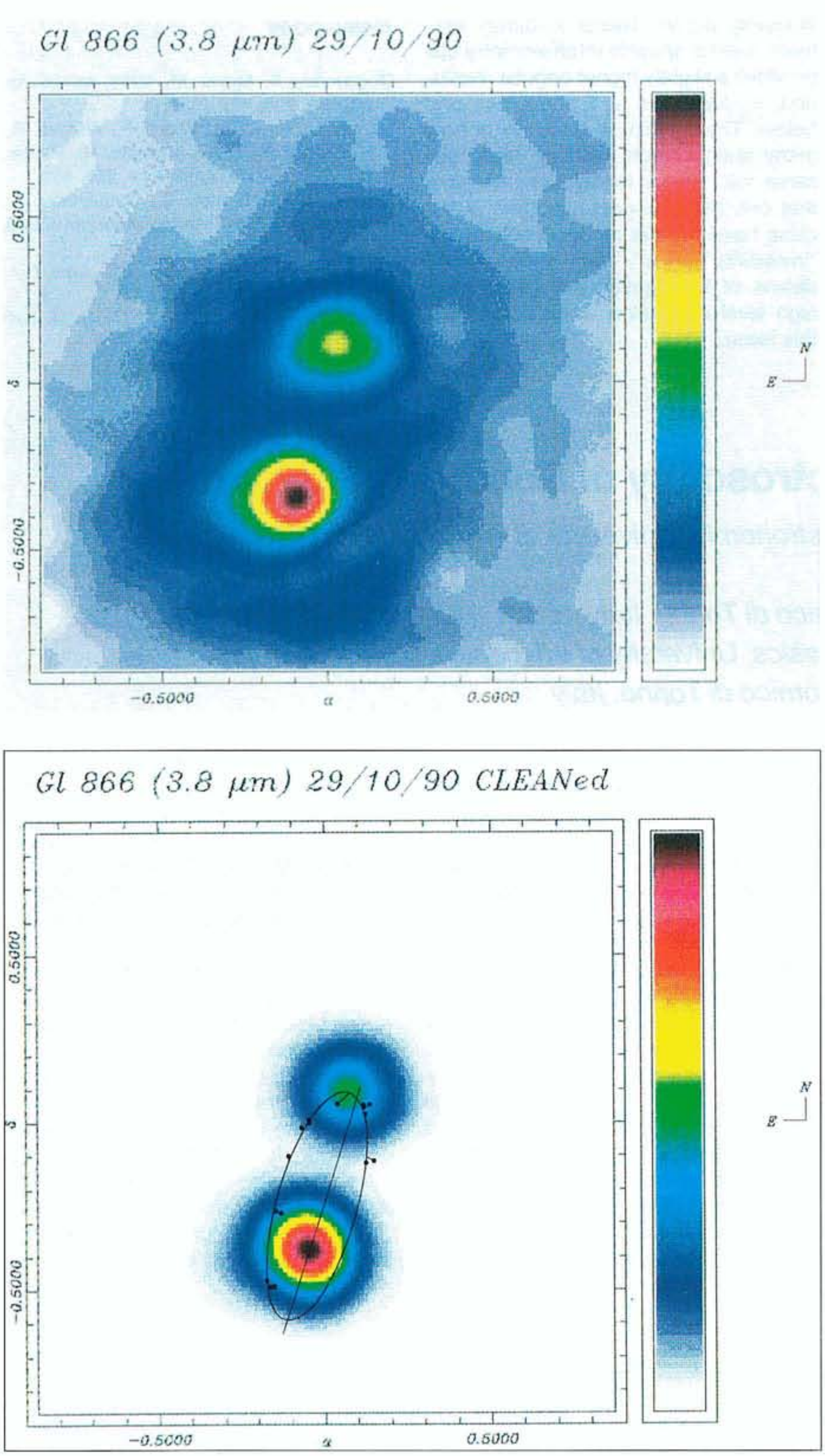

Figure 3: *Adaptive-optics image of Gliese 866 at 3.8 microns.*
3.a: Raw image.
3.b: Final image after restoration using CLEAN algorithm: the ellipse is the orbit computed by Leinert et al. (1990) from infrared speckle interferometry measurements. Units on axes = arcseconds.

this has led us to propose, in collaboration with A. Duquennoy and M. Mayor of Geneva Observatory, a study of a few dozen candidate red-dwarf binaries selected from the CORAVEL database. We have just completed the fourth of a series of systematic speckle observing runs devoted to this programme that turned out to be extremely successful and on which we will report in a forthcoming article.

But again, according to the preliminary analysis of the data, no new brown dwarf candidate was spotted during these observations. Sometimes a faint sign has revived our hopes, but up to now always in vain (Fig. 2). Indeed, it is well known that speckle interferometry is a technique rather limited in terms of dynamic range. In other words, the maximum magnitude difference between the primary and the companion that we can hope to reach is at best 4.5: so, even the "brightest" brown dwarfs can be detected by speckle interferometry only if they orbit very low luminosity red dwarfs ($L < 2 \cdot 10^{-3} L_{\odot}$), i.e. of type dM5 or later, which severely restricts our target sample.

4. New Techniques

Fortunately, the on-going development of the infrared observational techniques offers us a new and powerful way of tackling the difficult problem of spotting the dim light of a brown dwarf close to a (relatively) glaring star: Adaptive Optics can already provide at the 3.6-m telescope diffraction-limited images at a wavelength of 3.6 microns and nearly diffraction-limited images at 2.2 microns with an excellent dynamical range *The Messenger,* **60**, p. 9 and **63**, p. 76). This is why we have proposed to resume our hunting equipped with this new weapon.

In October 1990, we observed again a dozen of the closest stars of the southern hemisphere: although the final data reduction is not complete at the time of this writing, the real-time quick look on the data did not lead to any positive detection. However, we have taken this opportunity to image a few previously known red dwarf binary systems, and Figure 3 illustrates the efficiency of Adaptive Optics applied to the detection of close binary systems: Gliese 866 was first resolved by speckle interferometry, and has been followed since then during two orbits by several groups around the world including our team (Leinert et al., 1990). In contrast with the strict and rather tedious procedure mandatory in speckle observations, the Adaptive Optics observations revealed the binary nature of the source after only a few tens of a second of exposure time. The magnitude difference between the two components of this binary is small but it is clear from Figure 3 that a high dynamical range can be reached in the clean images provided by this technique.

If necessary, a coronographic mask could further improve the detection limit of a very faint companion: this is one of the advantages of the *a priori* compensation provided by adaptive optics compared to the *a posteriori* nature of speckle interferometry restoration. Another advantage is that, if the separation of the system is larger than one Airy disk, as it is the case here, the two components can be independently analysed by, for instance, feeding the corrected image into a spectrograph.

5. Outlook

Considering these advantages, we have no doubts that Adaptive Optics is on the verge of becoming the most convenient way of first detecting, then studying, brown dwarfs in binary systems, even if speckle interferometry still provides a slightly higher angular resolution, in particular at 2.2 microns and below. The remaining question is how many such objects we can really observe with these techniques, knowing that only the youngest members of the class have not yet plunged behind the "invisibility barrier". The recent ups and downs of the hunting still prescribe a high level of caution when addressing this issue.

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Low-Resolution Spectroscopy of Southern Old Novae

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Current Views about Classical Novae at Minimum

Old novae, like dwarf novae, recurrent novae and nova-like variables, are Cataclysmic Variables (CVs). CVs are interpreted as interacting close binaries with a white dwarf primary and a red dwarf, or seldom a red giant secondary filling its Roche lobe. According to the current views, in many CVs matter from the secondary flowing through the inner Lagrangian point forms a hot viscous accretion disk around the white dwarf. Due to dissipation of angular momentum, this material moves inward across the disk until it is accreted by the white dwarf. The modes of accretion are different in CVs with strongly magnetized white dwarfs (their surface magnetic field is however only up to 10^8 Gauss, much less than the 10^{10} Gauss that isolated white dwarfs can reach).

In such objects accretion can occur without a disk, with flow of material to the polar caps as in AM Her systems, or a disk may exist but its inner part be disrupted, as in Intermediate Polars. Periodic thermonuclear runaways in the envelope accreted around the white dwarf are believed to produce the classical nova phenomenon (see Starfield, 1989 and references therein). Dwarf novae instead, show recurrent small amplitude outbursts which are believed to be caused by instabilities of the disk or of the mass transfer from the secondary. Old novae appear brighter and hotter than dwarf novae and this is thought to be due to larger mass transfer rates ($10^{-10} - 10^{-8}\ M_\odot yr^{-1}$ vs. $10^{-13} - 10^{-11}\ M_\odot yr^{-1}$). For accretion rates above $10^{-10}\ M_\odot yr^{-1}$ CV disks should be stable.

Current views of CVs, however, admit and suggest that secular changes of the mass accretion rates might cause an object to transit from one sub-class of CVs to another. To justify the space density of old novae, too low compared to the nova frequency, it has been hypothesized that most of the life of nova systems is spent in a state of "hibernation", with a very low mass transfer rate that makes most old novae faint and even undetectable (Livio et al., 1990). The nova phenomenon should then occur during the "high-state" of the mass transfer rate. Dwarf-nova like outbursts of three old classical novae have been observed and seem to confirm this theory (Vogt, 1986). Presently, however, the observational evidence for such an interpretation is still rather poor and modifications to the "hibernation" theory have already been suggested (Livio et al., 1990).

Some of the oldest recovered novae tend to become fainter, but their photometric behaviour can also be interpreted as very long term light oscillations, recently revealed for all CVs. The secondary components seem to have solar-type activity cycles which modulate the mass-transfer rate even long after the nova explosion (Bianchini, 1990, and references therein).

Many other features of the post-outburst behaviour of classical novae are

Table 1

Nova	Year	Mag (Dürbeck)	Mag (observed)
OY Ara	1910	17.5_p	19.5
CG CMa	1934	15.9_p	16.5
nova Car	1953	19.0_p	17.5
nova Cen	1986 N. 1	14.5_v	15.0
AR Cir	1906	15.0_p	14.2
BT Mon	1939	15.5 (var.)	17.3
GI Mon	1918	18.0_p	16.1
V616 Mon	1975 X-ray	20.2_B	18.2
RR Pic	1925	11.9_p	12.2
T Pyx	recurrent	15.3_p	15.5
CP Pup	1942	15.0_v	15.1
HS Pup	1963	20.5_p	18.1
HZ Pup	1963	17.0_p	17.4
nova Pup	1673	20.0_p	20.0
XX Tau	1927	18.5_p	20.0
CN Vel	1905	17.0_p	18.4–17.8

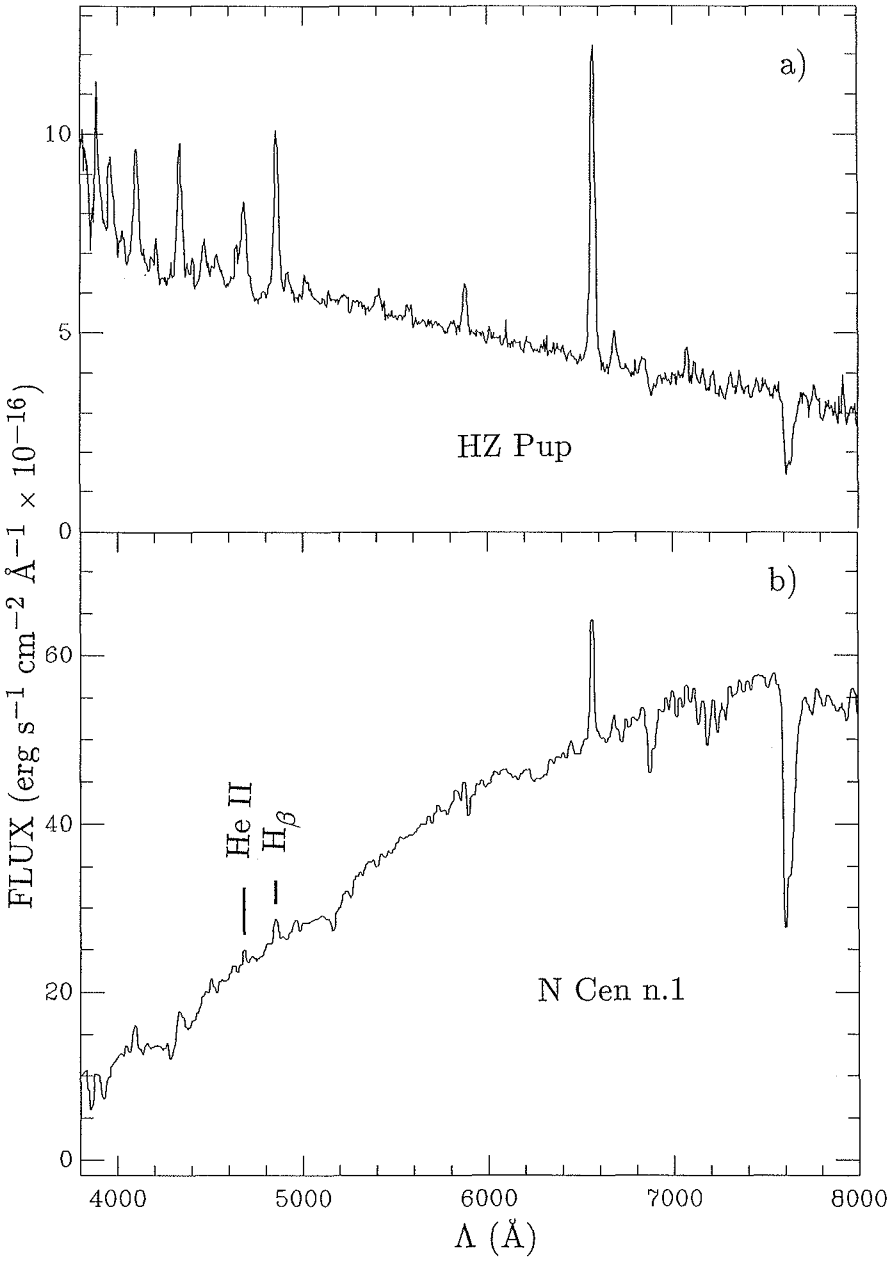

Figure 1: *The average spectrum of HZ Pup (Fig. 1a) compared with that of N Cen N. 1 1986 (Fig. 1b) that resulted much redder and symbiotic-like. The positions of H_β and He II 4686 are marked. Telluric absorptions are also visible.*

still very puzzling. It is not even clear when the white dwarf returns, after the explosion, to a true quiescent state. During the outburst, a fraction of the accreted envelope works its way back on the white dwarf, producing a long phase of constant bolometric luminosity. While the theory foresees a length of ≥ 100 years for this phase unless the white dwarf is rather close to the Chandrasekhar mass, UV observations (Gallagher and Code, 1974) and X-ray observations of nova remnants (Ögelman et al., 1987), suggest a turn-off time of only a few years.

A systematic study of novae at minimum is very promising not only for understanding the correlations between the properties of the binary systems (periods, masses, mass-transfer rates, etc.) and the characteristics of the explosion, including the chemical composition of the ejected material, but also as a test of the "hibernation" scenario sketched above.

The spectra emitted by old novae may be rather complicated: different parts of the binary system radiate in infrared, optical, ultraviolet and X-rays through a variety of thermal and non-thermal physical mechanisms. Most old novae are rather faint and although more than 200 galactic novae have been hitherto discovered, the spectra of only a very small fraction of them has been studied at quiescence, despite the importance of the post-outburst stage for the models. Only systematic spectrophotometric surveys including a large sample of objects allow a systematical approach to the problem, but there are only few and incomplete CV surveys with general results for novae for the northern hemisphere and none for the southern (see Shara et al., 1986, Williams, 1983).

The Programme

The aim of this spectroscopic survey is to study the continuum energy distribution at very low resolution and the intensities of low and high excitation lines in the spectral range 3000–9000 Å of the largest possible number of objects at different evolutionary stages. The survey of southern old novae has recently been started with the 1.5-metre ESO telescope, equipped with the B & C spectrograph, a 150 groves/mm grating and the CCD detector. The resolution is about 25 Å.

Old novae in the northern hemisphere are observed with the 1.8-m telescope of the Asiago Observatory, with equivalent equipment. In the first run at ESO in February 1991, 22 objects have been pointed and 16 spectra have been obtained. Exposure times ranged from 20 to 60 minutes. Our survey is part of a more general programme of multiwavelength study of post-outburst novae, that we are also pursuing with other means in other energy ranges: a selected number of post-outburst objects is being monitored with IUE in the UV range and with Rosat in soft X rays; significant results are expected also from the Rosat all sky survey.

First Results

Table 1 gives for each one of the observed objects the year of the outburst, the magnitude given in Dürbeck's catalogue (1987) and a rough estimate of the visual magnitude observed by us. For 10 of these objects the spectra at quiescence were obtained for the first time. The faintest object we were able to detect is N Pup 1673, the oldest of our sample, that has V ≃ 20. The signal-to-noise ratio in this case is only ≃ 3, but it is sufficient to measure at least the continuum level which seems to have a maximum around 5000 Å. No emission lines could be detected above the noise. HZ Pup (1963) is a classical example of a quiescent nova, with a very blue continuum, strong emission of H I, He I and He II (Fig. 1a). The identification of the quiescent OY Ara, that had an outburst in 1910, is classified as ambiguous in the Dürbeck catalogue (Dürbeck, 1987), but the strong and broad H emission lines, even if on an unusually red continuum, seem to confirm the previous identification beyond doubt. CG CMa

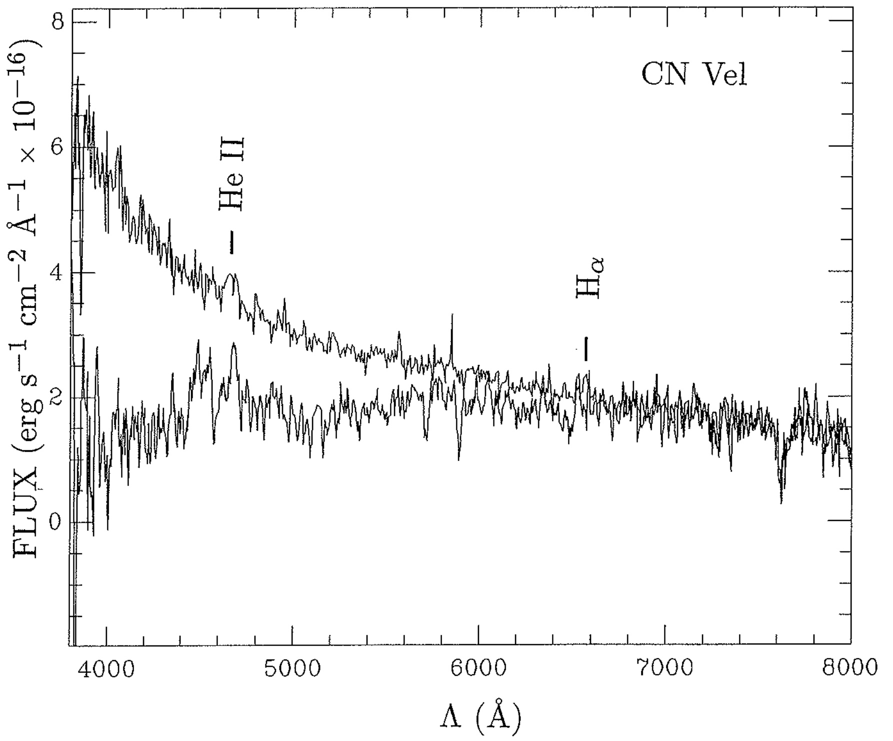

Figure 2: *The "blue flare" of CN Vel. The spectrum taken on February 21, compared to the average of the spectra of February 18 and 19, when the nova was at quiescence.*

(1934) does not appear as a classical nova, and even the suggested dwarf nova nature is extremely unlikely: the characteristic features of its spectrum are a hot continuum and H lines in absorption like a B star. An interesting possibility could be that of an X-ray source that bursted also in the optical range. Also the spectrum of N Car 1953 is not nova-like, but a late-type star absorption spectrum, casting doubts either on the classification as a nova or on the position recorded. An even later-type spectrum is that of AR Cir (1906), previously classified as a very slow nova, but probably a symbiotic star. GI Mon (1918) shows a blue continuum with weak H and HeII emission lines. The spectrum of HS Pup (1963) has an F-type continuum, very strong $H\alpha$ emission and a strong Balmer decrement (≥ 4) that could be ascribed to interstellar material. XX Tau (1927) shows a blue continuum and strong Balmer emissions.

Among the novae for which the spectrum at quiescence is already known, there are BT Mon (1939), with a flat continuum with strong emission lines and HeII fainter than $H\beta$; T Pyx (recurrent), whose continuum is very blue; RR Pic (1925), which is very blue and has very strong lines of HeII and λ4650 (CIII); CP Pup (1942) with a blue continuum and equally strong $H\beta$ and HeII; the optical and X-ray nova V616 Mon (A0620-00) (1975), black hole candidate (Mc Clintock and Remillard, 1986). We also observed N Cen 1986, that has $H\alpha$ in emission and weak HeII overimposed on a very red spectrum that resembles a symbiotic star rather than a classical nova (Fig. 1b).

The most interesting finding is a flare of the very slow nova CN Vel (1905). The nova was observed for 3 nights and in the 3rd the continuum seemed to flare in the blue region, as it is shown in Figure 2. More observations of this interesting object are undoubtedly needed.

The variety of the observed spectra, noted also in the pioneering survey of Williams (1983) is very interesting and confirms that the nova phenomenon is still poorly understood, so that systematic studies of the old nova population are requested.

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Two Cannonballs Shot Out from the Core of the Globular Cluster 47 Tucanae

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I. Introduction

In dynamics of globular clusters, the worst problem is by far their dynamical evolution, which turns out to be unstable. During the past decade, an important observational and theoretical activity related to the problem of core collapse has partly changed and greatly improved our theoretical understanding of the dynamical evolution of globular clusters (see the proceedings of the ASP Conference on Formation and Evolution of Star Clusters, ed. Janes, 1991, and references therein).

There are at least three different ways to look at the dynamical evolution of a globular cluster towards gravitational instability, an evolution characterized, during most of the life of the cluster, by a slow contraction of its core and an equally slow expansion of its envelope. First, relaxation through encounters ejects stars from the core and causes the cluster central part to contract, since its binding energy is shared among fewer stars. The contraction speeds up the relaxation and the whole thing runs away (Spitzer and Härm, 1958, *Ap. J.* **127,** 544). Second, with two populations in equipartition, if the total mass M_2 of the heavier stars is sufficiently large compared to the total mass M_1 of the lighter stars, there is no equilibrium distribution of heavy stars in which v_2 is much less than v_1. Then, if m_1 and m_2 are the individual masses of the lighter and heavier stars, respectively, then $M_2/M_1(m_2/m_1)^{3/2}$ must be less than 0.16 for equilibrium (Spitzer, 1969, *Ap.J.L.* **158,** L139). When violated, this criterion indicates that the large self-gravitation of the heavier stars drives them into a high-temperature sub-system in the core of the cluster. Third, beyond a certain concentration – $\varrho_{core} \geq 709\ \varrho_{halo}$ – the system is subject to the remarkable gravothermal instability, consequence of the negative specific heat of a self-gravitating stellar system. The core of the cluster can no longer stay in equilibrium with the envelope. It makes a thermodynamic turnabout, the energy flows the wrong way and the centre of the cluster collapses (Antonov, 1962, for an English translation see IAU Symp. 113, 1985, p. 525; Lynden-Bell and Wood, 1968, *M.N.R.A.S.* **135,** 495).

The essential conclusion which can be drawn from theoretical works consists of expecting the core of an old cluster eventually to collapse, suffering what Lynden-Bell called the *gravothermal catastrophy.* If theoreticians have, for a long time, little doubt about core collapse, the situation has been less clear observationally. From the survey concerning about 110 galactic globular clusters (Djorgovski and King, 1986, *Ap.J.L.* **305,** L61), it is established that 20% of them have surface brightness profiles which are not easily fitted by King-Michie multimass anisotropic dynamical models. Part of these problems may be the result of the discrete nature of the core of such high-concentration clusters, whose light is dominated by the contribution of a few (less than ten) bright stars. Recent observations with the Hubble Space Telescope failed to display the expected central casp in the core of M15 (Lauer et al., 1991, *Ap.J.L.* **369,** L45), and in NGC 6397 as well. This could be explained by recent theoretical simulations (Chernoff and Weinberg, 1990, *Ap.J.* **351,** 121) which show that the changes in the cluster during deep core collapse could be largely invisible, i.e., not strongly impressed on the luminosity profile. These authors show that high-concentration King-Michie

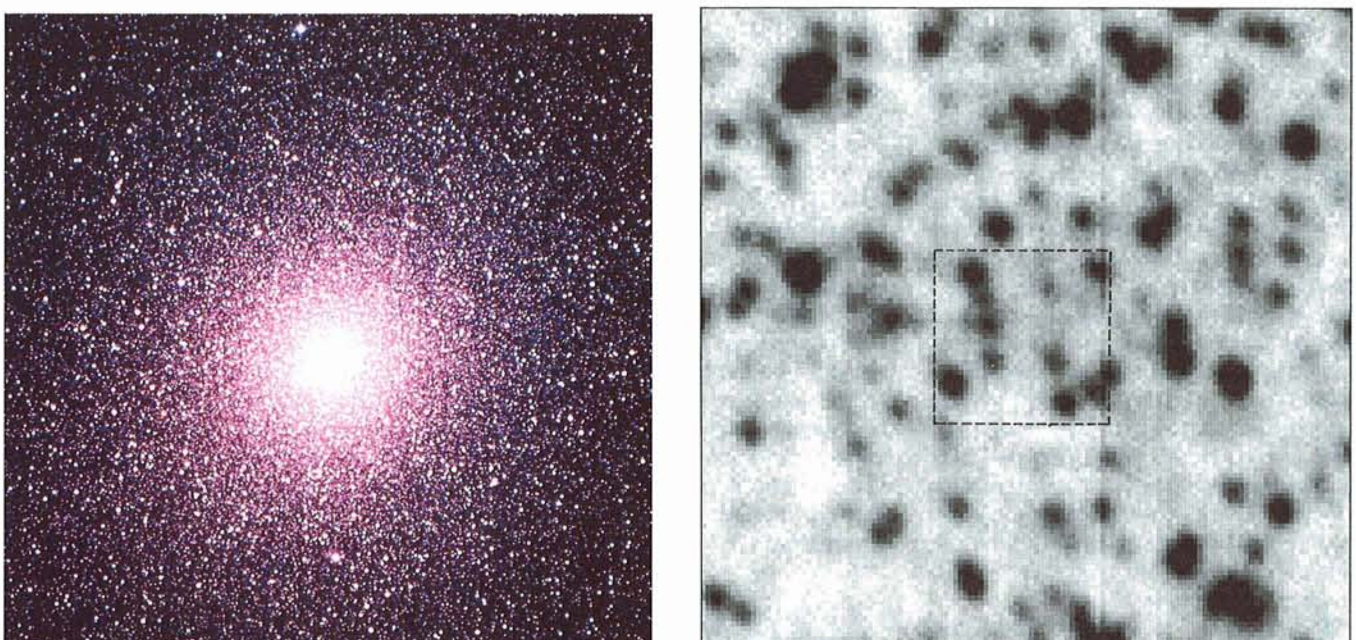

Figure 1: *(a) Composite photograph of 47 Tucanae obtained from three ESO Schmidt plates centred on different wavelengths (3850 Å, 4950 Å and 6300 Å), taken by H.E. Schuster at La Silla, Chile, and processed by the ESO photographic laboratory in Garching bei München, Germany. (b) Enlarged chart of the innermost area of 47 Tuc. The dashed square represents the 6″ × 6″ sampling area. North is up and east to the left.*

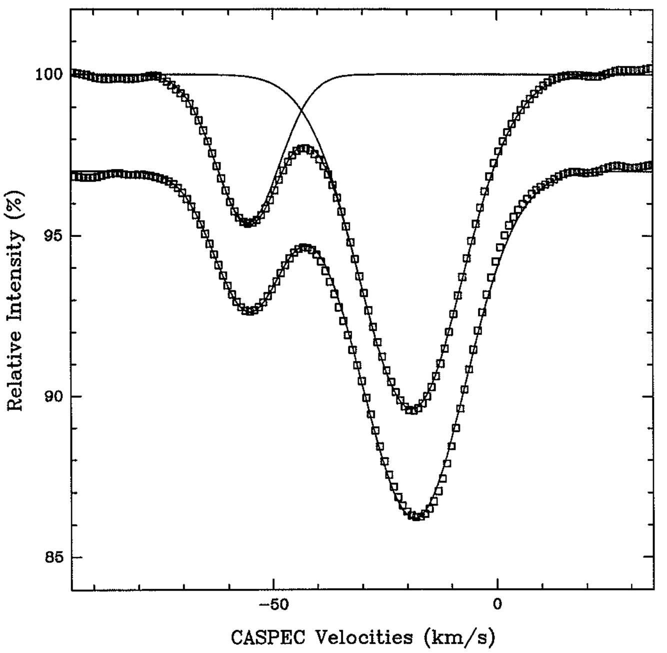

Figure 2: *Cross-correlation functions (CCFs) from the two integrated light spectra obtained in the core of 47 Tuc (one curve has been vertically shifted by 3% for clarity). The squares represent the CCFs themselves, the continuous lines the fitted functions which are combinations of two gaussians.*

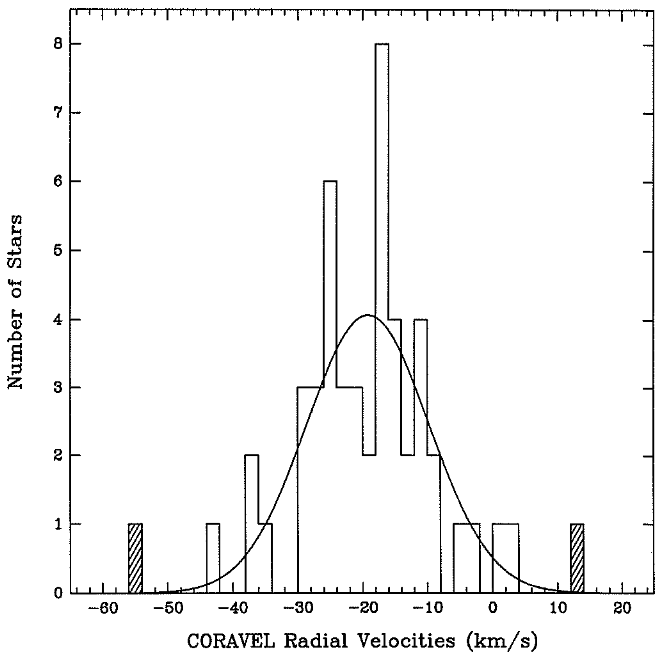

Figure 3: *CORAVEL radial velocity histogram of 50 stars located within the central arcminute of 47 Tuc, including the high-velocity star found in CASPEC spectra.*

models produce good fits not only during the early long phase of slow pre-collapse evolution of the cluster, but also during the late core-collapse phase. During the increase of central density, the visible stars do not follow the total density profile, but have much flatter profiles.

Actually, the gravothermal catastrophy does not look as catastrophic as it sounds! Since the seminal paper by Hénon (1961, *Ann. d'Astrophys.* **24,** 369), it is known that primordial binaries may delay the core collapse, and that, later during the collapse, because of the high increase in stellar density, binaries formed in the core are able to stop this collapse and even to trigger the re-expansion of the core, driving the cluster through a series of gravothermal oscillations (Sugimoto and Bettwieser, 1983, *M.N.R.A.S.* **204,** 19 p). Including in their model a term to represent the input energy from binaries, they found that after collapse, instead of decreasing monotonically, the central density undergoes nonlinear oscillations spanning several orders of magnitude. They suggested that many galactic globular clusters are at present undergoing just such gravothermal oscillations, the core spending the vast majority of the time in the expanded state.

Considering the high concentration and short central relaxation time of 47 Tucanae, the fact that this cluster does not show any evidence for core collapse is interesting. This cluster has perhaps already suffered the consequences of the gravothermal catastrophy and lives presently in the expanded phase between two consecutive contractions. The possible advanced stage of the dynamical evolution of this cluster may perhaps be unveiled through the observations of the characteristic and dynamics of individual stars. This southern globular cluster contains already an extremely rich zoo: one low-mass X-ray binary, about ten pulsars and a very high density of centrally clustered blue stragglers recently observed with the Hubble Space Telescope (Paresce et al. 1991, submitted to *Nature*).

As a contribution to the understanding of the dynamics of globular clusters, we undertake a survey dedicated to the measurement of the central velocity dispersion in the core of high-concentration galactic globular clusters (Dubath, Meylan, and Mayor, in preparation). The data concerning the core velocity dispersion from integrated light spectra in 47 Tuc and presented here are part of this survey. They are completed by a second determination of the velocity dispersion from mean radial velocities of about 50 stars located within one arcminute from the centre of the cluster.

II. Integrated Light Observations with CASPEC

The observations are integrated light spectra obtained in the core of 47 Tuc with CASPEC, the ESO Cassegrain Echelle Spectrograph, mounted on the 3.6-m telescope at La Silla, Chile. The CCD used is an RCA SID 503 high-resolution (ESO # 8). The instrument setup is standard, with the 31.6 line mm^{-1} grating and with a wavelength domain between 4250 and 5250 Å. We have two spectra obtained at an interval of two nights in July 1989. Both nights are characterized by strong winds and seeing values of the order of 2″ FWHM (recorded at the 1.54-m Danish telescope). The integration time is 15 minutes for both spectra, with a spectrum of a thorium-argon lamp taken before and after each exposure. The dimensions of the entrance slit are 1.4″ × 6.0″ for the first series of observations, and 1.2″ × 6.0″ for the second one. During the two exposures on the cluster core, a scanning of the nucleus was done with the entrance slit, in order to cover a zone of 6″ × 6″ and to avoid any problem of sampling which could occur by integrating only over a few bright stars. This sampling area is represented in Figure 1b by the dashed-line square of 6″ × 6″, superposed on a portion of a CCD image of the core of 47 Tuc, obtained by one of us at the ESO/MPI 2.2-m telescope at La Silla, with a standard B filter and 2 seconds of integration.

The spectra are reduced following standard procedures. No flat field operation is applied, since flux calibration is useless when cross-correlating spectra for obtaining radial velocity or velocity dispersion. The reduced spectrum is then cross-correlated with a numerical mask. The properties of this mask, as well as the details of our cross-correlation technique, are described in a previous study concerning the Magellanic globular cluster NGC 1835 (Dubath, Meylan, and Mayor, 1990, *AA* **239,** 142). The mask used so far for optical cross-correlation with the spectrophotometer CORAVEL (COrrelation – RAdial – VELocities: Baranne, Mayor, and Poncet 1979, *Vistas in Astron.* **23,** 279) has been simply extended in order to cover the complete spectral domain of our CASPEC spectra, i.e., the interval from 4245 to 5275 Å. Our cross-correlation technique produces a cross-correlation function (CCF) which is nearly a perfect gaussian. Comparison with CCFs of standard stars displays the broadening of the cluster CCF, produced by the Doppler line broadening present in the integrated light spectra because of the random spatial motions of the stars. The quadratic difference in half-width at half-maximum gives a precise estimate of the stellar velocity dispersion in the sampled area of the globular cluster (Dubath et al. ibid).

III. Results from CASPEC Spectra

Figure 2 shows the CCFs – relative intensity as a function of the radial velocity – for the two spectra obtained in the core of 47 Tuc. The squares represent the CCFs themselves, the continuous lines the fitted functions which are combinations of two gaussians. The later are represented separately only in the case of the upper CCF. In a totally unexpected manner, both CCFs coming from two similar but independent spectra, exhibit an identical double dip. The deepest gaussian represents the light coming from the cluster as a whole, since it reproduces (V_r = −18.4 and −19.1 $km s^{-1}$, respectively, see Table 1) the systemic radial velocity of 47 Tuc known to be V_r = −18.8 ± 0.6 $km s^{-1}$ from the radial velocities of 272 member stars (Meylan and Mayor, 1986, *AA* **166,** 122). This gaussian is also much broader than the mean CCF (stellar gaussian) defined as the mean of a set of CCFs from standard stars with late spectral types (Dubath, Meylan, and Mayor, in preparation). Consequently, the projected velocity dispersion σ_p in the core of 47 Tuc is derived, the two independent CCFs giving σ_p = 9.0 an 9.2 $km s^{-1}$, respectively (Table 1).

The second, less deep, gaussian corresponds to a radial velocity totally different from the systemic radial velocity of the cluster. Its width is much smaller and typical of CCFs coming from a single star. Therefore, we conclude that this second dip reveals the presence of a relatively bright star, inside the 6″ × 6″ sampling area, with a radial velocity value V_r = −55.5 $km s^{-1}$ (V_r = −55.4 ± 0.2 and −55.5 ± 0.2 $km s^{-1}$, respectively from the upper and lower (CCF). Its radial velocity relative to the cluster is about four times larger than the velocity dispersion in the core of the cluster, i.e., V_r(star) – V_r(47Tuc) = −36.7 $km s^{-1}$ with σ_p(core) = 9.1 $km s^{-1}$.

Challenged by this double dip, we were wondering which star in the sampling area (Figure 1b) was the interloper. We have unveiled at least part of the puzzle, by obtaining individual radial velocities for some of the brightest stars in the sampling area. These results, acquired in December 1990 by direct radial velocity measurements with CORAVEL mounted on the ESO 1.54-m Danish telescope at La Silla, Chile, allow to locate the high-velocity star. The CASPEC radial velocities are confirmed by two CORAVEL measurements which give V_r = −54.3 ± 1.6 $km s^{-1}$ on 26-27 December 1990 and V_r = −55.5 ± 2.2 $km s^{-1}$ on 28-29 December 1990 (Table 1). These observations show also that the radial velocity of this star is not variable. The long time-baseline between the CASPEC and the CORAVEL observations and the constancy of the velocity values are an indication that the star is not part of a binary system.

Table 1 summarizes the above results. The errors on the radial velocities from integrated light, mentioned in this table, are formal errors. A more realistic uncertainty on these values is of the order of ≤ 1 $km s^{-1}$. For a more detailed discussion about the accuracy of such results, reference is made to Dubath, Meylan and Mayor (ibid. and in preparation).

Table 1: *Results from CASPEC and CORAVEL*

Instrument	$\bar{V}_r$ (cluster) ($km s^{-1}$)	σ_p (core) ($km s^{-1}$)	V_r (Caspec star) ($km s^{-1}$)
CASPEC integrated light spectra within r = 3″			
6–7 July 1989	−18.4	8.8–9.2	−55.4 ± 0.2
8–9 July 1989	−19.1	9.1–9.3	−55.5 ± 0.2
CORAVEL measurements			
26–27 Dec. 1990	...	...	−54.3 ± 1.6
28–29 Dec. 1990	...	...	−55.5 ± 2.2

CASPEC and CORAVEL radial velocities and velocity dispersions concerning the 6″ × 6″ central area and the high-velocity star found in the CASPEC spectra.

IV. Stellar Radial Velocities with CORAVEL

The above measurements of radial velocities of individual stars in 47 Tuc are not the first ones done with CORAVEL. During the past decade, a few hundred stars, members of 47 Tuc, have been measured (Mayor et al. 1983, *AA Suppl.* **54,** 495 and in preparation). For a few years, individual radial velocity measurements for a sample of about 50 stars located within the central arcminute (≃ 2 r_c) from the centre of 47 Tuc, have been carried out using CORAVEL mounted on the ESO 1.54-m Danish telescope at La Silla. Most of these stars have several measurements, with a minimum interval of time between two measurements of the same star of about one year.

A histogram of the mean CORAVEL radial velocities is presented in Figure 3. It reveals, in addition to the first high-velocity star (V_r = −55.5 $km s^{-1}$), a second star (V_r = +13.20 $km s^{-1}$) with a radial velocity relative to the cluster 3.6 times larger than the velocity dispersion, i.e., V_r(star) – V_r (47Tuc) = +32.4 $km s^{-1}$ with σ_p(core) = 9.1 $km s^{-1}$. Omitting these two high-velocity stars, this sample of 48 stars gives a systemic radial velocity of −19.2 ± 1.3 $km s^{-1}$ and a dispersion of 9.4 ± 1.0 $km s^{-1}$.

Values of both systemic radial velocity and velocity dispersion, obtained here from individual radial velocities, are in perfect agreement with those obtained in section 3 from integrated light spectra, i.e., a systemic radial velocity of −18.8 ± 0.6 $km s^{-1}$ and a velocity dispersion of 9.1 ± 1.0 $km s^{-1}$.

V. Membership of the Two High-Velocity Stars

The first question arising about these two stars concerns their membership. Unfortunately, the relatively low systemic radial velocity of 47 Tuc (V_r ≃ −19 $km s^{-1}$) does not allow an immediate discrimination between field stars and members of the clusters. A first check consists of looking at their position in the colour-magnitude diagram (CMD). Two CCD images of the core of 47 Tuc, obtained by one of us at the ESO/MPI 2.2-m telescope at La Silla, give a CMD

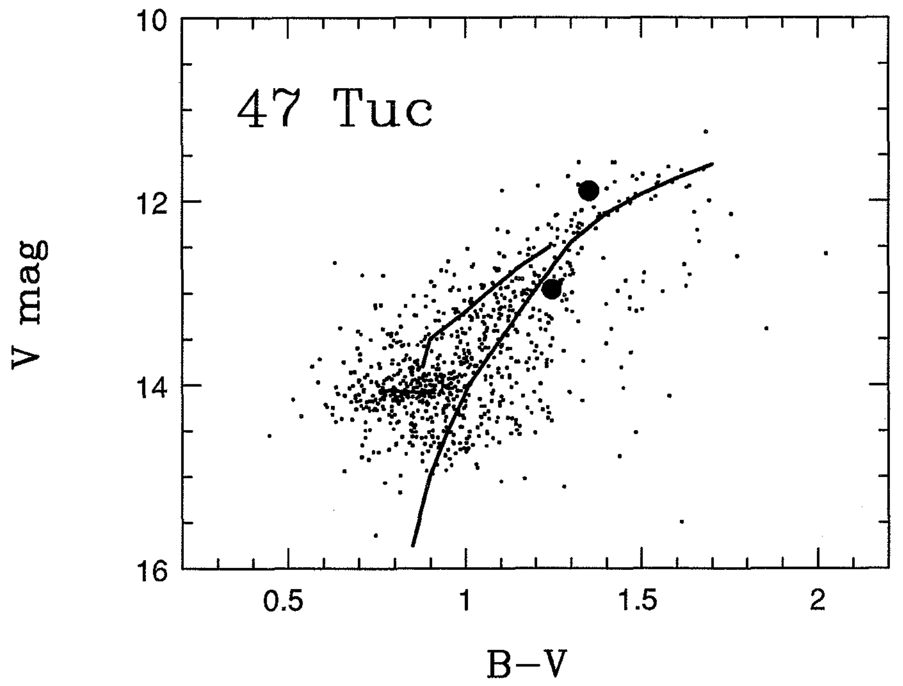

Figure 4: *Colour-magnitude diagram of the centre of 47 Tucanae, from two CCD images obtained at the ESO/MPI 2.2-m telescope at La Silla. The solid lines are the fiducial lines (Hesser et al., 1987,* P.A.S.P. ***99**, 739) for the RGB, HB, and AGB. The two stars (large dots) have positions on the red giant branch and asymptotic giant branch which tend to confirm their membership.*

by stellar encounters between a single star and a binary, or between two binary stars. Numerical scattering experiments (see, e.g., Leonard, 1991, *A.J.* **1991,** 562) show that gravitational interactions can eject stars at very high velocity. The presence of binaries (the required on-site gunners!) is now confirmed in globular clusters through different kind of observations. Apart from a few binary candidates from variable radial velocity, the core of 47 Tuc contains one low-mass X-ray binary, about ten pulsars and a very high density of centrally clustered blue stragglers recently observed by HST (Paresce et al., ibid.).

Nevertheless, there is a serious shortcoming with the binary interpretation: calculations mentioned above are valid only for ejection of main-sequence stars. So far no study has simulated the ejection of stars with larger radii. Because of their large size, giants cannot be members of close binaries. Their large radii imply larger impact parameters. Therefore, it is not known if the most energetic interactions can involve giant stars, it is not known if such interactions can accelerate giant stars sufficiently to produce such high velocities as observed in 47 Tuc and M3.

displayed in Figure 4. The two stars have positions on the red giant branch and asymptotic giant branch which tend to confirm their membership. However, foreground dwarf stars cannot be ruled out since dwarfs at a distance of about 100 pc may appear superposed on the giant branch of 47 Tuc.

Because of its rather high galactic latitude (b = −44°), 47 Tuc does not suffer too strong a galactic pollution by field stars. Ratnatunga and Bahcall (1985) give estimates of the number of field stars per square arcminute toward galactic globular clusters. For 47 Tuc, taking into account a colour range, their estimates give about 1.8 10^{-2} stars per square arcminute. Therefore, the probability to find two such stars inside the central 40″ of 47 Tuc is very low.

From the above considerations there is no reason to disregard these two high-velocity stars; there is no indication that they are not members of the cluster. The ultimate proof of their membership will be obtained if spectroscopy shows that they are giants.

In this context, it is also worth mentioning that Gunn and Griffin (1979, *A.J.* **84,** 752) in their seminal study of the globular cluster M3 (≡ NGC 5272), find two similar high-velocity stars very close to the cluster centre. Their interlopers have velocities at 4.5 and 3.5 sigmas from the mean. In this case, however, the membership of these stars is quasi certain because of the high radial velocity of M3 (about −146 $km s^{-1}$).

VI. Ejected Out of the Core of 47 Tuc?

The main mechanism which may be called upon for explaining these two interlopers is the ejection out of the core

Before discussing more accurately the interpretations of these observations and their implications on various possible detailed ejection scenarios, the still tiny but remaining doubt concerning the membership of these high-velocity stars has to be definitely eliminated. The simplest way consists of obtaining spectroscopic observations, and deducing the luminosity classes of the two stars. If they are giants, their apparent magnitudes put them at about the distance of 47 Tuc, where field pollution is absolutely negligible, given the rather high galactic latitude (b = −44°): their membership will be certain. Observing time has been requested in order to get such valuable spectroscopic data. We hope that by the end of the year confirmation of the membership of these two stars will prove that two cannonballs have really been shot out from the core of 47 Tucanae!

STAFF MOVEMENTS

Arrivals

Europe:

ANSORGE, Wolfgang (D), Product Assurance Manager
BEUZIT, Jean-Luc (F), Associate
IWERT, Olaf (D), Electronics Engineer
LATSCH, Hedwig (D), Accounts Clerk
MICHOLD, Uta (D), Librarian
REYES, Vicente (E), Remote Control Operator
URBAN, Ullrich (D), Administrative Assistant, General Services
WIEDEMANN, Günter (D), Infrared Instrumentation Scientist
ZOLVER, Marc (F), Coopérant

Chile:

CORRADI, Romano (I), Coopérant
LUNDQVIST, Göran (S), Associate (SEST)

Departures

Europe:

BERGER, Christian (D), Student
FISCHER, Marianne (D), Administrative Assistant
HALD, Birgit (DK), Administrative Assistant

Chile:

GUNNARSSON, Lars (S), Associate (SEST)

New Distant Planetary Nebulae

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Discovering New Planetary Nebulae

The number of known galactic Planetary Nebulae (PN) is at present above 1600. Even so, they are thought to be only 10% of all PN present in the Galaxy, the rest being hidden due to heavy absorption. In fact, the known PN are concentrated in the solar neighbourhood at distances which are usually smaller than 3 to 4 kpc and the PN statistical parameters such as kinematics, luminosity functions, chemical abundance, etc. have been derived for this local sample and extrapolated to the whole Galaxy population. Therefore, it appears important to extend the observations to PN at larger distances.

It is not a surprise that the improving instrumentation allows to find new PN even in regions of sky that have previously been carefully searched. The search we are performing, however, does not require last-generation instruments, but involves a comparative analysis of plates taken, in some cases, more than 20 years ago.

The starting point was the realization that, due to differential absorption, all distant, *normal* stars tend to be fainter in the red (6000–7000Å) than in the near infrared (7500–8500Å) prints of the Palomar Near Infrared Photographic Survey of the Galactic Plane (PNIPS). Only emission-like objects can appear brighter in the red. Following this idea, Sabbadin (1986) was able to identify a number of misclassified Planetary Nebulae in existing catalogues.

A quick look at some of the prints suggested that this comparison was very effective also for the identification of hitherto unknown PN. In particular, it appears well suited for faint, compact PN which were missed by other types of searches.

The first attempts at a systematic work in this direction made clear that, in order to diminish the number of candidate PN (excluding plate faults, variable stars, etc), the simultaneous examination of the blue and red prints of the Palomar Observatory Sky Survey (POSS) was very useful. The efficient comparison of the four different images of the same sky region (B, R of POSS; R, IR of PNIPS), allowing for slightly different field centres, print scales and quality, required a devoted system as result of a considerable experimentation.

In the procedures developed at the Astronomical Observatory of Padua, each Palomar print is automatically digitized, by means of a fixed CCD camera, as 216 adjacent fields, exploiting, for the X and Y movements, the carriage of the PDS machine, after a proper alignment on some reference stars. The

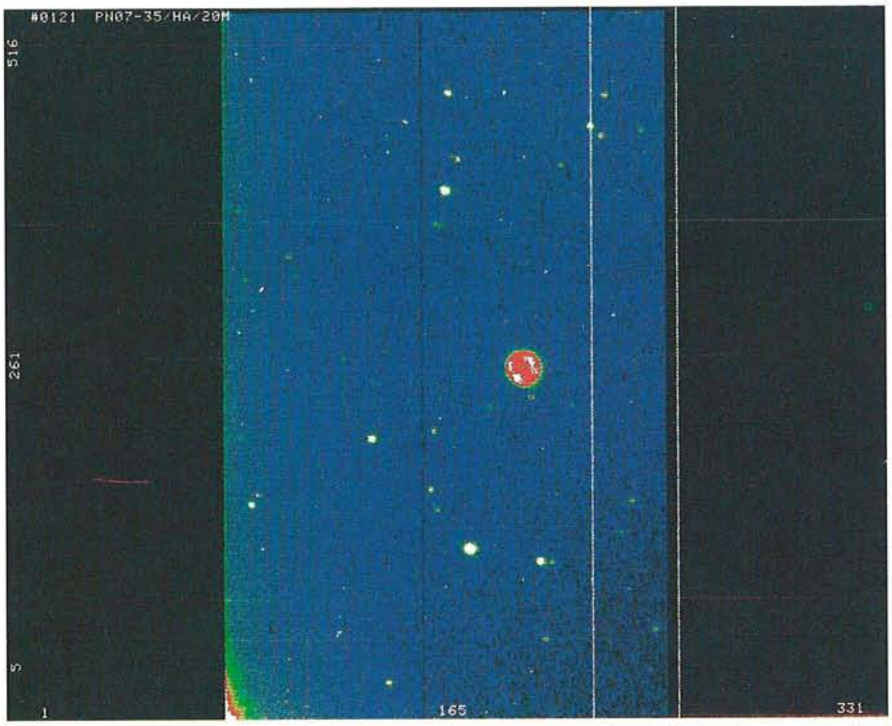

Figure 1: *Hα + [NII] image of the PN at α = 07ʰ55ᵐ20ˢ, δ = −35°58′ (ESO filter # 694, CCD RCA # 15, 20-min. exposure). North is at the top, east is right.*

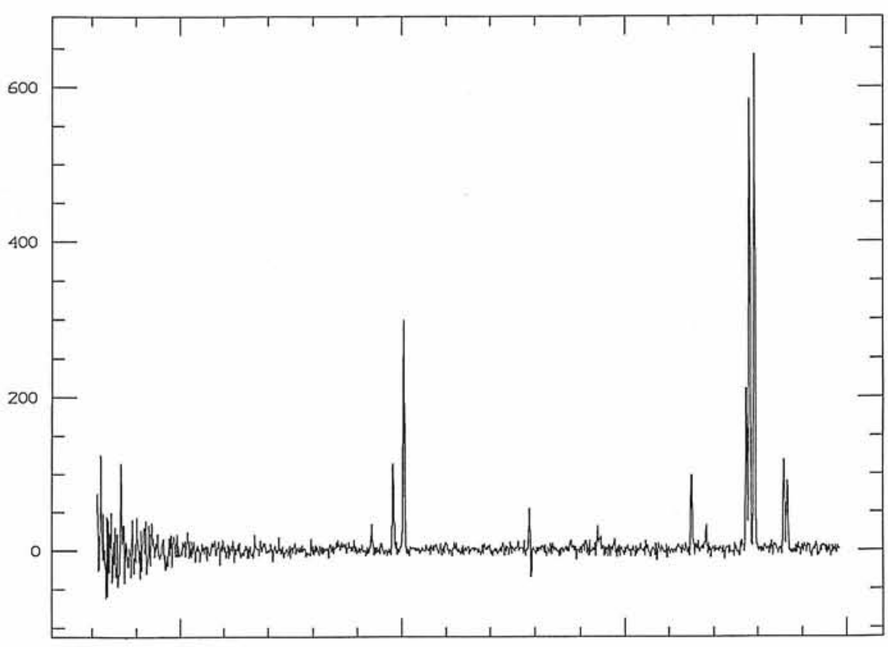

Figure 2: *B&C spectrum of PN α = 07ʰ55ᵐ20ˢ, δ = −35°58′ (B&C ESO grating # 2, CCD RCA # 15, 60-min. exposure). In the x-axis is wavelength in Å, in the y-axis is flux in erg cm^{-2} s^{-1} $Å^{-1}$ × 10^{-16}.*

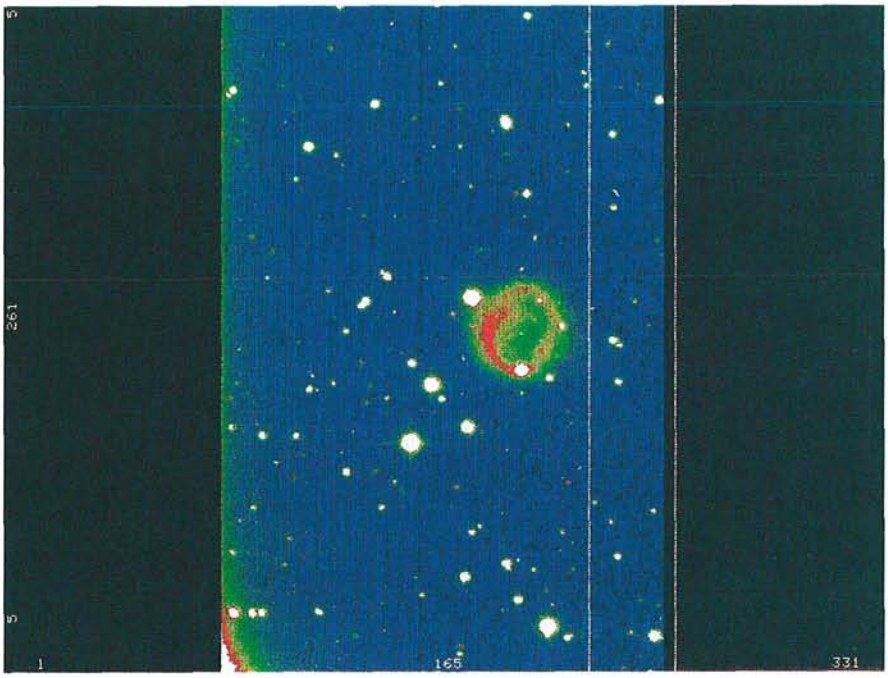

Figure 3: *Hα + [NII] image of the PN at $\alpha = 08^h11^m23^s$, $\delta = -32°52'$) (20-min. exposure).*

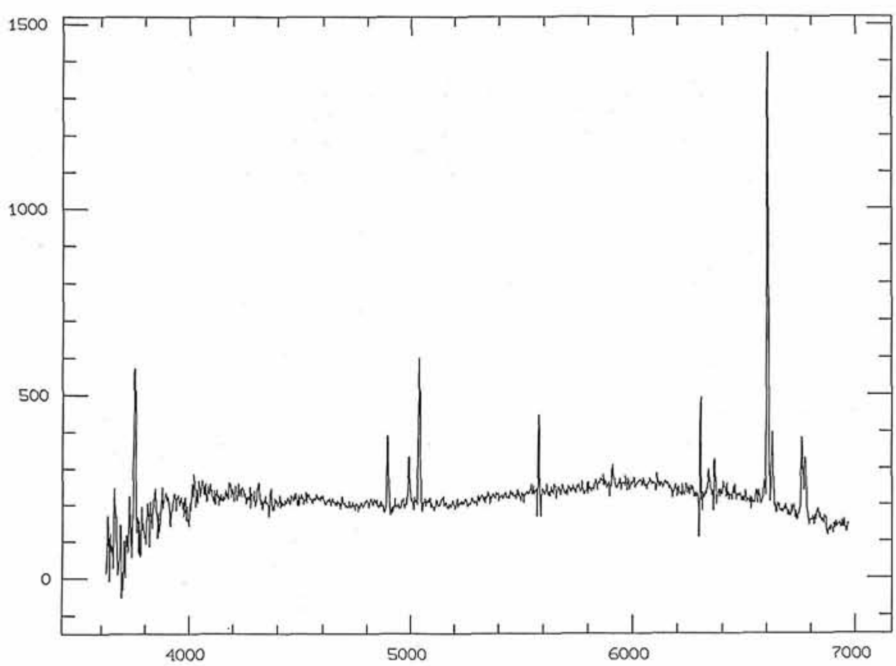

Figure 4: *B&C spectrum of the PN at $\alpha = 08^h11^m23^s$, $\delta = -32°52'$) (60-min. exposure).*

4 × 216 images are stored on tape, and then examined by means of a devoted software which allows the subtraction and blinking of the different images of each field. When a candidate is found, using a cursor, we can measure its rectangular coordinates that, with reference to a sample of SAO stars, can be promptly converted to right ascension and declination.

With the aim to extend our search to the southern hemisphere, we conceived a proposal for the ESO Schmidt telescope at La Silla, to obtain red and near-infrared plates of selected fields centred at the position of the ESO-Survey plates (which will be used for confirmation of the candidates). The proper plate-filter combination and exposure times, and the comparison of plates of each field taken in the same nights, will allow to distinguish more effectively stars of unusual colour from PN candidates (the first six pairs of plates have been recently delivered to us and will be analysed in the near future).

Verification

With this method we found up to now almost one hundred new PN candidates. Of course, the identification is only the first step of an effective scientific programme. Candidates need first a spectroscopic confirmation and, later, true PN deserve detailed morphological and spectroscopical investigation.

The first results of the search are very encouraging. Thanks to the effectiveness of the method and the careful examination of the different images of the field, the number of candidates which do not turn out to be emission-line objects is virtually zero. In fact, most candidates can be positively identified as PN (cf. Turatto et al., 1990; Cappellaro et al., 1990).

While northern sky objects can be investigated at the Asiago 1.82-m telescope, a first sample of southern sky PN was observed at ESO using the 2.2-m telescope last February. In principle, EFOSC is the best instrument to observe these faint nebular objects lost in crowded galactic fields. At the start, an interference filter image can been obtained, which allows both the morphological classification of the nebula and the accurate pointing for the following long-slit spectroscopy, needed for the final confirmation and the study of the physical condition of the PN. Moreover, broad-band photometry in different bands of the central star can also be promptly assured allowing to derive absolute magnitude and colour temperature for the ionization source.

Unfortunately, in the first run we got in February this year, EFOSC2 was not yet available, and we had to perform the spectroscopic programme with the Boller and Chivens spectrograph and the imaging with the CCD camera. This implied the selection of a subsample of the brighter PN.

As an example, in Figures 1 and 2 are shown the Hα image and spectrum of the PN candidate at $\alpha = 7^h55^m20^s$ $\delta = -35°58'$ (1950.0). The spectrum, with strong [NII] and [OIII] emissions, is typical of a heavily absorbed PN. In fact, the observed ratio $H\alpha/H\beta \simeq 17$ compared to the recombination value of 2.85 (Aller, 1984) allows to estimate the extinction $A_V \simeq 4.8$ mag. The nebula appears as a roundish disk of about 15 arcsec diameter.

A second example is illustrated in Figures 3 and 4. This object (at $\alpha = 8^h11^m23^s$, $\delta = -32°52'$) is another typical PN, suffering a smaller extinction. From the observed $H\alpha/H\beta \simeq 6.5$ can be derived $A_V \simeq 2.4$ mag. This fact and the larger apparent dimension of the Hα image (about 30 arcsec) suggest that this PN is closer than the previous one. The

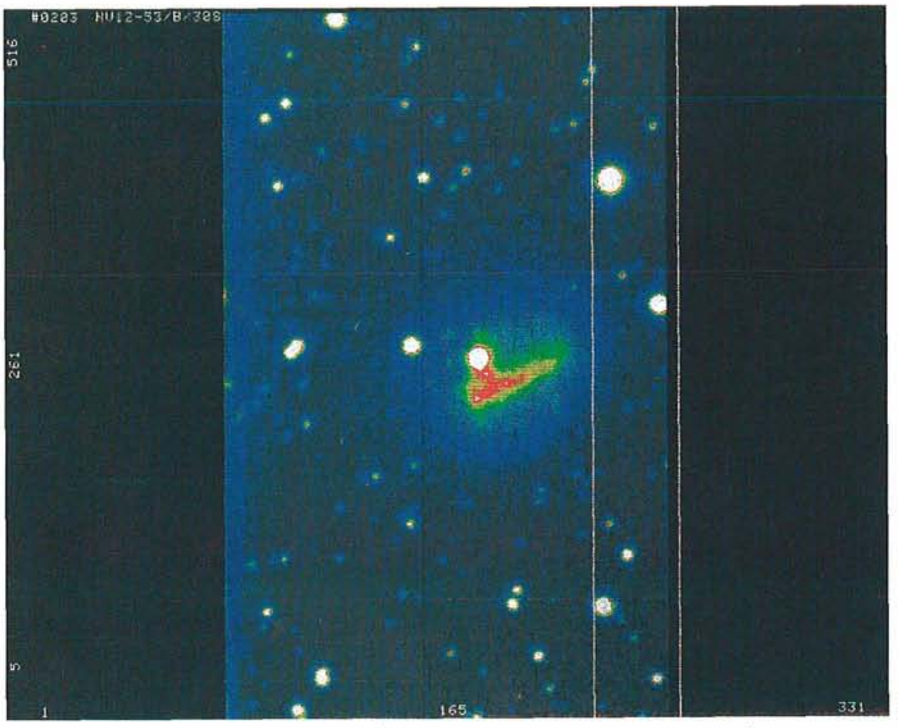

Figure 5: *Image of the galaxy at α = 12ʰ44ᵐ16ˢ, δ −53°17′) (30-sec. exposure).*

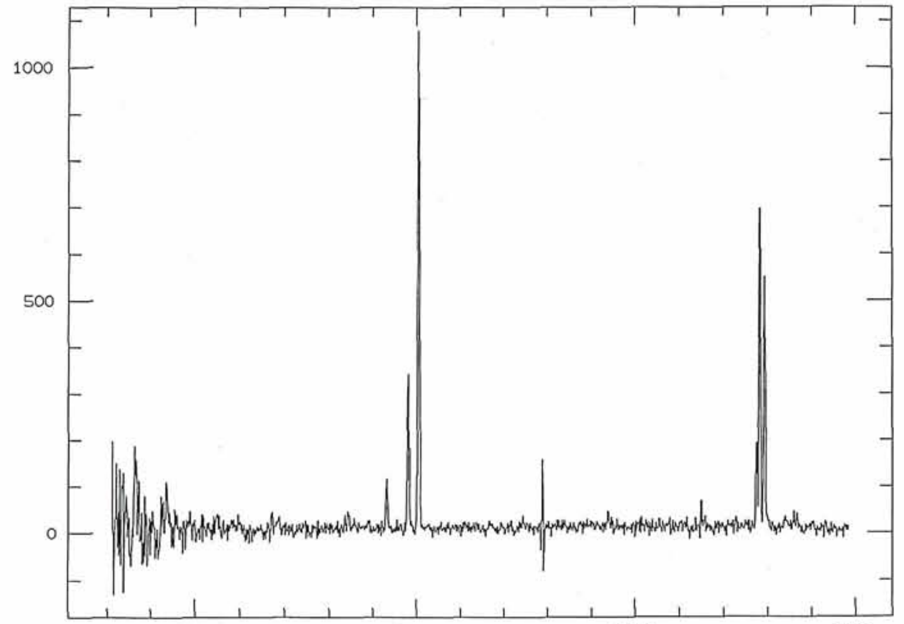

Figure 6: *B&C spectrum of the galaxy at α = 12ʰ44ᵐ16ˢ, δ = −53°17′) (60-min. exposure).*

latter object was later found to be included as possible PN in the Atlas of Galactic Nebulae (Neckel and Vehrenberg, 1990).

Among the candidates that are not PN, a few are identified as emission-line galaxies, at relatively small redshift (cf. Sabbadin et al., 1989). This is especially interesting as our search concentrated on low galactic latitude fields where the extinction is usually very high, some of these galaxies may be nearby "backyard" objects.

The spectrum of one of these galaxies is shown in Figure 5. This galaxy ($\alpha = 12^h44^m16^s$, $\delta = -53°17'$) has redshift v $\simeq$ 1800 km s^{-1}, from the position of the emission lines typical of HII regions. The extinction, implied by the ratio $H\alpha/H\beta \simeq 3.6$ is quite small. Finally, the preliminary investigation suggests an irregular morphology (Fig. 6).

The full reduction of the first run of observations is now in progress, and we are confident to collect much more material in the future. We hope therefore to be able, in a relatively short time, to perform a statistical analysis of the physical properties of this class of compact PN.

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New ESO Preprints

Scientific Preprints

(March – May 1991)

753. M.-H. Ulrich: The Signatures of an Accretion Disk in the Electromagnetic Spectra of Quasars and AGNs. Proc. of the 6th IAP Meeting/IAU Coll. No. 129, Paris, 2–6 July 1990.
754. M. Stiavelli: Dissipationless Galaxy Formation? Proc. of TEXAS/ESO/CERN Symp. on "Relativistic Astrophysics, Cosmology and Fundamental Physics", Dec. 16–21, 1990, Brighton.
755. M. Stiavelli and L.S. Sparke: Influence of a Dark Halo on the Stability of Elliptical Galaxies. *Astrophysical Journal.*
756. R.P. Saglia, G. Bertin and M. Stiavelli: Elliptical Galaxies with Dark Matter: II. Optimal Luminous-Dark Matter Decomposition for a Sample of Bright Objects. *Astrophysical Journal.*
757. ESO Photographic Laboratory: ESO Contributions to the Meeting of the IAU Working Group on Photography. Garching, October 30–31, 1990. To be published in the Proc. of the meeting (ed. J.-L. Heudier, Observ. de Nice, France).
758. B.J. Jarvis: An Optical (Emission Line) Jet in M87. *Astronomy and Astrophysics.*
B.J. Jarvis and J. Melnick: The Nucleus of M87: Starburst or Monster? *Astronomy and Astrophysics.*
759. L. Pasquini and R. Pallavicini: High-Resolution Spectroscopy of Cool Stars at ESO. *Memorie della Società Astronomica Italiana.*
760. L. Ciotti, A. D'Ercole, S. Pellegrini and A. Renzini: Winds, Outflows and Inflows in X-Ray Elliptical Galaxies. I. *Astrophysical Journal.*
761. F.R. Ferraro, G. Clementini, F. Fusi Pecci and R. Buonanno: CCD-Photometry of Galactic Globular Clusters. III: NGC 6171. *Monthly Notices of the Royal Astronomical Society.*

762. M. Bersanelli, P. Bouchet and R. Falomo: JHKL' Photometry on the ESO System: Systematic Effects and Absolute Calibration. *Astronomy and Astrophysics.*
763. Bo Reipurth: Herbig-Haro Objects. Review presented at the NATO Advanced Study Institute "Physics of Star Formation and Early Stellar Evolution", held in Crete, June 1990.
764. Non-Thermal Excitation of Helium in Type Ib Supernovae. *Astrophysical Journal.*
765. B.J. Jarvis and R.F. Peletier: The Core of M87: New High Spatial-Resolution Kinematic Measurements. *Astronomy and Astrophysics.*
766. E.J. Wampler, J.-S. Chen and G. Setti: Has Interstellar [Fe x] been Detected in the Spectrum of SN 1987 A? *Astronomy and Astrophysics* (Research Notes).
767. F. Bertola, M. Vietri, W.W. Zeilinger: Triaxiality in Disk Galaxies. *Astrophysical Journal, Letters.*
768. S. Djorgovski, G. Piotto, E.S. Phinney and D.F. Chernoff: Modification of Stellar Populations in Post-Core-Collapse Globular Clusters. *Astrophysical Journal* (Letters).
769. W.C. Saslaw and P. Crane: The Scale Dependence of Galaxy Distribution Functions. *Astrophysical Journal.*
770. P.A. Shaver: Radio Surveys and Large Scale Structure. To be published in *The Australian Journal of Physics.*

Technical Preprint

27. J.M. Beckers: Blind Operation of Optical Astronomical Interferometers: Options and Predicted Performance. *Experimental Astronomy.*

The Striking CMD Features of the Very Metal-Rich Globular Cluster Terzan 1

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E. BICA, Universidade Federal do Rio Grande do Sul, Brazil
B. BARBUY, Universidade de São Paulo, Brazil

The region of the Galactic centre is known to have some high metal-content globular clusters (e.g., Ortolani, Barbuy and Bica, 1990, OBB90). Recently, we have started a programme to study such peculiar, generally obscured clusters, interested mostly in the high-metallicity effects on the colour-magnitude diagrams (CMDs) morphology. Such studies can bring valuable information on the evolutionary paths of metal-rich stars, blanketing effects, and to establish their connection with metal-rich populations in bulges of galaxies.

Only little information is so far available for these clusters because, for such studies, it is necessary to observe under excellent seeing conditions, due to the crowding of fields. The extension of the photometry to long wavelength bands, such as I and Gunn z, is required in order to minimize the absolute, as well as the differential reddening influence.

In our previous study of NGC 6553 (Barbuy, Bica and Ortolani, 1989; OBB90), we already revealed peculiar features in the CMDs, as for example the turn-over of the red giant branch (RGB) and its faint tip, due to high opacity in the cooler giants. Now the study of the globular cluster Terzan 1 (ESO 455-SC 23) at only 2.6° from the direction of the Galactic centre reveals a more extreme case. Terzan 1 is a compact cluster, as shown in a V CCD frame taken at the Danish telescope (Figure 1). The

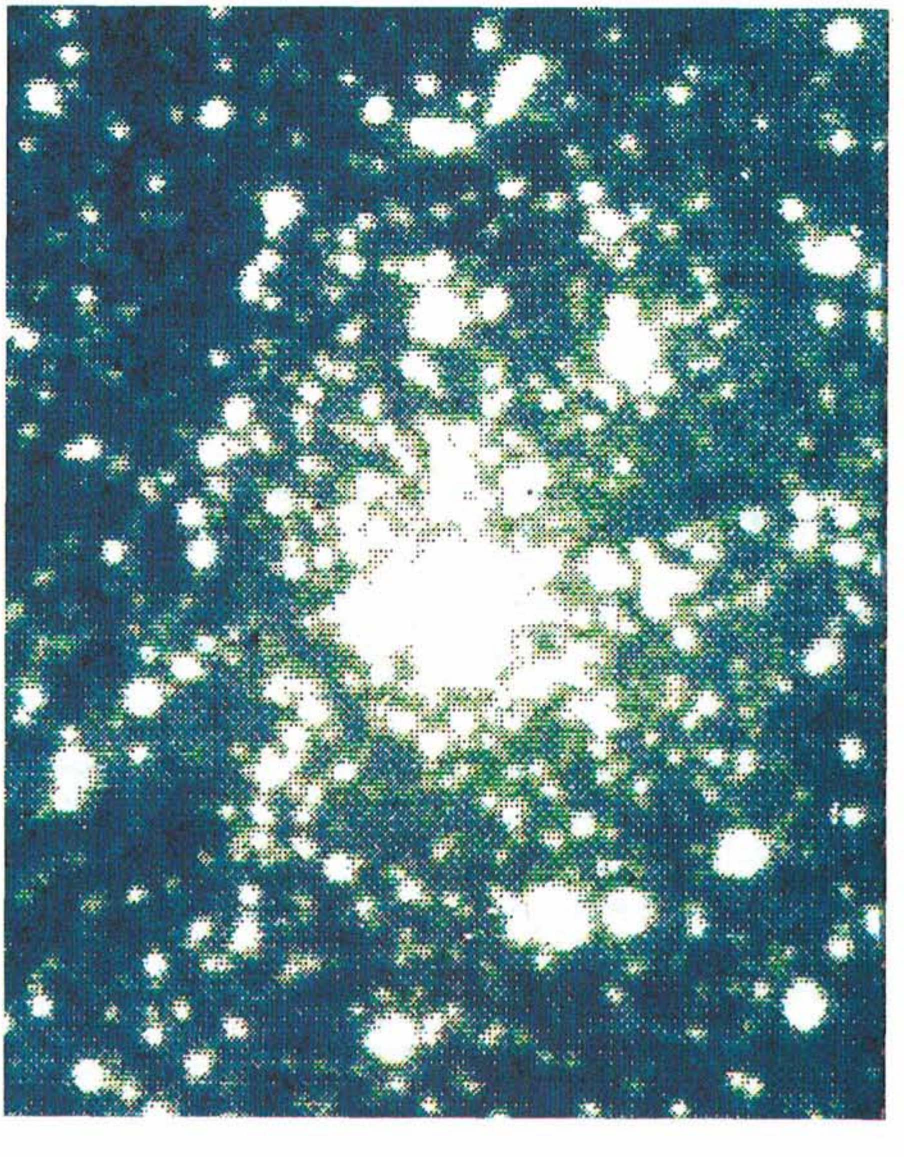

Figure 1: *V CCD frame of Terzan 1.* ▶

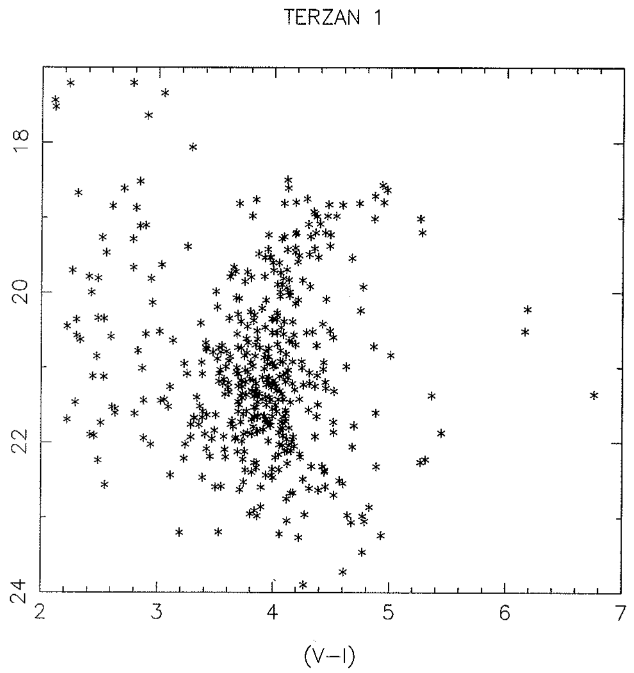

Figure 2: *Whole frame CMD in V vs. (V-I).*

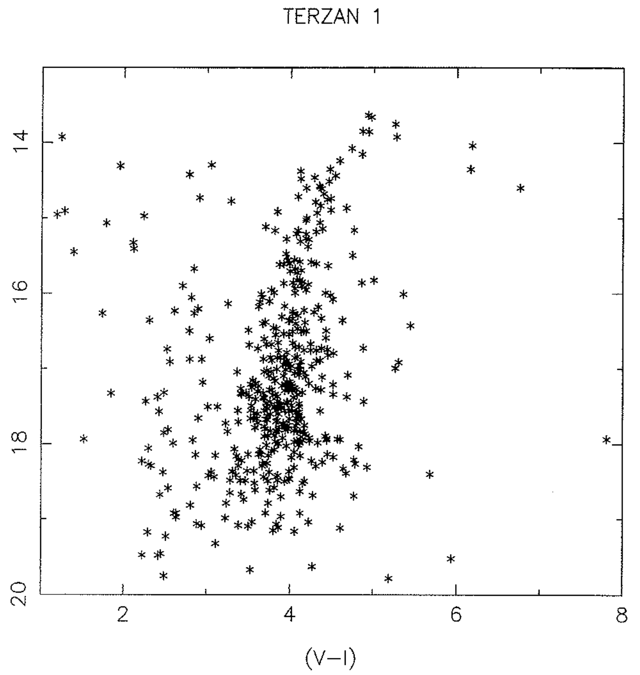

Figure 3: *I vs. (V-I): circular extraction of 0.8 arcmin.*

only information available for this cluster is based on the integrated infrared photometry of Malkan (1982), which suggests a very high reddening and very high metallicity.

Colour-Magnitude Diagrams

We observed Terzan 1 in June 1990 at the Danish 1.54-m telescope, under good seeing conditions (≈ 1″) in BVRI and Gunn z colours. The CCD was the RCA ESO # 5, which has a high sensitivity in the near-infrared. We show in Figure 2 the whole frame CMD in V vs. (V-I). Notice the pronounced blue main sequence on the left part of the diagram. This corresponds to projected disk stars on the cluster direction, since the cluster is located less than 1° from the Galactic plane. The concentration of points on the right side of the diagram defining a tilted strip appears to be an extreme case of Horizontal Branch (HB) morphology in metal-rich globular clusters.

This diagram V vs. (V-I) shows a Red Giant Branch (RGB) turn-over which is more pronounced than that of NGC6553 (OBB90). The RGB tip goes below the HB level, clearly fainter than in the case of NGC6553, indicating a stronger blanketing due to a higher metal content. The "horizontal" branch itself is very peculiar: it is tilted, quite elongated crossing over the RGB.

In the following figures we present CMDs from a circular extraction of 0.8 arcmin around the cluster centre, in order to minimize field contamination. The I vs. (V-I) diagram (Fig. 3) shows a more compact HB which, however, still extends beyond the RGB on the red side. The RGB in Terzan 1 has a more pronounced curvature than that of NGC6553, and is as well more extended, although this extension relies on few stars. Also the above evidences point toward a higher metallicity for Terzan 1 with respect to NGC6553. There

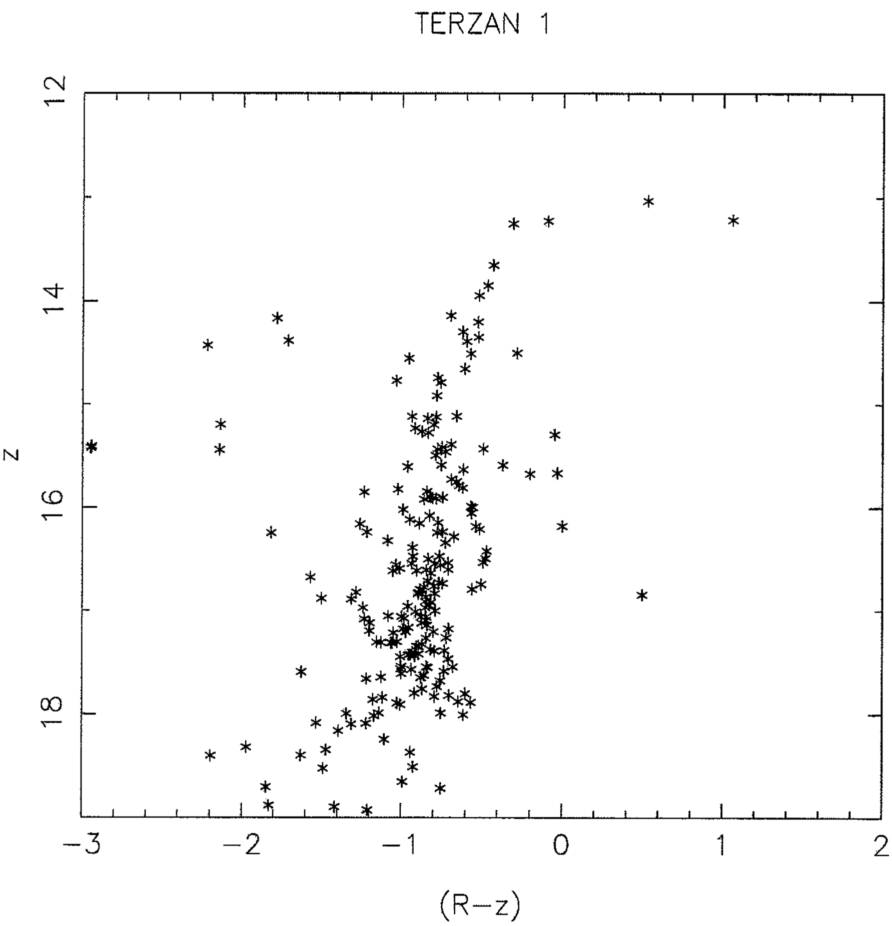

Figure 4: *z vs. (R-z): circular extraction of 0.8 arcmin. The z colour is not calibrated due to a lack of reference data.*

is no other known example of such extreme behaviour. In a corresponding diagram for NGC 6553, the RGB is flat near the tip (OBB90).

A new experiment was attempted using the Gunn z band (effective wavelength λ_e = 8900 Å), which is close to the red limit reachable with the CCD. In this band considerably less blanketing and reddening are expected. The diagram z vs. (R-z) – Figure 4 – shows little spread at the SGB and RGB, and a flat RGB tip. It is interesting to note the peculiar HB crossing the RGB and showing an extension to the red side.

Distance and Reddening

We estimate the reddening using NGC 6553 as reference (OBB90). From the usual position of the HB in metal-rich clusters (the stubby red clump to the left side of the RGB), we derive E(V-I) = 2.38 which corresponds to E(B-V) = 2.04, one of the largest so far found for globular clusters. This implies that the cluster is located at d $\approx$ 5.2 kpc from the Sun and about 3.6 kpc from the Galactic centre, therefore another genuine bulge (and "disk") globular cluster. This reddening value is considerably higher than that obtained by Malkan (1982) from integrated properties.

These reddening and distance estimates are however conservative values, because we are taking intrinsic values of HB position from nearby solar-metallicity clusters. For the above discussed reasons, we are probably dealing with a more extreme metallicity case, and consequently stronger blanketing effects could play an important role.

Conclusion

The interesting CMD properties of Terzan 1 place this cluster as the best candidate for stellar studies, in order to make the link with the nuclear stellar populations in the massive galaxies.

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Deep Hα Survey of Gaseous Emission Regions in the Milky Way and the Magellanic Clouds

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1. Introduction

The aim of this survey is to obtain the radial velocities of the ionized gas and the structure of the southern H II regions in our Galaxy and in the Magellanic Clouds.

The spiral structure of our Galaxy can be studied through young stars, individual H II regions and CO molecular clouds; the selection of giant regions similar to those observed in external galaxies allows to draw more precisely the spiral pattern. A first detailed model, with four spiral arms, has been established (Georgelin and Georgelin, 1976) from the distances of exciting stars and from H II regions radial velocities (Hα and radio recombination lines). Recent radio-recombination-line surveys by Downes et al. (1980) and Caswell and Haynes (1987) have confirmed and expanded this four-arm pattern. The CO surveys made by Columbia University, Stony Brook and Sydney teams show that the giant molecular clouds follow the same spiral arms. In spite of all these agreements this large-scale distribution of ionized hydrogen remains imprecise and complementary observational data are needed. Moreover, the distances are a fundamental parameter for physical studies of interstellar matter; they di-

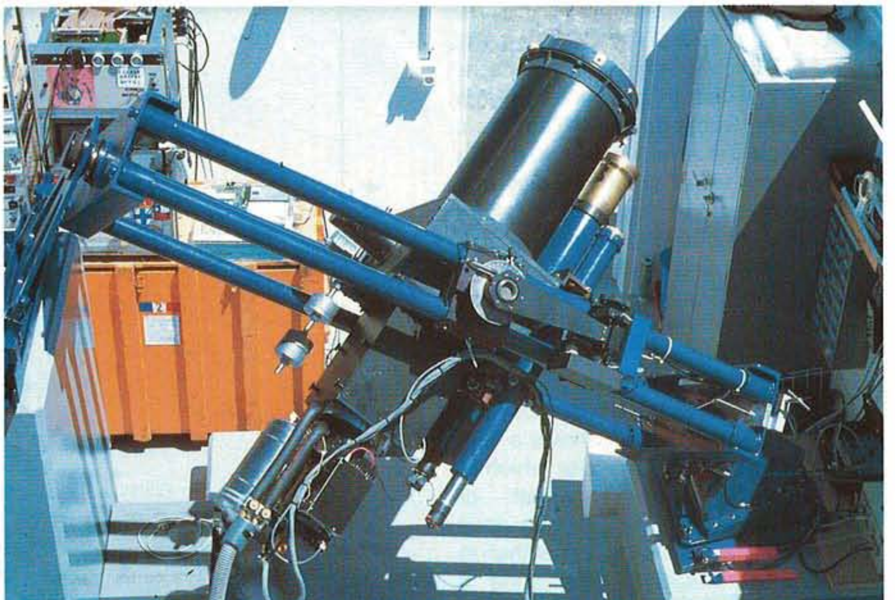

Figure 1: *The 36-cm telescope of the HαSurvey at La Silla. Assembled and tested on the sky at Marseille Observatory in April 1989, it was installed at La Silla in October 1989. Its shelter, built by ESO, has a sliding roof, and an adjacent room has been added to accommodate the data-acquisition and visualization system. Below the main tube one can see two small refractors: one is equipped with a small CCD camera for guiding and the other one with a normal eyepiece for field identification. Prominent at the lower part of the instrument are the bright cryostat containing liquid nitrogen for cooling the photocathode of the Photon-Counting Camera (dry nitrogen circulates inside the pipes to prevent frost formation on the photocathode) and the High-Voltage power supply (black box).*

Table 1: *Main characteristics of the instrument*

Telescope
- Ritchey-Chretien type (for a large field)
- Primary mirror: 36 cm diameter
- Final aperture ratio F/D = 3.3
- Spatial resolution 9″/px
- Field of view 38′ × 38′

Detector
- Photon-counting camera composed of a microchannel plate intensifier electrostatically focused coupled to an SIT camera through optic fibres
- Number of pixels: 256 × 256
- Resolution: 1 px = 52 μm
- Dynamic range: 2 ev/px/h to 3000 ev/px/h
- Dark noise: 2 ev/px/h
- Time resolution 1/50 s for each frame

Interference filters
- Wavelength Hα, [NII], [SII], Hβ, [OIII]
- Bandpass 10 Å FWHM for each filter

Interferometers
- 2 scanning Fabry-Pérot. At Hα wavelength characteristics are:

– interference order for Hα	p = 796	p = 2600
– free spectral range	8.2 Å = 376 km/s	2.5 Å = 115 km/s
– spectral resolution	0.68 Å = 31 km/s	0.25 Å = 11.5 km/s
– typical scanning	24 steps	24 steps
– sampling step	0.34 Å = 16 km/s	0.10 Å = 5 km/s
– velocity accuracy	2 to 3 km/s	1 km/s

Typical exposure time
- 2h = 60 scanning sequences
- 1 scanning sequence = 5s per scanning step × 24 steps

Detection limit
- 10^{-9} Jm^{-2} s^{-1} sr^{-1} with a S/N ratio between 1 and 2 for a 15-min exposure time

rectly influence the energetic balance and phenomenological process.

Optical and radio observations are complementary data; however, the overlap is poor, only 30% of the objects having been observed in both ways. The radio observations are limited to the most intrinsically bright objects whereas the optical observations are mainly limited by absorption. Radio data give two possible distances for a given observed radial velocity; the flux, the localization, the morphology and the radial velocities of optical H II regions allow to resolve this distance ambiguity for a lot of objects. Optical observations are an essential link between stellar distances (the only straightforward process) and the radio radial velocities. They can also help discriminating between a "physical link" and a "fortuitous coincidence" when HII regions and molecular clouds are found on the same line of sight and appear close to one another in the sky.

The high sensitivity to monochromatic Hα emission, the large field of view, and the high spectral resolution of our new equipment enable us to start detailed emission-line studies. We hope to define the components (bright condensations, classical H II regions, diffuse emission, radio components) and the limits of the large complexes and we intend to study most particularly the H II regions in areas of stellar formation.

Our Survey should be helpful for the understanding of the physics of the Magellanic Clouds. Since it will provide a homogeneous set of data with wide-field high sensitivity and sufficient angular resolution for both clouds. This will allow to study the global kinematics of these galaxies together with their interstellar medium. A better understanding of several phenomena is expected: mechanisms of galactic fountains, motions and interactions of superbubbles, classical H II regions and SNRs in relation with the amount of energy deposited through several mechanisms (SN explosions, stellar winds, star formation, cloud collisions, etc.) in the various components of the SMC and LMC, detailed study and identification of the nebulae (for instance identification of large diameter SNR). Fabry-Pérot observations are especially well suited for the study of superbubbles or large nebular complexes such as N 11 in the LMC. Furthermore, an absolute calibration will be possible all over the LMC since our large field always contains at least one nebula already calibrated by other authors through photoelectric measurements.

2. Hα Survey Station: A Small Telescope and a High-Performance Software

Thanks to the agreement of the ESO Director General, a 36-cm diameter telescope (see Fig. 1) was installed at La Silla (Chile) in October 1989, near to the GPO. Its Cassegrain focus is equipped with a focal reducer, a scanning Fabry-Pérot interferometer and a Photon-Counting Camera. The concept is similar to our CIGALE instrument (Boulesteix et al., 1984) already used successfully on several large telescopes. The main characteristics are given in Table 1. The telescope and its focal reducer built at Marseille Observatory provide a large field and a high luminosity. The two available scanning interferometers are manufactured by Queensgate Instruments Ltd., London; in such a device, the spacing of the plates may be adjusted step by step through a special electronics controller driving piezo-electric spacers. The Image Photon Counting System – based on a photon-counting camera manufactured by Thomson CSF (France) that we developed with the help of INSU, OHP and LAS in 1975-77 – allows to analyse the photon events frame by frame with a time resolution of 1/50 s. The events are centred with a special detection electronics. The huge amount of data (originally 240 M_o/night when we recorded all the addresses of the detected events) and the systematic nature of this survey led us to conceive a new acquisition system.

A high performance software allows the astronomer to act pertinently on the observational sequence (field identification, S/N ratio estimate, interferometer stability checking, etc.) and to have a complete access to the reduced data while observing, for example to deconvolve and decompose profiles and to measure radial velocities in selected areas of the observed field.

The data-acquisition system is built around VME technology with a Motorola 68020 microprocessor and a real-time operating system PDOS. It is manufactured by Force Computers (Germany). This machine controls the spacing between the plates of the Fabry-Pérot interferometer and receives each 1/50th second the addresses of the photon events found in the frame of the Photon-Counting Camera. These events are used to build up integrated images for each of the 24 values of the spacing of the interferometer (see section 3 to know how a Fabry-Pérot works). While acquiring the data, the free time of the computer may be used to run a set of powerful programmes for reducing the data already recorded in memory.

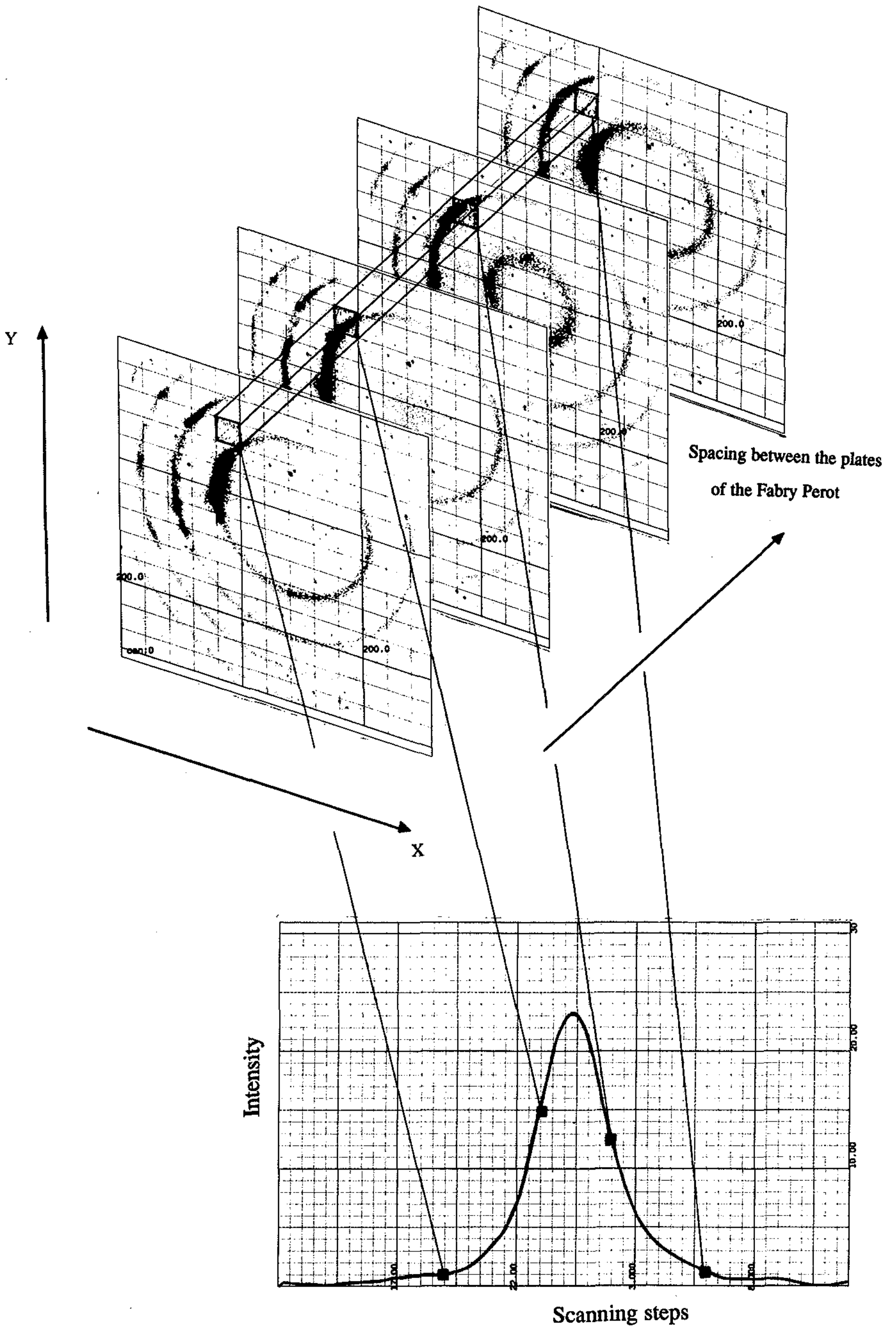

Figure 2: *Schematic representation of how a scanning Fabry-Pérot interferometer allows one to obtain detailed profiles of an emission line from all over a nebula. The series of interference-ring images shown here is a selection from the 24 images given by the interferometer through its scanning process. To show what happens we have exaggerated the pixel size and focused our attention on a given pixel. The profile at the bottom is obtained by plotting the intensity measured inside this pixel for each scanning step. Comparison with calibration rings produced by a well-known emission line allows one to find the precise wavelength origin for the profiles observed inside each pixel of the field.*

When an observation is completed, the data are saved on tape with high efficiency using a dedicated compression algorithm permitting to reduce by 5 the size of the files.

The computer also takes on the automatic guiding of the telescope. In this purpose a small cheap CCD has been attached at the focus of a guiding refractor. The frames are digitized and added in memory to increase the S/N ratio (typically 50 frames). The flat-field correction is done automatically and a dedicated software computes the required corrections to be applied to the telescope driving system. The originality of this automatic guiding system is that it directly stops the interferometer scan and data acquisition whenever the guiding star is lost (because of clouds for instance), everything going on normally as soon as the star is retrieved.

What makes this computer powerful, besides the multitasking system, is the very fast context switching of the real-time kernel of PDOS permitting to convert all interrupts in terms of events in order to preserve the integrity of the kernel and use all of its facilities to synchronize properly each different task.

3. How Does a Fabry-Pérot Interferometer Work?

The Fabry-Pérot interferometer is composed of two semi-transparent parallel plates coated with dielectric layers. A constructive interference occurs – i.e. an incident monochromatic light will be transmitted – only when the wavelength λ, the angle of incidence i and the spacing e between the plates follow the formula

$$\frac{2\,ne\cos i}{\lambda} = p$$

where p is an integer.

p is called the interference order and n is the refractive index of the medium (n ~ 1 for the air).

The three main parameters are always linked together through the above formula:

– λ is the wavelength of the nebula we observe. It is the spectral information we are looking for.

– i is the angle of incidence of the light. The cylindrical symmetry of the problem explains why we observe rings through a Fabry-Pérot. The successive rings are found at spatial locations in the field where p is an integer following the above formula. Spectral and spatial information are linked.

– e is the spacing between the plates. It is in fact the only parameter we may adjust easily (this spacing may be changed step by step).

A necessary and sufficient condition to have a complete information all over the field of view is to scan a total quantity Δe defined by:

$$\frac{\Delta e}{e} = \frac{1}{p} = \frac{\Delta\lambda}{\lambda} = \frac{i_{n+1} - i_n}{i_n}$$

(where n refers to the ring number)

One can see that, through the scanning process:

p is changed by one unit

λ has scanned a free spectral range $\Delta\lambda = \frac{\lambda}{p}$

i has scanned the whole field of view. The interference rings have scanned the field and each ring has moved to replace the following one.

An often used parameter is the effective Finesse

$$\mathcal{F} = \frac{\Delta\lambda}{\delta\lambda} = \frac{\text{(free spectral range)}}{\text{(spectral resolution)}} = \frac{i_n - i_{n-1}}{\Delta i}$$

$$= \frac{\text{(angular separation between two rings)}}{\text{(width of ring profile)}}$$

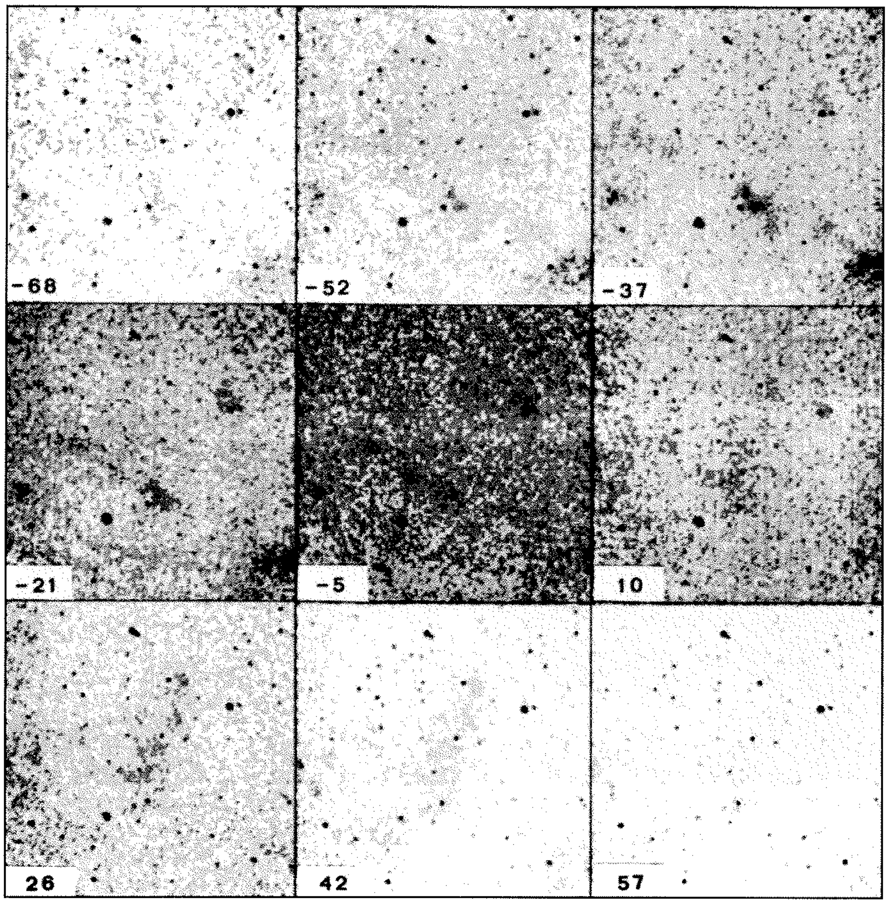

Figure 3: *Area of the Milky Way around longitude l = 302° (Field 38′ × 38′). Series of λ Maps (Hα wavelength) of the same field with narrow bandpass (0.34 Å or 15.6 km s^{-1}) centred at the V_{LSR} radial velocity indicated within each frame. Three emissions are observed in that field. The general diffuse emission produced by the local arm and related with the Coalsack can be seen on the 3 central λ Maps around V_{LSR} = –5 kms^{-1}. Two other nebular components, 3 times fainter, are seen around –37 kms^{-1} and around +26 kms^{-1}. These three faint nebulae are not seen on the Sky Survey (ESO SRC, red). The emission observed at –37 kms^{-1} comes from the Scutum-Crux spiral arm, while the emission around +26 kms^{-1} comes from the tip of the Sagittarius-Carina spiral arm and corresponds to an HII region much farther out on the line of sight. This region, already known as the radio source 302.5 –0.7 had never been detected at optical wavelengths. It is some 11.7 kpc distant.*

For our interferometers the Finesse is about 12 or 10, that is why we scan through 24 scanning steps.

Figure 2 is another way to understand what really happens in such a device where spatial and spectral information are so intimately linked. When the interferometer is scanning, one can see that the observed flux in a given pixel suddenly increases when an interference ring crosses this pixel.

4. Why a 36-cm Telescope?

Is it madness to initiate an observing programme with a 36-cm telescope at a time when everybody is talking about 8-m telescopes? This would be true if one observed point-like sources, since in that case the light gathered would be proportional to the mirror area. But this is not true for extended sources (such as the Hα emission of the Milky Way) because of the so-called optical extension conservation principle (SΩ = constant). For extended sources, the received light is the same for a 36-cm as for a 3.60-m – the loss in collecting area is exactly compensated for by the increase in the observed angular field Ω. The limiting detection is thus the same for both large and small telescopes and in fact is most often set by our ability to subtract the parasitic nightsky lines (OH 6553.5 Å, geocoronal Hα 6562.8 Å, OH 6568.7 Å, OH 6577.2 Å).

Since we study interstellar matter, it is worth making a comparison with radio telescopes. Observing CO clouds is done at two different scales. On the one hand, a survey of the southern Milky Way has been done with 8.′8 spatial resolution: Grabelsky et al. (1988), Bronfman et al. (1989). On the other hand, a more detailed analysis of regions where high-mass stars are forming is currently being done at La Silla with the SEST radio telescope at 44″ spatial resolution. Our 9″ pixel size and our wide field (38′ × 38′) will enable us to observe the ionized hydrogen in a manner directly comparable with both types of radio observations.

5. Why a Photon-Counting Camera?

On the basis of purely physical characteristics our photon-counting camera is clearly overtaken by modern CCD cameras (number, size and stability of pixels, d.q.e., dynamical range, etc.). However, it offers a real advantage for this precise type of observation with a scanning interferometer. Since our IPCS has no reading noise at all, we may scan the interferometer as rapidly as we want (typically 5 seconds for each scanning step), reading and recording the images for each of the 24 steps, then scanning again the whole free spectral range and adding up in memory the successive exposures for each scanning step. For a typical observation, the scanning sequence is repeated 60 times. This enables us to average the transparency conditions encountered along the exposure for each scanning step (which would be due to the mere inevitable change in air mass).

Another advantage for the astronomer is that as soon as the first complete scan is finished, it is possible to visualize on the TV monitor the observed profiles in selected areas.

6. Some Results

Three observing runs have already been made with this instrument (a typical run occupies a new moon) since April 1990. Most of the observed fields are in the Milky Way and in the Small Magellanic Cloud.

For each typical observation we obtain the following information (all of which are accessible in real time on the TV monitor during the observation):

– *24 calibration interferograms* from which we derive *one phase-map* giving for each pixel the wavelength origin. Instrumental profile and flat-field are also obtained from this series of calibration rings.

– *24 nebular interferograms* of the observed field. Owing to the calibration phase-map they allow to compute *24 λ-maps* analogous to the radio maps, thus giving *one data cube (x, y, λ).*

– *65,536 detailed Hα profiles* (one profile for each of the 256 × 256 pixels).

– *one velocity map* derived from the Doppler shift of the profile inside each pixel.

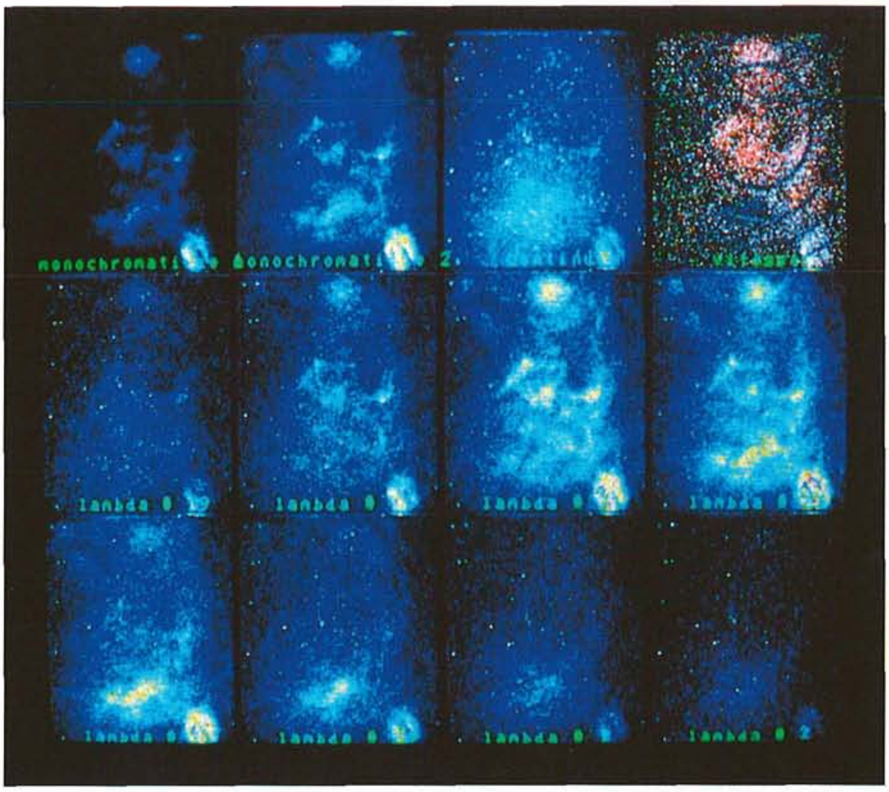

Figure 4: *Area of the Milky Way around galactic longitude l = 328°. This image has been taken on the TV monitor while observing a 38′ × 38′ field at galactic longitude l = 328°. It shows a typical example of real time visualization of the data already reduced while the instrument is scanning. The images built from the scanning sequence are, from left to right and starting from upper left corner: two monochromatic images of the field obtained with different thresholds, a continuum image of the field, the radial-velocity field with colour coding of the velocities (note that the fine blue rings are artefacts of the data processing, this problem has been fixed since). One clearly sees on this image that there is a group of nebulae around −40 kms^{-1} (pink colour) meanwhile there is a nebula down in the centre at about −20 kms^{-1} (blue colour). This means that now two spiral arms are resolved in this direction: the Sagittarius-Carina arm at −20 kms^{-1} and, just behind, the Scutum-Crux arm at −40 kms^{-1}. The following images on the screen (5th to 12th) are λ Maps (like the λ maps commonly used by radio astronomers) which are also computed from the scanning sequence. The bandwidth for each image is 0.34 Å (15.6 kms^{-1}). The heliocentric radial velocity is increasing from left to right (and then downwards) and goes through the following values: −83 kms^{-1}, −67 kms^{-1}, −51 kms^{-1}, −36 kms^{-1}, −20 kms^{-1}, −4 kms^{-1}, +12 kms^{-1}, +27 kms^{-1}. One clearly sees that the "peculiar" nebula down in the centre does not show up in the same frame as the others but with a shift of about two images.*

– *one monochromatic image* computed by integrating the flux found inside the emission line profile for each pixel.

– *one continuum image* computed by integrating the flux outside the emission line profile for each pixel.

Several tools for data analysis are available for the astronomer while observing to subtract the nightsky lines and to make a detailed analysis of the profiles.

The instrumental profile is the convolution of an Airy function (for the Fabry-Pérot) with a gaussian function (for the IPCS sampling). This instrumental profile is used to subtract the nightsky lines. Then the nebular profile can be decomposed into several Hα component profiles, each one being the convolution of the instrumental profile with a gaussian profile.

By now one can say that it will take a lot of time for the understanding of all the observed data since each run produces some 30 fields, each field containing 65,536 detailed Hα profiles inside which there are most often two or three different velocity components (after having subtracted all the nightsky lines) due to the different spiral arms of the Milky Way seen along the same line of sight. Both the intensities and velocities of the different components change all over the field, making the analysis of the data very complex.

Here are a few of the results already obtained in April 1990 and November 1990.

Several radio sources (detected through radio observations of the 6-cm H 109α hydrogen recombination line) have been detected at Hα wavelength for the first time. Figure 3 illustrates such

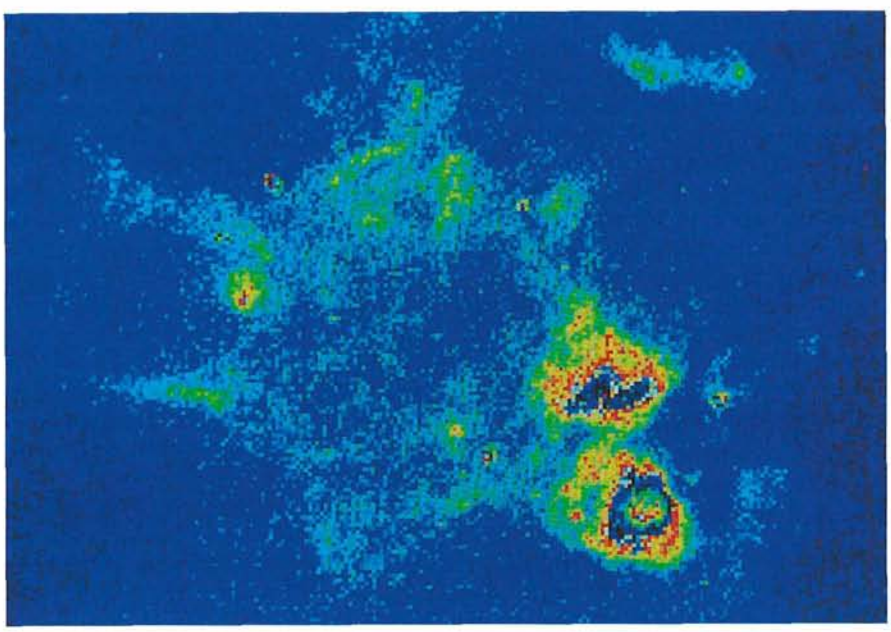

Figure 6: *A superbubble in the SMC. This figure shows a monochromatic image in Hα of a superbubble in the SMC. The diameter of this superbubble is about 20′ (360 pc at a distance of 60 kpc to this galaxy). This superbubble is formed of several smaller bubbles such as N36, N37 and N41 (Henize, 1956) to the west, DEM 80 to the east (Davies et al., 1976) and the SNR N 50 (SNR 0050 – 728) to the north. While this complex appears in DEM photographs, here it is really appreciated as a superbubble, although of less extent than superbubbles in other galaxies. From Hα profiles we have found two components of the radial velocity separated in 20 kms^{-1} at the centre of the superbubble. The SNR 0050 – 728 shows violent motions revealed as splitting of the profiles.*

a detection, showing the farthest H II region detected during the run of April 1990. It is 11.7 kpc distant, a true performance at optical wavelengths.

Figure 4 illustrates a typical example of a group of nebulae seen together in the sky (toward galactic longitude l = 328°), although they belong to different spiral arms of the Milky Way as shown by their different radial velocities.

Figure 5 is an example of analysis of the profiles over a mosaic of two connected fields (38′ × 38′ each) around galactic longitude l = 291°. The variety of Hα profiles obtained illustrates how difficult it is to analyse this type of data. Several components may be distinguished with widely varying intensities all over the field. Continuity considerations generally enable one to unambiguously decompose the profile into its main components, but particular cases may be encountered where the solution is not unique. The recently purchased high-resolution Fabry-Pérot interferometer should help solve these particularly difficult cases, since it offers a much better separation of the different components.

Figure 6 displays a monochromatic image of a superbubble in the SMC where two components of radial velocity profile have been detected at the centre. Violent motions have been found at the periphery due to the SNR 0050-728.

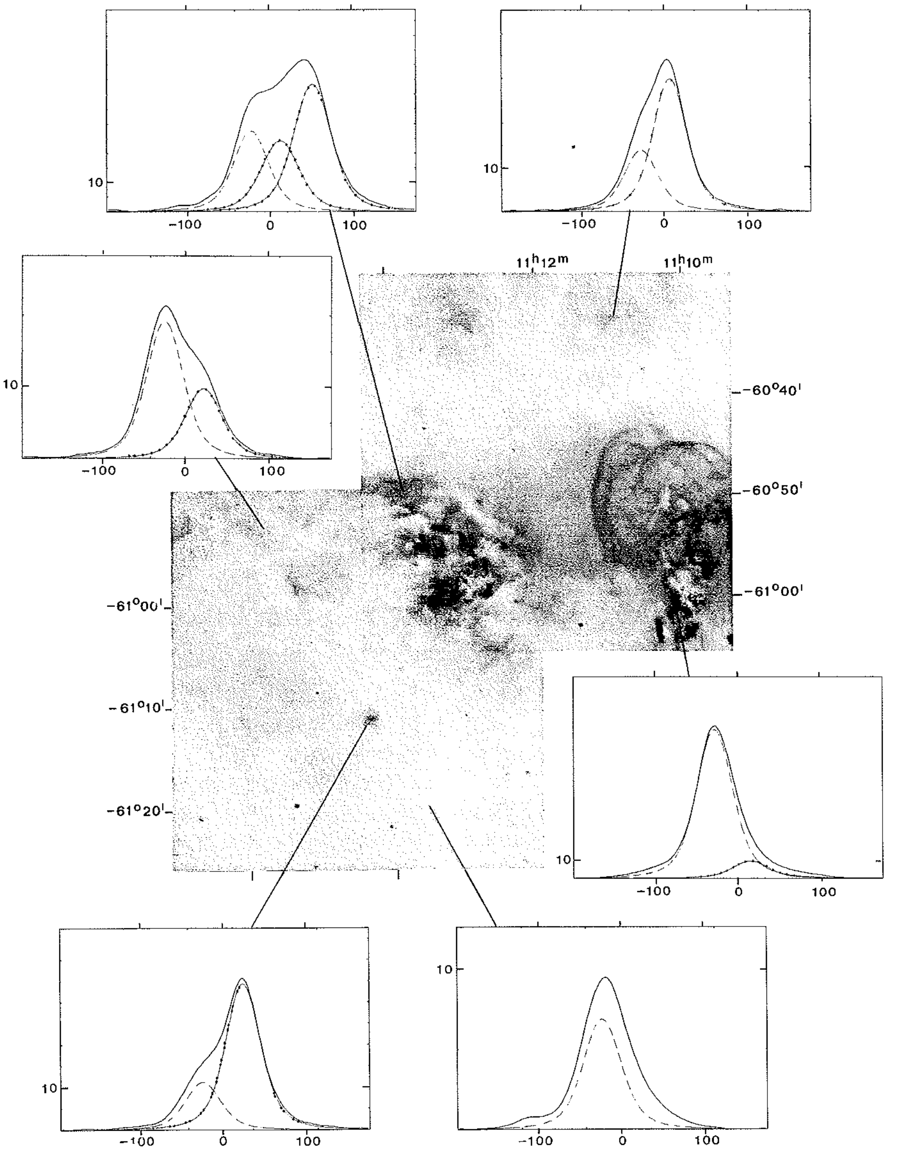

Figure 5: *Area of the Milky Way around galactic longitude l = 291°. This is an example of two connected fields around l = 291°, showing a great variety of H II regions at very different distances in the Carina spiral arm seen edge on. The two giant H II regions seen on the Hα monochromatic images built from the scanning sequence are westward NGC 3576 (V_{LSR} = −25 kms^{-1}, stellar distance = 3 kpc), saturated in its brighter part down to the right, and eastward NGC 3603 (average V_{LSR} = 15 kms^{-1}, stellar distance = 7 kpc). NGC 3603 is one of the most massive H II regions in our Galaxy already known for its strong internal motions (Balick et al., 1980), their comparison with the very complex CO profiles observed with the SEST (Melnick, 1989) will be very fruitful. A beautiful colour image of these H II regions has been published in the central pages of the Messenger No. 60 (Block and Madsen). Our Hα profiles in selected areas are shown all around and illustrate different cases encountered, showing how difficult the interpretation of the results may be. A general emission component, related with NGC 3576, can be seen all over the two fields (dashed line component inside each frame). Other Hα components (dotted lines) of variable velocity and intensity are superimposed. They may be separated into simple components analysing the profiles step by step all over the field with the help of morphology, intensity variations, radio results and so on.*

7. Conclusion

The large quantity of data expected from our Hα Survey led us to extend the capabilities of our CIGALE instrument, with real time processing of the data. The whole instrumentation of the Survey (focal reducer, interferometer, IPCS and data acquisition and processing electronics) may be attached at the Cassegrain focus of the ESO 3.6-m telescope where it becomes a powerful tool for studying the kinematics of the galaxies. A first successful trial was done in February 1990 with, among others, the observation of the detailed velocity field of the ionized gas in the famous Arp's Antennae (Amram et al., 1991).

Our Hα Survey will go on for several years. When completed it will offer a fairly good coverage of the Southern Milky Way and the Magellanic Clouds through a series of 38′ × 38′ fields with detailed Hα profiles inside the 65,536 pixels of each field. More than half of the SMC is already covered (12 fields have been scanned) together with some fields of the LMC. As for the Milky Way we want to have a complete coverage of the most interesting areas, which should comprise more than 200 fields. Then we hope to be able to assess whether the Milky Way actually has 4 spiral arms or not.

Acknowledgements

We are much indebted to Prof. L. Woltjer who authorized and helped the installation of our instrument at La Silla when he was Director General of ESO. We also thank the present Director General, Prof. H. van der Laan, for continuing this help through the extension of the building and providing the astronomers accommodation at La Silla. We thank INSU for financial support of a large part of our instrumentation and for covering the travels fees. The installation of the telescope has been done efficiently with the help of the ESO mechanics workshop and the electronics workshop. The telescope has been designed at Marseille Observatory

with the help of P. Joulié and manufactured with the help of our observatory mechanics workshops, more especially J. Urios who also helped us at La Silla. We also want to thank A. Viale for her constant help when reducing the data in Marseille.

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Salpeter Mass Functions of Young Populous Clusters in the LMC?

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1. The Magellanic Clouds as Laboratories for Deriving IMFs

Although astronomers are not able to perform experiments with their objects under study, the Magellanic Clouds provide quite well what we may call an "astrophysical laboratory" (see Westerlund, 1990, for a review on Magellanic Cloud research). An important topic which can be tackled by investigating Magellanic Cloud objects is the shape of the Initial Mass Function (IMF) of newly formed stars.

The question whether the mass spectrum of stars that are born in a star-forming region has a universal shape or varies according to some (still unknown) laws, is fundamental for understanding both star formation and galactic evolution. A theory of star formation which is unable to predict the IMF of stars will always be considered as incomplete. The stellar mass spectrum is of relevance for galaxy evolution, since it controls the supernova rate and generally the amount of energy injected into the interstellar medium by massive stars. Moreover, the yield of freshly synthesized elements is a direct function of the stellar mass spectrum.

It has long been acknowledged that the young populous star clusters in the Magellanic Clouds are principally ideal targets for the investigation of the mass spectrum of their stars: They offer a high number of stars and a large mass interval with an upper limit of 10–15 solar masses. Such conditions are not found in the Milky Way. On the other hand, the extreme crowding of the stars complicates severely the derivation of a reliable luminosity function.

The crowding difficulty appears indeed prominently in papers related to this subject. Elson et al. (1989) counted stars on photographic plates in the surroundings of several young populous clusters in the Magellanic Clouds and determined mass functions which were surprisingly flat. If we assume a power law description of the shape $dN = m^{-(1+x)}$ dm (where dN is the number of stars in the mass interval between m–dm and m+dm), then Elson et al. found values for x in the range $-0.8 < x < 0.8$). Remember that the population in the solar environment can be described by x = 1.3. A systematic difference between stellar mass functions in the Magellanic Clouds and in the Milky Way would be a very important result.

However, in a paper by Mateo (1989) on the same topic, a quite different conclusion was reached. Mateo performed CCD photometry in Magellanic Cloud clusters of a wide range in age, among

The 2nd ESO/CTIO Workshop on

Mass Loss on the AGB and Beyond

will be held in La Serena, Chile, on 21-24 January 1992.

The aim of this workshop is to bring together observers and theoreticians to discuss the evolutionary stage of low and intermediate mass stars between the AGB and planetary nebulae: the **transition objects**.

Specific topics will include: transition objects, protoplanetary nebulae, mass-loss mechanisms and estimators, PN formation, new techniques: FIR, mm and sub-mm.

Invited speakers are: J. Dyson, Manchester; H. Habing, Leiden; P. Huggins, New York; M. Jura, Los Angeles; M. Morris, Los Angeles; H. Olofsson, Onsala; A. Omont, Grenoble; F. Pijpers, Leiden; D. Rouan, Meudon; R. Waters, Groningen; B. Zuckerman, Los Angeles.

Organizing Committee: D. Geisler, B. Reipurth, R. Schommer, H.E. Schwarz, (chair).

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them also young clusters and he found the clusters to exhibit very steep mass functions with x exceeding 3.

At the time of appearance of the two cited papers, we had started working on the problem of determining stellar mass functions in Magellanic Cloud clusters and those contradictory statements meant an additional motivation for us to study this problem in more detail.

2. The Photometry

We used the Danish 1.5-m and the CCD #5 in December 1988 to observe the young clusters NGC1711, 2004, 2100, 2214, and 2164 in the Johnson B and V bands. We knew from earlier experience (Cayrel et al., 1989) that good seeing is the most important precondition for successful work on luminosity functions of this type of clusters. A seeing of around 1″ can already be considered as satisfactory and we were glad to meet this condition. Another experience was that long exposures, which are necessary to find faint stars, are affected by heavy charge overflow by bright stars in the cluster region. We thus obtained sequences of typically 10 shorter exposures, summed them up and proceeded the work on the summed images which now have a much larger dynamical range.

Stellar photometry on the frames was performed with DAOPHOT and the photometric calibration was achieved by using local photoelectrically measured stars (Alcaíno and Alvarado, 1989). We estimate the absolute error of our zero points to be around 0.03 mag. Figures 1 and 2 display the resulting colour-magnitude diagrams for NGC 2004 and 1711 and the neighbouring field regions. For NGC 1711, this is the first published CMD based on CCD photometry.

Earlier photographic work for our clusters has been done by Robertson (1974), and it is interesting to compare his data with ours. Bencevenni et al. (1990) also published a CMD for NGC2004, which was calibrated with the Robertson photometry and we included their data in our comparison. The residuals are more or less constant but show a magnitude- and colour-dependence at the bright end of the star distribution. We suspect that this effect is caused by a non-linearity in the Robertson magnitude scale since we found no saturation or non-linearity in our data. Clearly, one should be careful in using this photographic photometry for detailed comparison with theoretical colour-magnitude diagrams.

The next step on the way to mass functions is the determination of luminosity functions for our clusters which, with the help of theoretical mass-luminosity relations, can be afterwards transformed into mass functions.

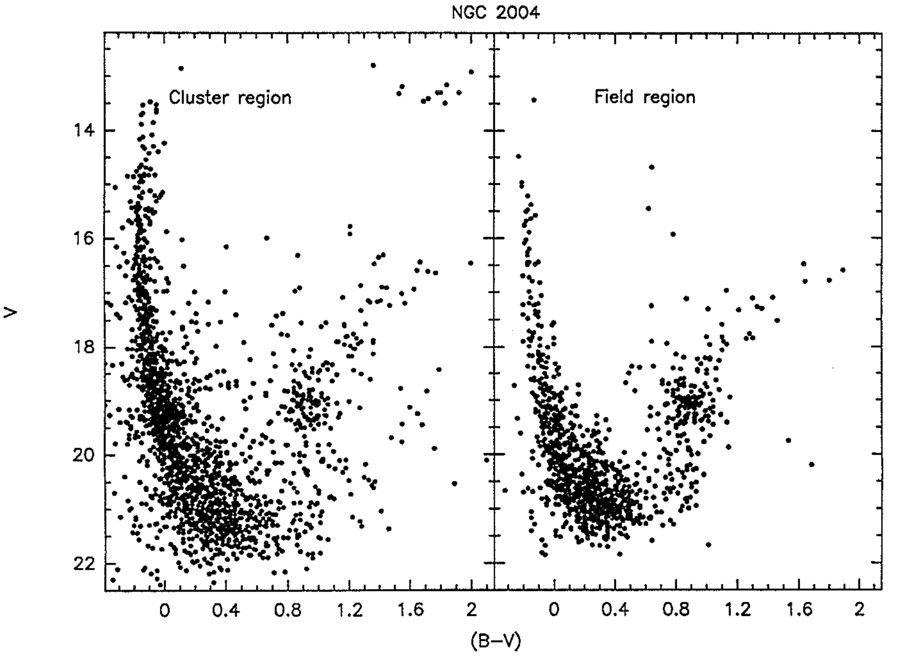

Figure 1: *The colour-magnitude diagram of NGC2004 and a neighbouring field region. One can distinguish also red giants belonging to older populations and the clump of intermediate-age He-core burning giants. The red supergiants are missing in the field region, indicating that a population as young as the cluster is not present in the field.*

3. Luminosity Functions and Data Incompleteness

Within the procedure of deriving LFs for our clusters, the most severe problem is the quantitative evaluation of the data incompleteness. It is very easy to find all bright stars in the frame but very difficult to find the faint ones! A widely used approach to this problem is to perform experiments with artificial stars, which are inserted in the original image with known coordinates and magnitudes. Recovering them in a normal

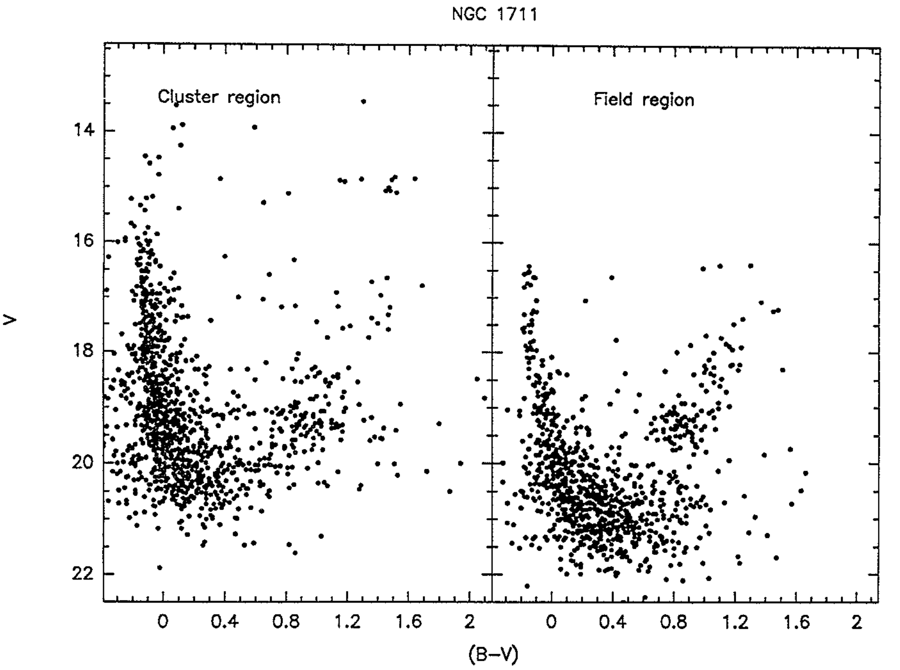

Figure 2: *The colour-magnitude diagram of NGC1711 and a neighbouring field region. Note that the photometry is deeper in the field, since the crowding is moderate with respect to the cluster region. Although NGC1711 is located far from the main body of the LMC, the number density of He-core burning field stars is not much lower than in the region of NGC2004. This shows that the distribution of faint stars in the LMC is much more extended than the distribution of the bright ones.*

reduction procedure leads to the derivation of "completeness factors" (ratio recovered stars/inserted stars), so one can correct the "observed" LF into a "real" LF.

What is the "completeness correction" to be applied to the stars figuring in a colour-magnitude diagram? After all, both the V and the B data have their individual completeness factors. The essential point is that the completeness is only dependent on the exposure level of the frame. The reduction, i.e. the reaction of the photometry software to the charge distribution on the CCD, is almost exactly the same for a V- and a B-frame, as long as the same star field is considered. As can be seen from Figure 1, there is almost no change in colour along our main sequences, so the relative magnitudes of the same stars are the same on B- and V-frames. Thus, given equal exposure levels, the photometry software finds the same stars in both wavelength bands and the completeness in the colour-magnitude diagram is the same as in the individual frames. In case of different exposure levels, the completeness in the colour-magnitude diagram is controlled by the smaller of the two completeness factors of the contributing frames.

4. Mass Functions

Transforming the luminosity function of a stellar cluster into a mass function requires knowledge of the cluster properties, distance, metallicity and age to select the proper isochrone. It is clear that the choice of the stellar models and their corresponding isochrones will have some influence on the end result. Thus a straightforward determination of a cluster MF is not possible if one does not know e.g. cluster metallicities, while one also has the freedom to select between different published theoretical models. What we can do instead is to assume several metallicities, derive the corresponding ages and show the effect of metallicity variation on the MF slopes. This is done in Table 1. Three sets of stellar models are employed, namely those by Maeder (1990), Bertelli et al. (1990) and Castellani et al. (1990).

It can be seen that the Bertelli et al. isochrones give the steepest slopes in the mass function which is due to their incorporation of strong convective overshooting. A high metallicity also tends to steepen the slopes. Only for NGC 2004 is a preliminary spectroscopic metallicity determination available (Jüttner et al., 1991) that points to −0.6 dex. In view of the low metallicity of another young LMC cluster (NGC 1818), for which Richtler et al. (1989) obtained −0.9 dex, it is probable that assuming a solar metallicity overestimates the metal content of young LMC clusters. In spite of the fact that we are forced to make the comparison between different stellar models with the assumption of solar metallicity (since neither Maeder nor Castellani et al. compute metal-poor tracks in the appropriate mass range), the MF slopes are (within the given uncertainties) not really distinguishable from the Salpeter value $x = 1.35$ (see Table 1).

Table 1: *Cluster properties and IMF slopes*

Object	Ages [Myr]			Z	MF slopes (x)		
	B	M	C		B	M	C
NGC 1711	60	32	25	0.02 0.001	1.9 1.2	1.3 –	1.3 –
NGC 2004	–	16	12	0.02	–	1.0	1.1
NGC 2164	100	63	36	0.02 0.004 0.001	1.5 1.4 1.1	1.1 – –	1.3 – –
NGC 2214	100	63	36	0.02 0.004 0.001	1.4 1.3 1.0	1.1 – –	1.3 – –

Z: Metallicity; B: Bertelli et al., 1990; M: Maeder, 1990; C: Castellani et al., 1990.

5. Comparison with Previous Work

How large the effects of isochrone uncertainty and completeness treatment can be becomes clear if we look at an earlier preliminary analysis of our data. Richtler and de Boer (1989) quoted IMF slopes for NGC2214 and 2164 with only crude assumptions for the completeness and the mass-luminosity relation and thus arrived at much steeper values than the present ones. Richtler et al. (1991) demonstrated the details of the effects of data incompleteness and model dependence.

What are the reasons for the differences between our results and those of Mateo and Elson et al.? One may suspect that star counts on photographic plates are an inadequate technique for those very crowded stellar fields and indeed, a comparison of our star counts with those of Elson et al. reveal that we have found more stars by a factor 2. Moreover, quantifying the completeness in photographic star counts is very difficult, but altogether there are no obvious reasons for the differing results.

Concerning the work of Mateo, we have one cluster in common, NGC1711. When we follow as close as possible the procedure described by Mateo (including his mass-luminosity relation) but using our own data, we get a reasonable agreement. The main difference, however, is in the treatment of completeness. Mateo considers the completeness on B and V frames as being independent, so that the resulting completeness factor would be the product of the individual B- and V completeness factors, whereas we found that they are fully dependent, as we explained already in section 2.

An example: Given 0.8 as the completeness factor for both B and V frames, Mateo would use 0.64 as the "resulting completeness" in the colour-magnitude diagram, while we would still use 0.8. This, of course, makes a large difference for the luminosity function to emerge, particularly if the completeness is low. Mateo does not list his completeness factors, but since he used a 1-m telescope for most of his data, we expect them to be lower than ours.

6. Conclusion and Prospects

What can we conclude? We can neither prove nor disprove the hypothesis that the shape of the IMF is universal, but we can show that at least the very steep IMFs found by Mateo (1989) are not real but result most likely from a special aspect of his data reduction. The IMFs which we derive from our photometry are, however, still uncertain. We require a better knowledge of the cluster metallicities before we can draw firm conclusions. Moreover, theoretical mass-luminosity relations for metal-poor and massive stars are missing. We also derived our IMFs with the assumption that all stars making up our luminosity function are single and not binaries. Nevertheless, our IMFs are indistinguishable from the IMF determined in the solar neighbourhood and thus the idea of a universal shape of the IMF gains additional support.

We think that photometry of Magellanic Cloud clusters with the NTT in excellent seeing would mean the most important step forward. Firstly, the number statistics could be improved by a significant factor thus allowing to decide whether the description of the IMF by a single power law is really adequate over a large mass interval or not. Secondly, the danger of contamination by merged stellar images is expected to decrease considerably. Thirdly, also older clusters with narrower mass intervals could be investigated in order to uncover the influence of cluster dynamics on the IMF.

The potential of the Magellanic Clouds as "astrophysical laboratories" is still very much alive!

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A "Happy Hour" at ESO Headquarters

On April 30, 1991, on the occasion of the 25th anniversary of Mrs. Christa Euler's services with ESO, the Section Visiting Astronomers had the pleasure to invite all ESO staff, on behalf of the Director General, to a "Happy Hour". The event was celebrated in a friendly and informal atmosphere. A beautiful book on the paintings in the Musée d'Orsay was presented to her by Prof. H. van der Laan, and J. Breysacher gave her a nice bouqet of spring flowers.

Mrs. Christa Euler joined ESO Chile on April 1st, 1966, at the time when Prof. O. Heckmann was the Director General of the Organization. At first she was installed in the office at the Santiago guesthouse and later in the Vitacura building, where she was responsible for all secretarial work in Santiago. Three years later, on the arrival of Prof. B.E. Westerlund, she took over the post of secretary to the ESO Director in Chile. With the exception of a ten-month period spent in the Personnel Department in Hamburg, she held this position until mid-1976. Her definitive move to Europe took place in September 1976. At the newly installed Headquarters in Garching, she took up duty in the Section Visiting Astronomers then headed by Dr. A.B. Muller. During the 15 years that Mrs. Christa Euler has now been working in this Section, she has – among many other things – remarkably handled about ten thousand proposals for observing time and perfectly organized several hundreds of travel arrangements to La Silla. Today her name is familiar to most European astronomers as well as to many others overseas.

J. BREYSACHER, ESO

Whatever Happened to Comet Halley?

As reported in the last issue of the *Messenger* (No. **63,** p. 22), Comet Halley was found to have undergone a major outburst, seen as a 19-mag cloud surrounding the nucleus in mid-February 1991 on CCD frames, obtained with the Danish 1.5-m telescope at La Silla. At that time, the comet was more than 14 A.U. from the Sun; this was the first time such an event had ever been observed, so far from the Sun. Observations at Hawaii (K. Meech) and Pic du Midi (C. Buil and collaborators) have confirmed the outburst. The French observers used a 61-cm telescope with a CCD, illustrating that Halley had become so bright that it was almost within reach of well-equipped amateur astronomers!

Very deep CCD observations were made at La Silla during March and April 1991, and it is now possible to say more about the nature of this outburst, although the cause has still not been unambiguously identified.

In late February, it was possible to obtain a low-dispersion, low-S/N spectrum of the coma with the 3.5-m NTT. It showed a solar reflection spectrum, which together with the measured colour strongly indicates that the coma mainly consists of dust particles. Still it cannot be excluded that there is a little gas present.

Comparing the many ESO images which were obtained during a 60-day interval, starting on February 12, it is clear that the surface brightness of the cloud progressively becomes fainter while its size increases. At the same time the brightness of the central condensation decreases and it becomes

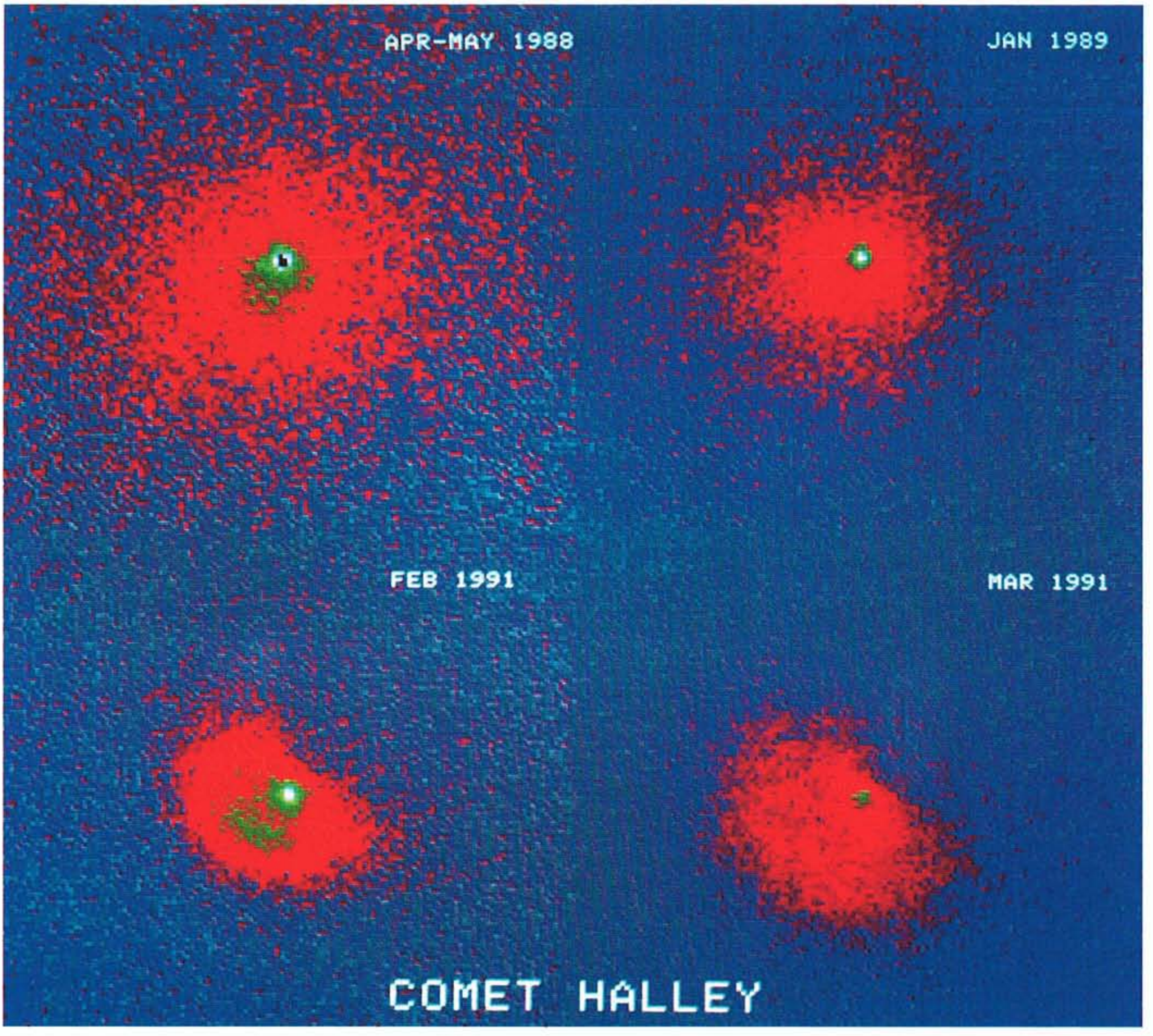
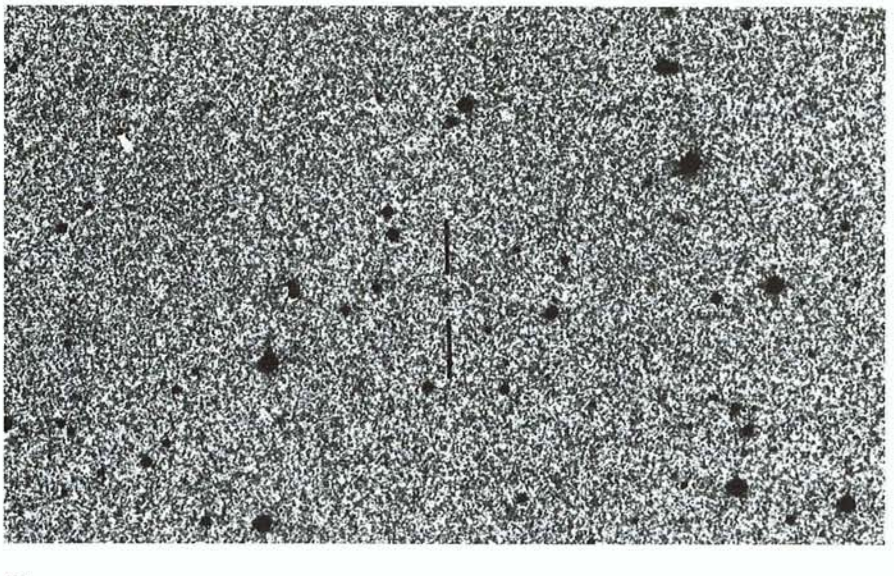


Figure 1: *Halley's coma, as observed in April–May 1988 at heliocentric distance 8.5 A.U. (upper left), in January 1989 at 10.1 A.U. (upper right), in February 1991 at 14.3 A.U. (lower left) and in March 1991 at 14.5 A.U. (lower right). The four images are composites of individually cleaned CCD frames obtained with the Danish 1.5-m telescope at La Silla. They have been normalized to the same flux scale and are reproduced at the same angular scale. To improve the visibility of the faint structures, the images are shown in false colour. The integrated exposure times are 675 min in 1988, 860 min in 1989, 422 min in February 1991 and 1605 min in March 1991. The integrated magnitudes of the entire coma are V = 17.6 (1988), 18.4 (1989), 18.9 (Febr. 1991) and 19.1 (March 1991). North is up and east is left. Each of the four frames measures 1 × 1 arcmin.*



more diffuse. A backwards extrapolation allows to fix the epoch of the "outburst" to December 17±4, 1990. (Some colleagues have jokingly hinted that Halley appears to have celebrated the winter solstice or perhaps Christmas!?) However, it also seems that it would be difficult to eject the entire mass of the cloud, estimated at 10^8 kg, or about 10^{-6}

Figure 2: *This is probably the last photograph that will be made of Halley, before it returns in 2061. The image of the comet is the faint "smudge" near the centre of the picture which was photographically enhanced from a 60-min ESO 1-metre Schmidt blue-sensitive (IIaO + GG385) plate, obtained on January 16.3, 1991. Observer: Oscar Pizarro; photographic work: Claus Madsen.*

of the total mass of the nucleus during a single event. It is perhaps more likely that an initial outburst was followed by a prolonged, steady outflow, producing the cloud seen in Figure 1. It is here compared with the dust clouds seen in 1988 and 1989; note the comparative strength of the 1991 event despite the larger heliocentric distance.

Comet Halley has also been identified on an ESO Schmidt plate which was obtained for another purpose on January 16.3, 1991 (Figure 2). Only the central condensation is seen on the blue-sensitive plate, very near the plate limit. This finding lends support to the above interpretation – it is a pity that apparently no observations have been made sooner after the initial outburst, when the comet would have been even brighter.

We have summarized our early findings in a Letter to the Editor of *Astronomy & Astrophysics* which will soon appear in print. Meanwhile, we have begun a much more detailed study of the observed structure and the development of Halley's coma, together with Zdenek Sekanina (JPL, Pasadena) and Steve Larson (Lunar and Planetary Laboratory, Tucson), both of whom are experts in this field. Perhaps it shall soon be possible to learn something more about the nature of the December 1990 event. Was it – after all – a collision with another, smaller body, or must internal causes be invoked? Whatever the outcome, we shall have learned more about the nature of comets and the conditions in the outer solar system.

O. HAINAUT, A. SMETTE and R.M. WEST, ESO

Recovery of (878) Mildred

After having been "lost" during a period of no less than 75 years, minor planet "(878) Mildred" has finally been found again.

Minor planet "Mildred" was discovered in September 1916 by American astronomers Seth B. Nicholson (1891–1963) and Harlow Shapley (1885–1972) with what was then the world's largest working telescope, the 60-inch telescope at the Mount Wilson observatory near Los Angeles. More observations were made until mid-October 1916 and a preliminary orbit was computed, showing that "Mildred" moves in a rather elongated orbit, just outside the orbit of planet Mars. "Mildred" was given the name of Shapley's infant daughter. Because of the faintness of the object, no further observations were made during the following years, and "Mildred" could not be found again, despite many valiant efforts by astronomers in different countries, and also at ESO in the 1980's.

At the request of Belgian astronomer Eric Elst, ESO night assistant Oscar Pizarro exposed a photographic plate with the ESO 1-metre Schmidt telescope at La Silla on April 10, 1991. When Elst received the plate at his home institute, the Royal Observatory at Uccle near Bruxelles, he found several images of minor planets and within a few days, he transmitted the measured positions to the Minor Planet Center of the International Astronomical Union at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., U.S.A.

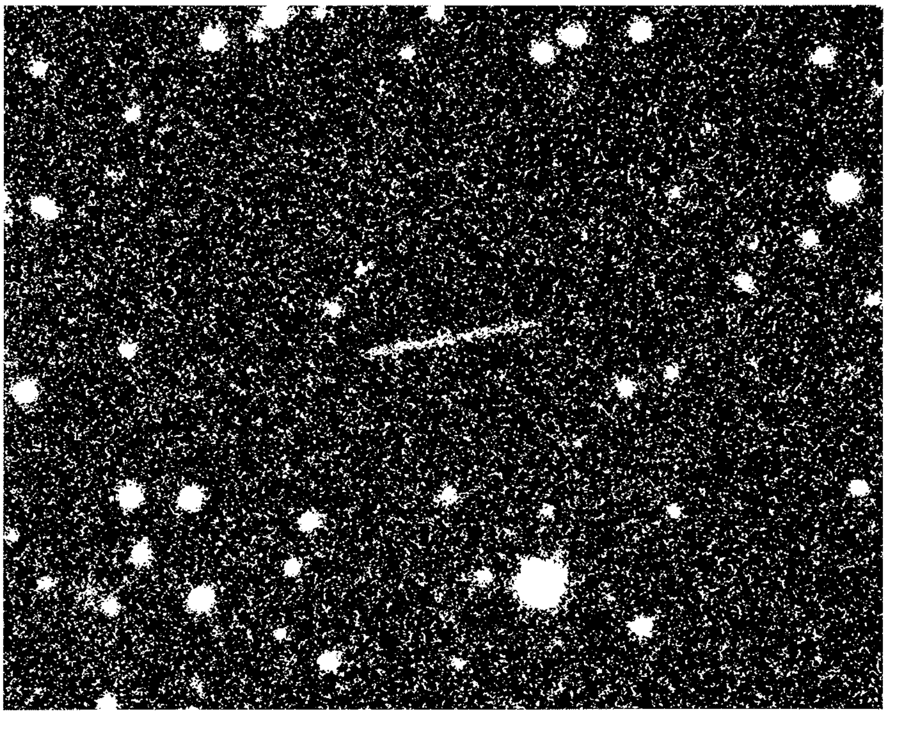
Here a young English astronomer, Gareth Williams, on May 24, 1991, performed a most clever piece of "astrodetective" work, which led him to believe that one of Elst's "new" planets, even though it was observed only one night, could possibly be identical to the long lost "Mildred", since its motion in the sky seemed to fit an extrapolation of the 1916 measurements. Williams became almost certain of this when he, in another demonstration of judicious intuition and hard work at the computer, discovered that another single observation of a minor planet made in 1985 by Ludmilla V. Zhuravleva at the Crimean Astrophysical Observatory in the USSR might then also be "Mildred". The final proof of the recovery of "Mildred" came when Williams notified the Siding Spring Observatory in Australia, where Robert H. McNaught found yet another image of "Mildred" on a photographic plate obtained on April 25, 1984 at that observatory. And two days later, astronomers at the ESO Headquarters in Garching identified three more faint images on ESO Schmidt plates, obtained already in 1977.

Mildred Shapley Matthews, for whom the minor planet was named in 1916, still works as an editor at the Lunar and Planetary Laboratory of the University of Arizona, Tucson, U.S.A. She was delighted to hear that her celestial namesake had finally been found again after 75 years.

With the recovery of "(878) Mildred", only one more minor planet is lost, "(719) Albert", which has not been seen since 1911. The recovery of another minor planet, "(1179) Mally" was described in the *Messenger* No. 46 (December 1986), p. 11.

The present photo shows a ~ 90× enlargement of a sky field with the faint image of "Mildred", as exposed on a blue-sensitive ESO Schmidt plate during 60 minutes on June 11, 1977. While the fixed stars are seen as points, "Mildred" moved an angular distance of 40 arcseconds during the exposure and is therefore seen as a short trail, near the centre of the field. The individual photographic grains in the emulsion are seen in the background.

The Editor



The Metallicity of the Young SMC Cluster NGC330 and its Environment Derived from CCD Strömgren Photometry

The distinct metal deficiency of the young globular cluster NGC 330 in the Small Magellanic Cloud, although independently found in several spectroscopic analyses (e.g. Spite and Spite, 1991) is nevertheless surprising. NGC330 belongs to the youngest population in the SMC. The metal abundances of young SMC field stars turned out to be about −0.6 dex (e.g. Spite and Spite, 1991), and not −1 dex or even lower as it was found for NGC330.

In an attempt to measure directly a possible metallicity difference between NGC330 and the surrounding field, we performed CCD Strömgren photometry in this region with the 2.2-m telescope on La Silla.

Our results are displayed in Figure 1. The filled circles are red supergiants which are radial-velocity members of NGC330, while the open symbols represent stars which are located at distances of more than 100″ from the cluster centre and which we consider to be field stars. Indicated are three loci of equal metallicities according to a calibration using published spectroscopic abundances and Strömgren colours of galactic stars of luminosity class III or brighter. We derive a mean abundance of the SMC field stars of −0.8 dex, while the cluster stars give −1.2 dex (a reddening of $E_{B-V}=0^m.03$ is assumed).

Here, we prefer not to put too much emphasis on the absolute values, although they are in reasonable agreement with the spectroscopic analyses. The important point is that cluster stars and stars in the neighbouring field show a differential offset in their metallicity as derived from photometry, a difference which agrees excellently with that predicted by spectroscopy. This questions the role of globular clusters as tracers of chemical evolution!

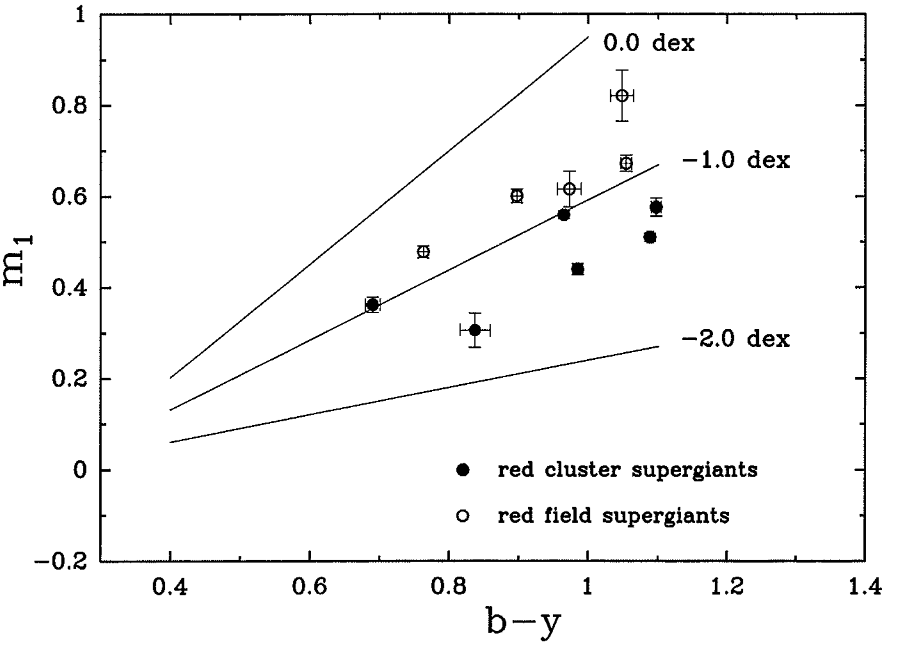


Figure 1: *This (b-y)-m_1 diagram shows the location of supergiants in NGC330 (filled circles) and in the surrounding field (open circles). A reddening of $E_{B-V}=0^m.03$ has been adopted. Indicated are three lines of equal metallicities. The cluster stars are clearly separated from the field stars, which is interpreted as an offset in metallicity of about 0.4 dex.*

The interpretation of this finding is beyond the scope of this short communication. However, a possible role of metal deficiency in a scenario of globular cluster formation has been suggested by several authors (e.g. Fall and Rees, 1985, Richtler and Seggewiss, 1989).

Our results show that CCD Strömgren photometry is a very promising tool for investigating the pattern of the distribution of stellar metallicities in the Magellanic Clouds.

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IC 4296: Observations of an Elliptical Galaxy Core

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Introduction

The cores of elliptical galaxies can provide very important clues to the formation and dynamical evolution of the parent galaxies, e.g. recent episodes of star formation, merging and cannibalism, possible presence of central black holes. Cores kinematically decoupled from the main body of the galaxy are known to exist in many ellipticals and are widely interpreted as evidence for galactic cannibalism. Different signatures of decoupling have been found:

- counter-rotation and, more generally, misalignment of the kinematic axes of the stellar component in the central region with respect to the main galaxy body (Franx and Illingworth, 1988);
- anomalous velocity gradients and dispersion profiles in the central parts (see, e.g., Tonry, 1984; Jedrzejewski and Schechter, 1988);
- central light excess (Kormendy, 1985).

More recently, central unresolved

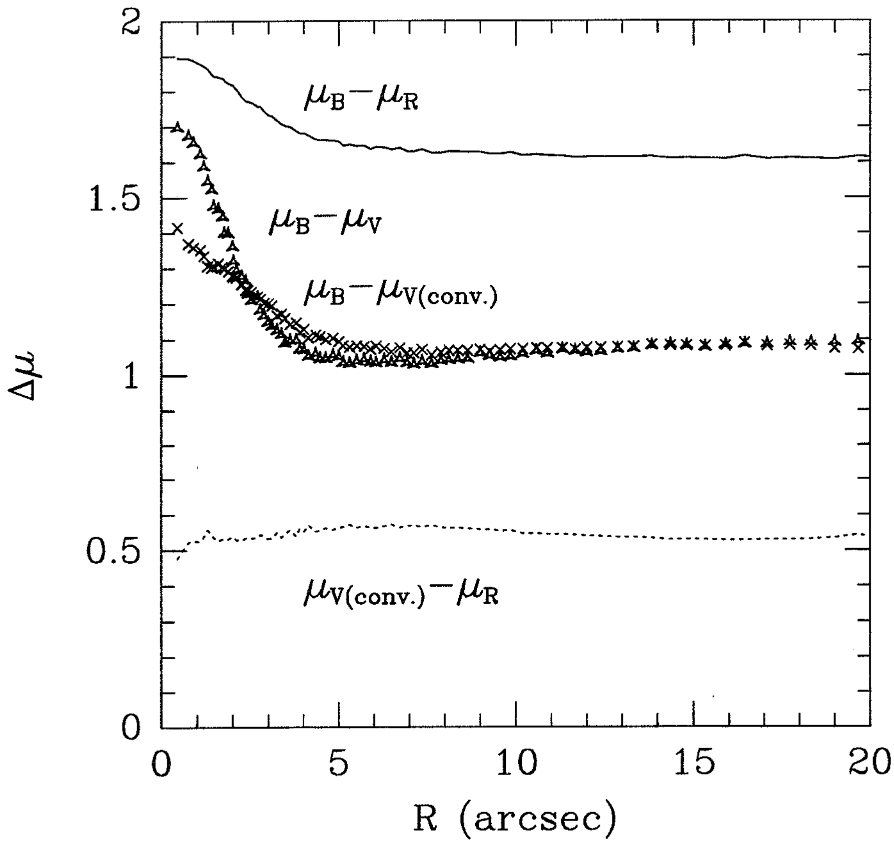

Figure 1: *The colours $\mu_B - \mu_R$ (solid line), $\mu_B - \mu_V$ (symbols), and $\mu_V - \mu_R$ (dotted line) are plotted versus the radius in arcsec. Since the V frame was taken with a seeing smaller than the B and R frames, we convolved the V image to obtain a $V_{conv.}$ frame of comparable seeing. As a reference we show both the colours derived from the original image ($\mu_B - \mu_V$, triangles) and those obtained from the convolved image ($\mu_B - \mu_{V(conv.)}$, crosses).*

nuclei similar to the well-known one in M87 (Young et al., 1978), have been discovered in several ellipticals (Jarvis, 1990) and seem to be a much more common phenomenon than previously thought, as pointed out in a very impressive manner by the HST observation of the core of NGC7457 (Lauer et al., 1991). The nature and physical interpretation of these nuclei are still subject of discussion, since up to now only few cases have been studied with the necessary high resolution. Two hypotheses are:

- *external origin:* the surviving core of a cannibalized companion with very high central density;
- *internal origin:* a self-gravitating massive stellar cluster or even a density cusp induced by a massive black hole.

It is possible to discriminate between the various hypotheses when photometric and spectroscopic data are confronted in detail with models. A young massive star cluster would be identified by the presence of a colour gradient in the core. A relatively "normal" young stellar population would be bluer than the rest of the galaxy, while a young star cluster made of very low-mass stars would be redder. A cannibalized companion would be detected more easily from the decoupled core kinematics mapped by taking spectra at various position angles. Even the hypothesis of a cusp induced by a central black hole can be investigated with ground-based observations. A black hole would induce both a cusp in the light distribution and a peak in the central velocity dispersion. Models with a central black hole and based on a distribution function which is of general applicability to ellipticals (Bertin, Saglia and Stiavelli, 1988) predict well-defined relations between these two observables. Such relations are confirmed by N-body simulations and models for the adiabatic black-hole growth (Lee and Goodman, 1989). Central compact nuclei also influence the shape of isophotes in the core (Gerhard and Binney, 1985; Norman, May and van Albada, 1985).

Evolutionary models of Active Galactic Nuclei predict that many nearby galaxies should contain a central massive black hole (Padovani, Burg and Edelson, 1990). The available mass function for central black holes in Seyfert nuclei peaks at $M_{BH} = 2 \times 10^7 M_\odot$ and has a tail extending toward larger masses. However, alternative models for Seyfert galaxies have recently been put forward (Terlevich and Melnick, 1985). In such models, Seyfert activity is explained in terms of starbursts. If this is the correct interpretation, then the number of galaxies containing a massive black hole in their core is much smaller and the black hole masses can be very different.

A Pilot Project: IC4296

In the following, we will describe in more detail our preliminary results for IC4296. This galaxy shows some of the above-mentioned signatures and is therefore an ideal object for a feasibility study for a larger project. IC4296 is a radio galaxy with jets extending out to about 5.1 kpc ($H_0 = 50$ km s^{-1} Mpc^{-1}) from the centre with its kinematical axes apparently not aligned with the radio jet. In addition, this galaxy was found to be also an X-ray emitter (see, e.g., Killeen, Bicknell and Carter, 1986, hereafter KBC). The most recent studies of this object are the very complete photometric and kinematic study by KBC, and the kinematic studies by Efstathiou, Ellis and Carter (1980, hereafter EEC), and Franx, Illingworth and Heckman (1989, hereafter FIH). Especially the kinematic properties of the objects are not clear. The results by EEC indicate a constant velocity dispersion profile in the inner regions, while both KBC and FIH show a steep raise inside 5 arcsec.

In order to clarify the ambiguous issue, we carried out a study of the photometric and kinematic properties of this object. During an observing run at the ESO/MPI 2.2-m we obtained direct images of IC4296 in R (5 and 10 minutes exposure time) and in B (10 and 15 minutes exposure time). A 640 × 1024 RCA CCD was used yielding a scale of 0.176 arcsec $pixel^{-1}$. Unfortunately, the weather conditions were not optimal for our purpose. The average seeing was not better than 2 arcsec. In addition, a 30-second V-band exposure was obtained at the 3.6-m telescope equipped with EFOSC and a similar RCA CCD as on the 2.2-m (0.337 arcsec $pixel^{-1}$ scale) under better seeing conditions (1.2 arcsec).

After dark and bias subtraction and flat-field correction, the images were aligned with each other. Then, the single exposures in each band were added together, eliminating also the cosmic-ray hits. Surface photometry was carried out using the PLEINPOT package, kindly made available by P. Prugniel. For all the colours we have derived luminosity profiles and determined position angle, ellipticity and "boxiness" of the isophotes. From our preliminary results,

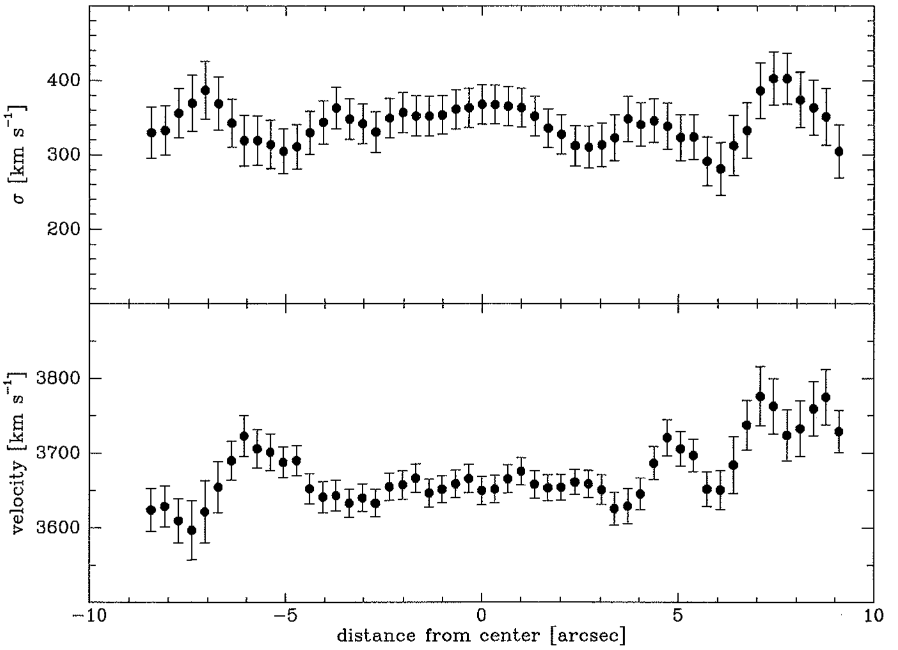

Figure 2: *Velocity-dispersion profile (upper panel) and rotation curve of the stellar component of IC4296 along the optical major axis (PA = 46°).*

distribution in the field of a supermassive black hole (Lee and Goodman, 1989). High-resolution kinematic data may pose constraints on this hypothesis. A long-slit spectrum along the optical major axis of IC4296 (PA = 46°) was obtained at the 3.6-m telescope equipped with EFOSC. Operating the grism O150 and a 1.5 arcsec slit, a resolution of ≈ 3.7 Å was obtained over the spectral range covered (λλ 5000–7000 Å). The integration time was 1 hour. In addition, also high S/N-ratio spectra of non-rotating K giants were secured in the same instrumental configuration in order to be used as velocity templates. The seeing was about 1.7 arcsec. The scale perpendicular to the dispersion is 0.337 arcsec.

The standard data reduction procedures of dark and bias subtraction, flat-field correction and wavelength calibration were performed. The night sky was subtracted from the galaxy spectrum using the light from the un-

shown in Figure 1, it appears that the core region (r ≤ 2 arcsec) is redder by about 0.2 magnitudes than the rest of the galaxy. No large-scale colour gradient is observed. The latter finding is in agreement with KBC, who used combined CCD and photograpic material for their surface photometry. The B–V central gradient appears steeper than the B–R gradient. In order to test whether this was a consequence of the better seeing of the V frame, we convolved the V image in order to obtain the same seeing as the B and R frames and derived again the V luminosity profile. As it is apparent in Figure 1, the convolved V profile is consistent with the R profile and no V–R colour gradient is observed. It is very likely that the core is not resolved even in the original V band frame. KBC found a significant U–B colour gradient within 5 arcsec from the core, a smaller B–V gradient and no V–R gradient. Our results are compatible with theirs, considering our somewhat better seeing. The B–R and B–V gradients obtained by us compare well with the U–B gradient obtained by KBC. Possible interpretations of the observed gradient (which has the opposite sign of the one observed in the core of M87) can be ascribed to the presence of a star cluster made of low-mass stars, to emission from ionized gas in the core, or to the presence of nuclear dust. The last hypothesis was ruled out by KBC since they failed to detect a gradient in B–V.

In addition to the colour gradient, the luminosity profiles show apparantly sizeable deviations from the $R^{1/4}$ law. They may partly be due to the seeing, but could also be caused by stellar re-

Second Announcement

Progress in Telescope and Instrumentation Technologies

ESO, Garching, 27–30 April 1992

The European Southern Observatory is organizing a Conference to be held in Garching bei München, Germany, 27–30 April 1992.

PROGRAMME:

Telescope Projects
Reports from recently completed telescopes and telescopes under construction. Plans for future telescopes.

Telescope Technology
Mirrors and Supports
Testing of Optics in Manufacture and Operation
Optical Coatings
Active Optics
Telescope Structure and Controls
Adaptive Optics
Telescope Environment: enclosure, wind and weather

Operation
Observatory organization and operational infrastructure
Telescope and instrument operation, remote control, flexible scheduling
Data acquisition, processing, archiving

Optical and Infrared Instruments
New materials and components: Gratings, glass, optical fibers
Detectors
Imaging and photometry
Low- and medium-resolution spectroscopy

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contaminated border regions of the spectrum. Cosmic-ray events were removed by means of a median filter. The calibrated data were then analysed using a modified and revised version of the Fourier-Quotient Package (Bertola et al., 1984) yielding the stellar velocity dispersion profile and rotation curve.

The heliocentric velocity of IC4296 derived from absorption and emission lines is 3650 km s^{-1} which is in good agreement with previous works. The obtained rotation curve and velocity-dispersion profile are presented in Figure 2. Our preliminary results agree reasonably with those by KBC and FIH, although the presence of a central steep increase in velocity dispersion is not that evident as in theirs. The upper limit to the central dark mass in IC4296, based on rough estimates, is of the order of 10^9 $M_\odot$. More stringent limits will probably be possible once the data will be fully analysed and properly modelled.

Analysis of the emission lines reveals a LINER-type spectrum, although underlying absorption lines are very strong and the Hα emisson is significantly diluted. The emission lines appear very narrow with typical velocity dispersions of about 140 km s^{-1} after subtracting the instrumental profile. As measured from the [N II] (λ 6583 Å) line, the emission is confined in ≈ 3 arcsec diameter core region. The amount of emission is not incompatible with the red photometric excess.

Our conclusions are that, although in general better than previous work, the seeing conditions were not good enough to resolve the core of IC4296. Therefore, no firm upper limit on the mass of a dark central component can presently be set. The data leave room for the presence of even a supermassive central dark object. The observed colour gradients could be explained as due to the presence of dust in the nuclear region, which is quite commonly found in ellipticals (Sparks et al., 1985).

One Step Ahead: An Observational Strategy

We are now carrying out a detailed study of a number of bona-fide candidate objects in order to investigate properly the wide range of core phenomena. A sample of early-type galaxies was selected which has systemic velocities ≤ 5000 km s^{-1}. We chose early-type objects because for them the interpretation of the data is made easier by the presence of a predominantly old massive stellar population, so that recent episodes of star formation and anomalous colours can be more easily singled out.

Since our angular resolution will in general be of the order of ≈ 1 arcsec, we cannot expect to gather any useful information for objects more distant than 50 h^{-1} Mpc. In addition to select relatively close-by galaxies, we have also considered objects for which some "anomalies" have already been detected in the cores: counter-rotation or kinematical decoupling, unresolved or very compact core radio sources, central light excesses. For these galaxies, we are planning to obtain long-slit spectra along several position angles in order to derive information on the stellar velocity field and on the velocity dispersion profile, as well as on the presence of emission lines. In addition, we intend to obtain direct images of the central regions in at least two (e.g. B and R), but possibly more, colour bands. When confronted with stellar dynamical models, these data will allow us to put upper limits on the mass of any central condensation and to suggest which model is in better agreement with the observed features.

As a follow-up of the study of a few "promising" objects we plan a complete survey of the properties of the cores of early-type galaxies. In fact, a complete survey of core properties of ellipticals is still missing. The most complete collection of data available so far is the compilation by Lauer (1985) of photometry for the cores of 42 early-type galaxies. Lauer's sample, however, was not complete and based on observations performed in a single band at the Lick Observatory 1-m telescope under average seeing conditions. In addition, no such survey is available for the southern sky. Our estimated "detection" limits (seeing ≈ 1 arcsec) for the case of a central light excess caused by a central black hole in a typical elliptical are: (i) $M_{BH} \gtrsim 10^9 M_\odot$ to resolve the cusp, (ii) $M_{BH} \gtrsim 10^8 M_\odot$ to observe the seeing convolved cusp as a "core within the core" at the 0.1-magnitude limit. For the northern part of the survey, we have already obtained time at the 2.5-m Nordic Telescope.

First Announcement

ESO Workshop on High Resolution Spectroscopy with the VLT

ESO, Garching, 11–13 February 1992

The European Southern Observatory is organizing a workshop to be held at ESO/Garching, 11–13 February 1992. The aim of this workshop is to discuss and clarify the specifications and priorities for the high-resolution optical and IR spectrometers for the VLT. (Resolution: 5×10^4 to 10^6.)

The need for high-resolution observations of a variety of phenomena (from solar system to QSO absorption lines) will be reviewed. The capabilities of existing instruments and plans for future instruments will be described. Technical solutions for achieving high spectral resolution will be presented. Ample time will be made available for discussion of topics concerning the VLT spectrometers:

- Echelle spectrometer vs. FTS.
- What resolution for what wavelength range.
- Focus station: Nasmyth, Coudé or Combined Focus.

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PLANETA TERRA – NOSSO DESTINO COMUM is the title of an international conference on ecology, which will be held in Rio de Janeiro in 1992, under the auspices of the United Nations. Under the umbrella of this conference, a number of scientific events, conferences and exhibitions in other scientific fields, e.g. in medicine and astronomy, will take place.

As an early kick-off, ESO's travelling exhibition was opened in the planetarium by Marcelo Alencar, Mayor of the City of Rio, on May 2. Attending the opening ceremony were members of the diplomatic representations of ESO's member countries, officials from the City and State Governments, scientists, etc. Speeches were held by the Mayor, the director of the planetarium, A. Cobbett, and by Jorge Melnick of ESO, who, on the basis of astronomy, emphasized the need for fundamental research and international collaboration in science.

The exhibition was presented several times on nationwide TV and also in full-page articles in the leading Brazilian newspapers and magazines, and no less than 3,000 visitors were registered during the first weekend.

The next stop of ESO's itinerant exhibition will be in Buenos Aires in July this year on the occasion of the XXIst General Assembly of the International Astronomical Union.

C. MADSEN, ESO

Molecular Absorption in Centaurus A: Probing a Circumnuclear Disk

*F.P. ISRAEL, Sterrewacht Leiden, the Netherlands**

When the Swedish-ESO Submillimetre Telescope (SEST) became available, many observers jumped at the opportunity to study molecules, especially CO, in hitherto inaccessible southern galaxies. So did we: our group has started a molecular survey of all southern galaxy nuclei detected with IRAS at 12 micron. We suspected that these galaxies would contain significant molecular concentrations in their central regions. Our survey intended to establish this and to derive basic properties of central molecular clouds for a large sample of galaxies.

Cen A Molecular Absorption: a Unique Case

Among the first series of objects observed was the nucleus of NGC 5128, parent galaxy of the strong radio source Centaurus A. We were quite surprised to discover, in the low-resolution back-end of the SEST, a clear and narrow absorption feature in the broad CO J=1−0 emission from the centre of this galaxy. This was unexpected, as just-published CO J=2−1 observations made with the CalTech Submillimetre Observatory (CSO) in Hawaii had failed to show absorption lines. Later, it was discovered that they are in fact present in unsmoothed data. The published CSO data were smoothed in order to increase the signal-to-noise ratio, and the narrow absorption was inadvertently filled in. At the time of our observation, the centres of several galaxies (including Centaurus A) were known as sources of molecular line absorption, but only at centimetre and decimetre wavelengths. Even now, *Centaurus A is the only extragalactic source in the sky with known (sub) millimetre absorption lines*. The reason is, of course, that we need a sufficiently strong continuum background source against which we can see the absorption. Most galaxies have nonthermal radio nuclei with only very weak emission at high frequencies. Only a very compact nucleus, as found in Cen A foots the bill. At wavelengths above a few centimetres, the radio nucleus of Cen A is resolved by VLBI measurements into a central radio source and inner jets, but their continuum emission is negligible at mm wavelengths. There, however, emission from the compact nucleus itself (optically thick above a few centimetres) has become strong. The VLBI observations show this nucleus to have a size of 0.5 milliarcsec (corresponding to about 0.01 pc or 2500 A.U. for a distance of 5 Mpc), i.e. much smaller than the SEST beam (40 arcsec at 115 GHz). Not only is Cen A unique in the sky, it is also well placed for observations with the SEST, as it passes high overhead at La Silla.

The Circumnuclear Disk Inferred

We also included NGC 5128 in our ESO 3.6-m/IRSPEC survey of southern galaxy nuclei for H_2 emission. Observations of the 1-OS (1) transition showed that the H_2 source in the nucleus should have a diameter of about 4 arcsec (corresponding to 95 pc). Data in the literature show that the nucleus of NGC 5128 is heavily obscured, with A_V = 15−25 mag. This extinction drops rapidly when going away from the nucleus. Moreover, far-IR observations with the Kuiper Airborne Observatory have shown that there exists in the centre of the galaxy a dense, warm (T_d = 35−45 K) dust cloud with a diameter less than 16 arcsec (385 pc). The combination of extinction and far-IR emission led us (Paper I) to propose the existence of a circumnuclear disk in Cen A with an overall diameter of about 400 pc, a mass of

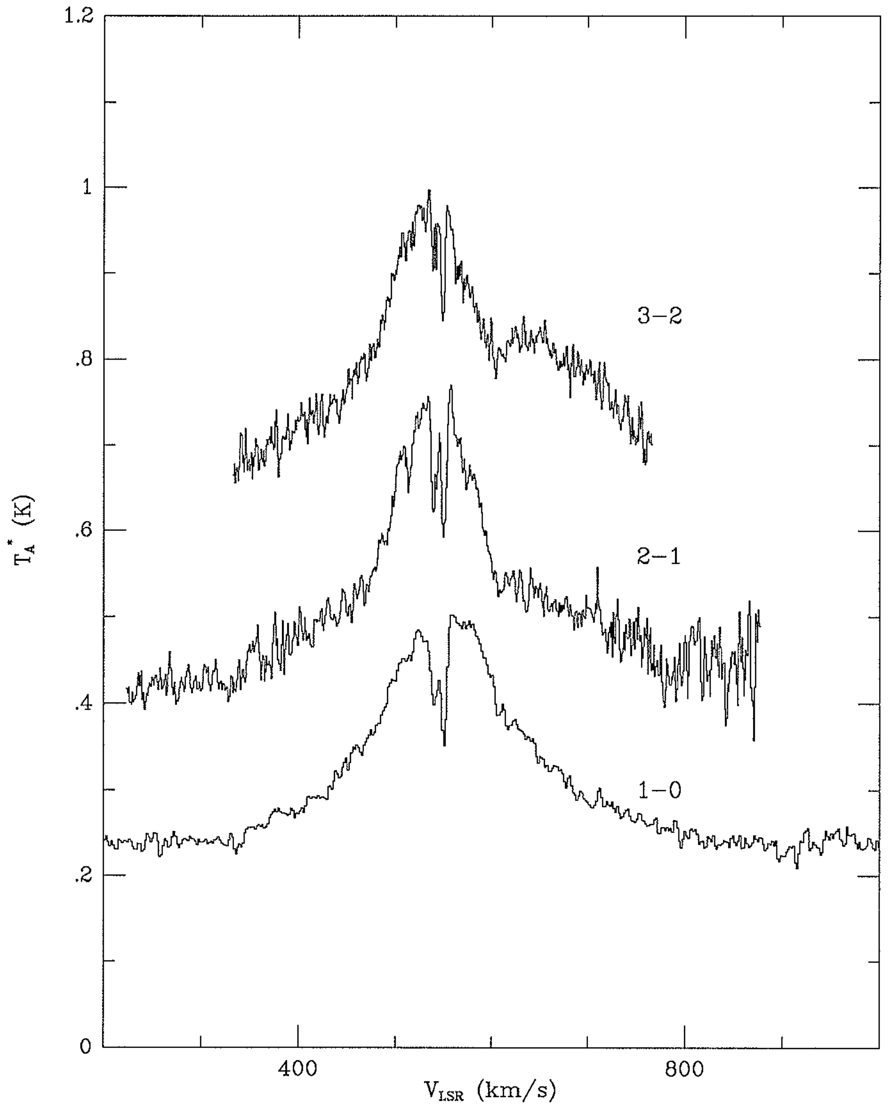

Figure 1: *[12]CO J=1−0, 2−1 (SEST) and 3−2 (CSO) spectra of the Cen A nucleus, smoothed to resolutions of 2.8, 0.9 and 0.9 km/s respectively. The 2−1 and 3−2 spectra have been offset by 0.25 K and 0.45 K respectively.*

* The work described in this paper was carried out in close collaboration with F. Baas, E.F. van Dishoeck (both Leiden), J. Koornneef (STScI), Th. de Graauw (Groningen), and also involved J.H. Black (Arizona) and T.G. Phillips (CalTech).

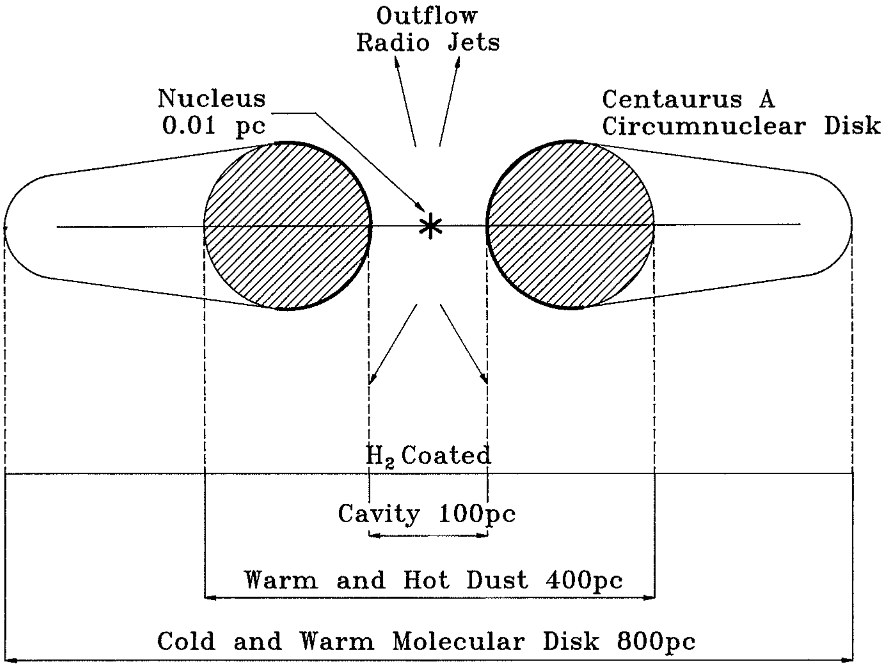

Figure 2: *Schematic representation of the Cen A circumnuclear disk seen edge-on (not to confuse with the NGC 5128 dark band).*

order 2×10^7 $M_\odot$, and a density gradient of order $n(r) \propto r^{-2}$. It should contain a central cavity of diameter 90 pc, whose edge is coated with H_2 excited by radiation and winds from the nucleus. *This circumnuclear disk should not be confused with the optically visible dark band crossing NGC 5128.* This dark band is located in the disk of the galaxy at much larger distances to the nucleus.

The Circumnuclear Disk Resolved

No unique solution could be derived from observations that do not spatially resolve this disk, but the literature data in particular put strong constraints on permissible configurations. The sizes inferred for the disk and the cavity suggested that only small increases in resolution at both mm and IR wavelengths would suffice to spatially resolve it. In the near-IR, arcsec-resolution observations should resolve the cavity. In the millimetre range, use of the SEST in the CO J=2–1 transition (20 arcsec resolution) should show the signature of the circumnuclear disk. Our SEST observations at 230 GHz indeed confirm this (Figure 1; Paper II). The CO J=2–1 data show the relatively strong continuum of Cen A, as well as the CO emission profile due to molecular gas in the outlying dark band. The profile width is primarily determined by the galactic rotation of the material in the 20 arcsec beam. Indeed, the CO J=1–0 emission profile (40 arcsec resolution) is significantly broader, as it covers a larger segment of the steep rotation curve of NGC 5128. However, *the CO J=2–1 measurement also shows a broad, plateau-like component underlying the regular emission profile.* A CSO measurement of the CO J=3–2 profile with 20 arcsec resolution also suggests the presence of this plateau. The plateau has a velocity half-width of 260 km/s, indicating the presence of rapidly rotating material, hence material close to the nucleus, within the beam. Comparison of SEST and CSO CO measurements with different beam-sizes imply that the size of the plateau-emitting region is 35 arcsec (820 pc). Clearly, *we have found the signature of the circumnuclear disk that so far was only inferred.* Its size is about twice that estimated from the emission of warm dust. Thus, the circumnuclear disk not only has a density gradient, but also quite plausibly a temperature gradient. As the CO emission profile samples relatively cool material as well as hotter material, it indeed should show a greater extent than the very temperature-dependent far-infrared emission. Figure 2 shows a schematic representation of the circumnuclear disk seen edge-on, as from Earth.

The Absorption Line Survey

As soon as we saw the narrowness of the absorption features, we realized the importance of using the high-resolution SEST back-end in parallel with the low-resolution back-end (when not broken!) in order to obtain high signal-to-noise measurements of not only the CO absorption lines, but also absorption lines of other molecular species such as HCO^+, CN, C_3H_2, C_2H, HCN, HNC, etc. Both back-ends are needed: high resolution to show the absorption lines in their full glory, low resolution to show the continuum level in the presence of emission. Whereas the emission is due to material spread over the full area covered by the beam, the absorption samples only a 0.01 pc pencil beam towards the nucleus. With that pencil beam, we observe only a narrow column through any cloud or cloudlet that is in the line of sight to the nucleus. The beauty of these measurements is that the simultaneous measuring of absorption depth and background continuum strength at one stroke eliminates all disturbing effects due to beam-source coupling and pointing errors and leads directly to *optical depths completely independent from these effects.*

Main Absorption Lines

The absorption lines fall into three categories. In all molecular species detected by us the strongest absorption is near the systemic velocity of V_{LSR} = 550 km/s. In ^{12}CO the absorption feature is completely saturated in all three transitions observed by us. It is most probably a blend of several much narrower individual components, all at about the systemic velocity. This greatly complicates the analysis, but we are reasonably certain that the majority of the absorbing material at these velocities is in the circumnuclear disk close to the nucleus and has excitation temperatures of 25 K (as compared to about 10 K for CO in the dark band). The columm density should be of order N(CO) = 10^{18} cm^{-2}. The second category consists of the strong absorption lines that are *blueshifted* with respect to the central feature. They consist of a narrow line (width about 1 km/s) at $\Delta V = -6$ km/s and a probable blend of lines at $\Delta V = -11$ km/s. Both have only weak HI counterparts. The CO column densities are half or less that of the central component. At present, it is uncertain whether they originate in clouds residing in the circumnuclear disk, or in clouds residing in the dark band.

The Redshifted Absorption Line Forest: Probing the Monster Feasting

Most intriguing is the third category, a series of absorption lines, many apparently blended, at velocities *redshifted* up to $\Delta V = +65$ km/s or more. Almost certainly, they represent clouds falling into the nucleus (feeding the monster). The optical depth ratios of HCO^+ and CO vary strikingly for these lines. Also, they tend to have stronger HI counterparts than the blueshifted lines. This suggests that the infalling clouds suffer from enhanced cosmic-ray ionization rates, enhanced dissociation or shock-induced processes. The study of these very lines provides the exciting possibility of *finding out just how an active galaxy nucleus is fed by the surrounding galaxy.* As in most molecular species these absorption lines have optical depths of only a few tenths or less, very long integration times (4–8 hours per species) are needed with the present sensitivity of the SEST receivers in order to obtain a sufficiently high signal-to-noise ratio. We have now observed almost all molecular transitions in the 85 to 115 GHz range to the limits feasible at present (but wait till SEST gets a 115 GHz SIS receiver!).

Future Observations

Still to be done are most transitions in the 230 GHz range. For this task, the new SIS receiver is essential. Even then it is not an easy task given the often non-optimal sky conditions at La Silla and the present pointing accuracy of the SEST. The planned installation of tiltmeters in the telescope, however, gives hope that the latter problem will be overcome soon. The observation of the 230 GHz window is of great importance, because it allows us to observe the higher transitions of the same species that were observed in the 100 GHz window. It is the comparison of different transitions of the same species, combined with interspecies comparison that has proven to be so fruitful in the past, and that we need here to unequivocally determine excitation temperatures, column densities and abundances.

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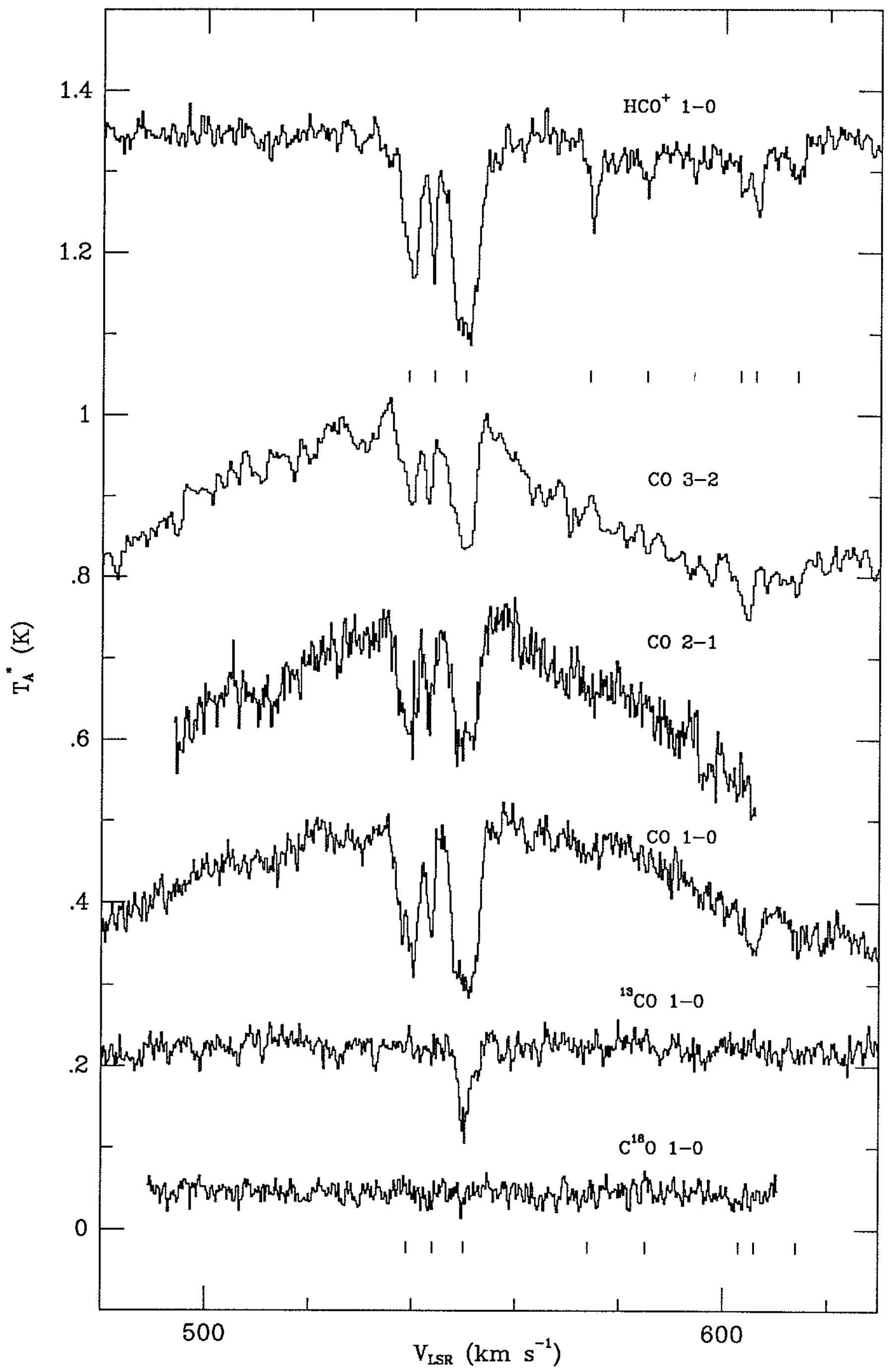

Figure 3: *High-resolution spectra of HCO^+ (1–0), CO (1–0), (2–1) and (3–2), as well as ^{13}CO (1–0) and $C^{18}O$ (1–0). The spectra have been shifted by +1.05, +0.4, +0.25, 0.0, –0.05 and –0.2 K respectively. Note the series of redshifted absorption components in the HCO^+ spectrum.*

Microlensing in the "Cloverleaf" Quasar H1413+117?

B. ALTIERI and E. GIRAUD, ESO

1. Introduction

The broad absorption-line quasar H1413 + 117 has been resolved in four components having comparable brightness by Magain et al. (1988). This makes the object a superb candidate for gravitational lens models. The angular separations of the images (noted A, B, C, D) are between 0.77″ and 0.96″. Individual spectra of the components were obtained at CFHT during a period of very good seeing (0.5″–0.6″) by Angonin et al. (1990). The four components have the same redshift (z = 2.55) and overall similar spectra. One of the components (B), however, shows 2 narrow absorption-line systems at z = 1.438 and z = 1.466, which are not detected in C and D and are possibly visible in A. Gravitational models reproduce well the positions of the images and the predicted time delays are rather short (Kayser et al., 1990). Perhaps the most interesting point is that the gravitational models fail to reproduce the luminosity ratios of the components. Monitoring the luminosity of the object is therefore exceptionally interesting, both for measuring the time delay of luminosity variations between the four components and for the search of microlensing effects which could be responsible for additional amplification.

2. Observation of the Cloverleaf Using Seeing Fluctuations

Monitoring the object is done in the ESO Key Programme by Surdej et al. One of us (E. G.) observed it independently at the 2.2-m telescope on February 17, 1991, for testing a simple method of observation which takes advantage of seeing fluctuations. The point is that a seeing of 0.95″ to 1″, which is frequent in La Silla telescopes, is too poor for observing objects like the Cloverleaf. The seeing, however, is an integrated measure which becomes stable at integration times larger than 20s. Between the speckle lifetime (10 ms) and 20 s there is a region where the image moves and is distorted. Taking a number of sufficiently short exposures should give a distribution of FWHM where the best images are about 15% better than the mean seeing. In practice most of the gain is obtained at about 0.2 s and there are less and less good images as we approach 20 s. The various equations can be found in Roddier (1981), and experimental results on DISCO (based on this principle) are described in Maaswinkel et al. (1988a, b).

For the Cloverleaf, an exposure time of 2 s was adopted as a compromise between having enough signal and resolving the image. The seeing measured on the field just before the observations was 0.95″ which is insufficient to resolve the components. Twelve exposures were obtained, one is excellent, separating well the four components, and two or three are reasonably good. The images were not all obtained at the same position of the CCD.

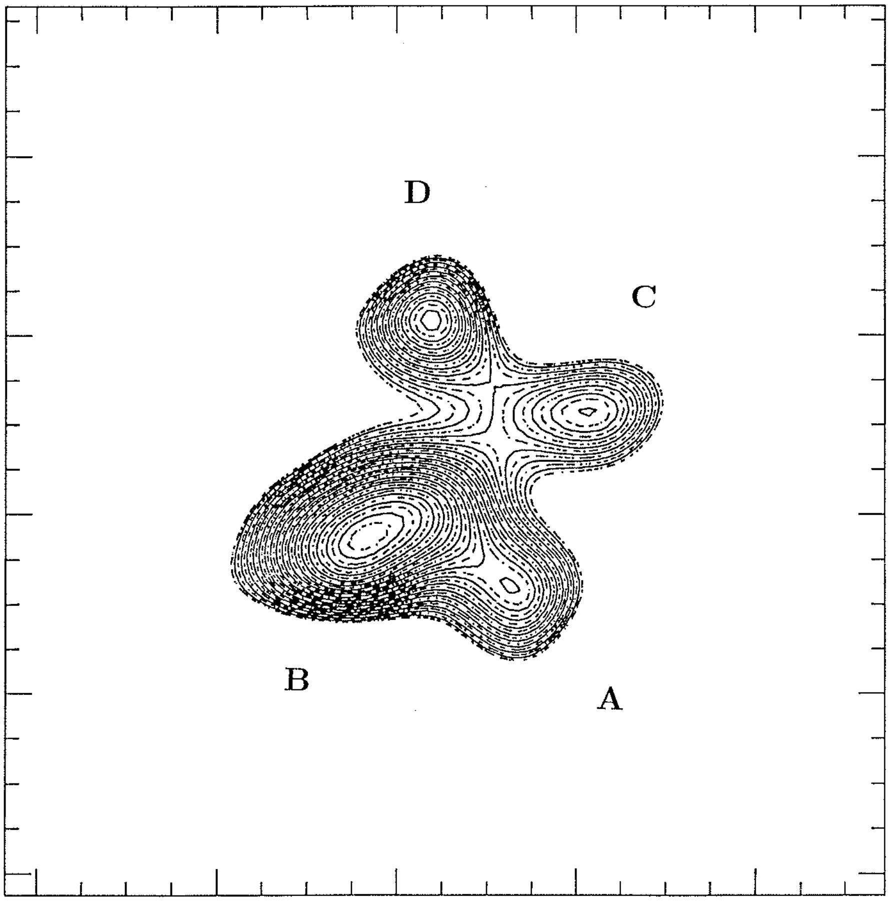

Figure 1: *Best image (in terms of spatial resolution) of the Cloverleaf quasar obtained from our data. North is up and east is to the left. Components A, B, C and D are as in Magain et al. (1988, their Fig. 1). The quality of the data is not sufficient for a comparison of A, C and D. Nevertheless, object B which was fainter than A in April 1988, is clearly brighter on this image, from February 17, 1991.*

3. Results and Discussion

Using MIDAS, we made the reductions on the images, and then recentred them after processing them with a rebin using a spline function, for the maximum positioning accuracy possible. The images were of different quality, because they were at a very faint, and therefore noisy level. However, they showed clearly the effect of image motions and distortions, due to seeing fluctuations between two short exposures. Our recentring involved only translation corrections.

With this method of short exposures, on almost every single image one can see distinctly at least three components, with surprisingly always a much more luminous one: component B. We therefore added some of the best images, whereby this result was confirmed.

In the image of Magain et al. (1988), obtained with a R filter as in Figure 1, object A is the brightest component followed by B, C, and D. The maximum luminosity difference is small: D–A = 0.4 mag. Within the accuracy of our composite image, the luminosities of objects C and D relative to A do not seem to have changed. This image, however, shows a dramatic increase in the relative luminosity of object B, which is now by far the most luminous component. This luminosity excess is well visible on our best (in terms of spatial resolution) individual images. The luminosity of B is about 1.5 ± 0.3 that of A, whereas it was 0.85 × A in Magain et al. measurements. Indeed, the feature is very obvious on all image compositions and we believe it is real. Just to be sure, we very carefully checked the orientation of our images; it is indeed object B which has brightened.

If the luminosity excess of object B is due to an intrinsic variation in the quasar source, this variation will be seen successively in all components. It is also possible that the observed event is not intrinsic to the quasar and is due to microlensing. This may help to explain the discrepancy in the predicted amplifications with the observations. Component B may play a special role because the absorption-line systems at z = 1.44 and 1.46 are much stronger in this component. Since the time delays predicted by the gravitational models are rather short, it should be possible to separate intrinsic variability from microlensing.

We are pleased to thank M. Sarazin for his explanations on the variance of image motion.

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A New Arc Candidate in a Compact Cluster

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1. Introduction

The number of arc candidates discovered in rich galaxy clusters over the past few years is less than about 10 (Fort, 1990). According to the lensing hypothesis, giant arcs such as those in Abell 370 and Cl 2244 are expected to be rarer than small arclets. Detecting faint arclets, however, requires doing photometry at extremely faint levels. While these objects can be used to trace the mass in clusters, they are not accessible to present-day spectroscopy. The number of reasonably good spectra of large arcs is still too small to prove that all distorted arc-like features are due to gravitational lensing. Hence it is crucial to substantially enlarge the sample of large arcs and obtain their redshifts.

The object presented here was discovered during a run of observations of rich clusters of galaxies. Our programme was not specifically designed to search for arc candidates. Nevertheless, since the observed clusters are rich and some are compact or have a compact core, they could have been included in a deep survey of arcs.

2. Results

The cluster (CL0017) was discovered on a deep CFHT prime focus plate in 1986 (Infante et al., 1986). It was first observed at La Silla during a non-photometric run of multispectroscopy with EFOSC at the 3.6-m ESO telescope. Measuring the redshift from red galaxies only, we find $< z > = 0.2716$. A 600-s B exposure shows a possible arc-like feature centred on the extremely compact core of the cluster.

We reobserved the cluster with EMMI at the NTT obtaining short exposures in B, V, and R. Our purpose was to obtain quick relative photometry to select blue objects for a further run. The image presented in Figure 1 is from a 120-s R exposure (seeing 0.9″). It shows the extremely compact core of the cluster and a thin faint arc. Clusters with such a compact core are not frequent. We included it in our survey to check the velocity dispersion around the core and to study the galaxy population in this case. The centre of curvature of the arc lies in the cluster core, and the object is significantly bluer than the red cluster galaxies. The feature is seen (with more or less contrast) on all the images, suggesting that it is real. The image quality is poor, and deeper images are of course necessary to study the object and confirm its appearance. The level of detection, however, is similar to that (for example) of the old (1975) video camera images of Abell 2218, Abell 379, and Cl2244 published by Petrosian, Bergmann and Lynds (1990) or those of Abell 963 obtained by Butcher et al. (1983). If confirmed, the arc will be accessible to spectroscopy using a purpose-made curved slit.

Using the red galaxies to probe the gravitational field around the cluster

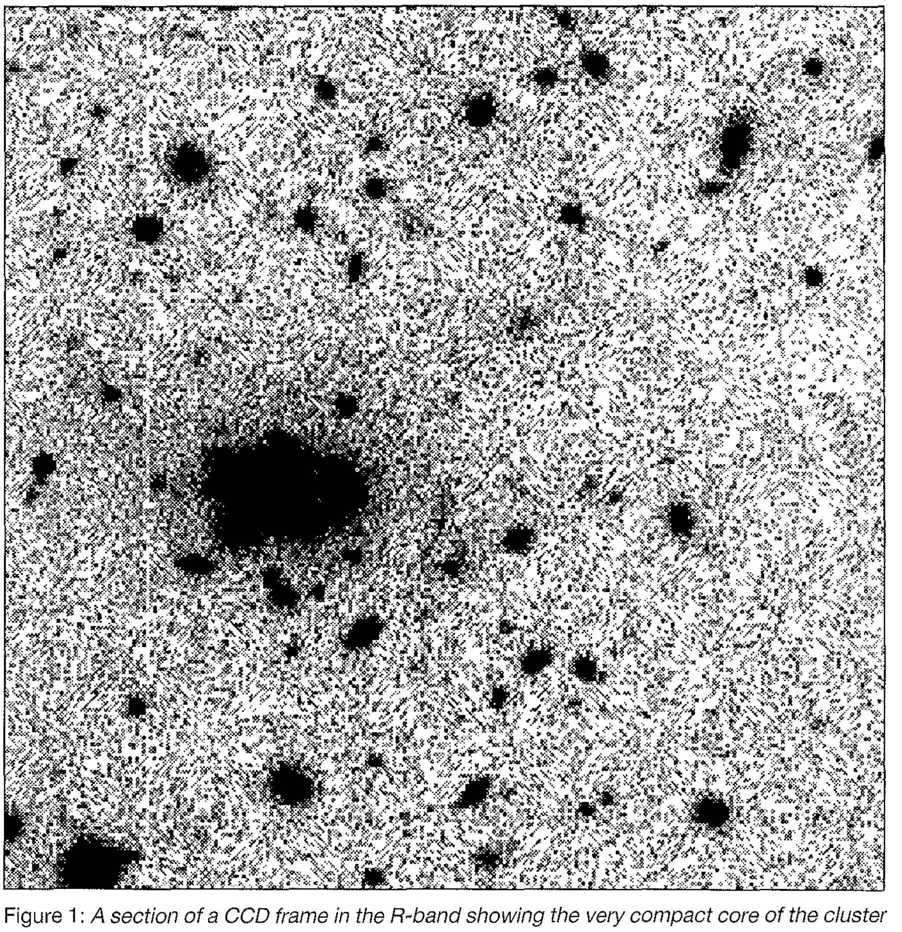

Figure 1: *A section of a CCD frame in the R-band showing the very compact core of the cluster CL0017 and a thin faint arc-like feature (telescope: NTT; instrument: EMMI; exposure time: 2 min., seeing 0.9″). North is up and east is to the right.*

core, we find a line-of-sight velocity dispersion of $\sigma/(1 + z) = 1300\ \mathrm{km\,s^{-1}}$ for 19 objects, a very large value indeed. Thus finding an arc around such a massive and compact core would not be very surprising.

Pending the question of the reality of this feature, we believe that this class of cluster should receive high priority in a programme dedicated to the search for arcs. Will the object belong to the class of gravitational arcs? There are several classes of possible interlopers. The most obvious are edge-on galaxies. Shells physically associated with certain cluster cores is a further possibility. Although the gravitational lens theory constrains the possible shapes of arc candidates, S-shaped features like the very well explained case in Cl 0500-24 (Giraud et al., 1989) show that the range of possibilities is not so small. Finally, a difference in colour between the arc and the red cluster galaxies is not by itself convincing since a blue object can lie almost at any redshift.

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Broadband Imaging Performance of IRAC with the New Philips 64 × 64 Array

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1. Introduction

IRAC, ESO's general-user Infrared Array Camera, has recently been upgraded with a new 64 × 64 array from Philips Components. A general description of IRAC can be found in *The Messenger* (**52**, 50; and **54**, 56). The new array was installed in IRAC and tested on the ESO/MPI 2.2-m telescope during two test runs, the first one in January and the second in March 1991. The first test run was aimed primarily at studying the capabilities of the new array in the L band. In between the two runs, the performance of the array was improved somewhat by decreasing the read-out noise and improving charge transfer efficiency, and during the second run capabilities of the array for deep imaging were investigated in more detail. Overall, the new array is considerably better than the 32 × 32 array that had been in use since November 1989, but, as will be shown, it falls short of expectations on several grounds.

2. The Philips 64 × 64 Array

The basic characteristics of the new array are summarized in Table 1. Note the low read-out noise (RON) of the new array. The RON could be even lower: with a presumed preamplifier gain of $150e^-$/ADU we were probably limited by the ADC resolution. Furthermore, in Section 6 we show that the actual gain may be as low as 100 e^-/ADU, indicating a RON of $\lesssim 65e^-$ RMS.

Since the pixel size has not changed, the same magnifications are available (0.3, 0.5, 0.8, and 1.6″/pix) as previously. Detector response is linear at least up to half-full wells when illuminated by a uniform background.

A typical bias frame has about 20 bad pixels, but the number of bad pixels increases with detector integration time (DIT), indicating that these pixels have high dark current. We will therefore call them "hot" pixels. There are about 120 hot pixels in a DIT = 30 sec dark frame.

From each hot pixel a long streak extends upwards and a short one extends to the right. These streaks are very prominent on dark exposures, and become progressively less prominent as the incident background increases. The streaks are probably due to trapping effects in the read-out CCD, and we are experimenting with the CCD electronics to try to reduce the problem.

The mean bias level is stable within ~ 20 ADU. The precise level depends somewhat on the background level of the previous frames, i.e. the array has some memory. This, however, is not a serious problem since (i) scientific observations are normally carried out in "beam switch" (b/s) mode, whereby a sky image is subtracted from the source image (the two images being acquired with the same integration time), and in the process the bias and the dark current are also subtracted; and (ii) flatfields have large enough signals that the uncertainty in the bias level is inconsequential.

3. Observations

During the first run, observations were carried out with both manual and automatic beam switching. In the latter mode, the telescope is moved automatically between the object position and a reference sky every 1–5 minutes. This mode was found to yield better quality data, and was subsequently used during the second run. Biases and flatfields were obtained throughout the runs, the latter were obtained on the day sky which provided a high signal in a short detector integration time (DIT), and hence flatfield frames with few hot pixels. The flatfields were then bias-subtracted and normalized to unity for use in data reduction.

Table 1: *Array characteristics*

Detector material	Hg:Cd:Te
Cutoff wavelength	~ 4.2 μm
Read-out system	Buried channel CCD
Pixel size	48 μm
Read-out noise (RON)	$\lesssim 130e^-$ RMS
Dark current (at 49 K)	$\sim 300e^-\ \mathrm{sec}^{-1}$
Net detector quantum efficiency	~ 20% at 2.2 μm
Full well capacity	$9 \times 10^6 e^-$

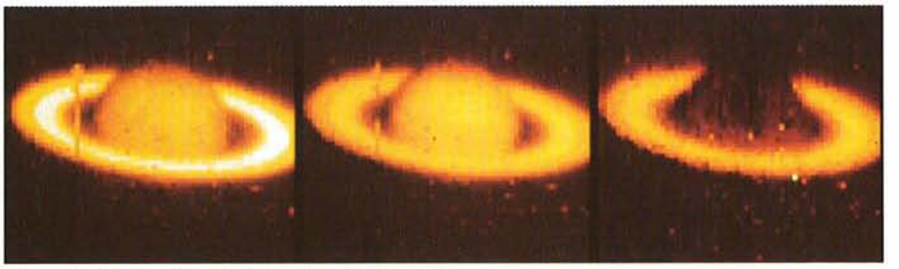

Figure 1: *Saturn; from left to right: J, H, and K.*

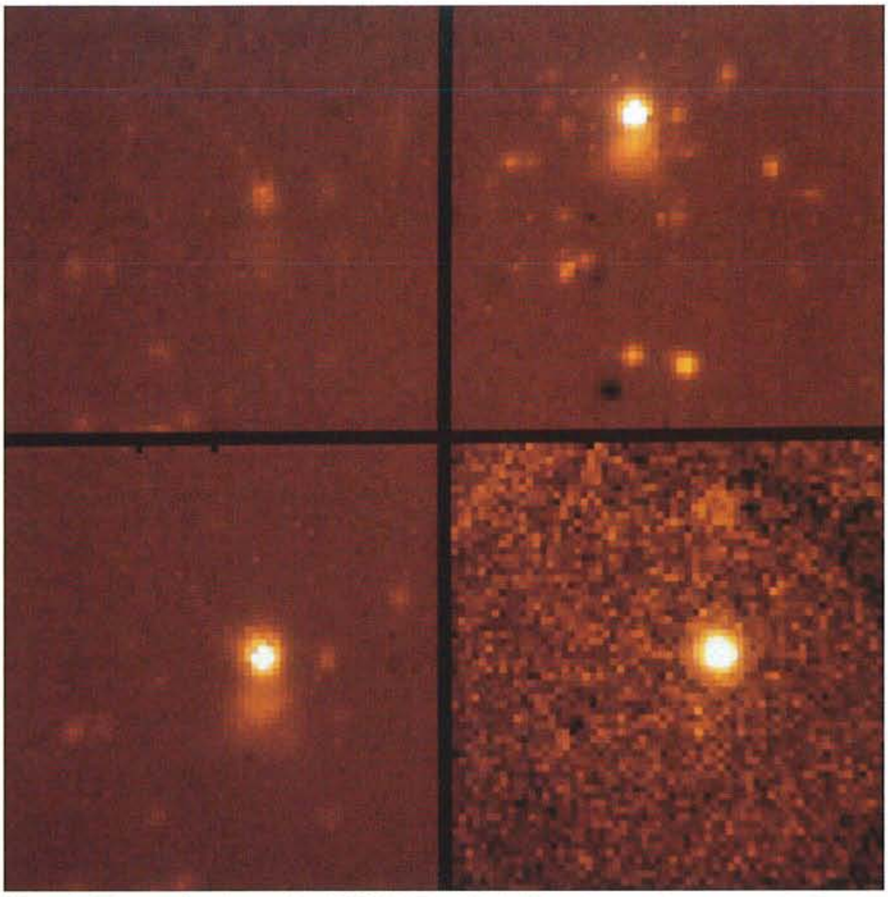

Figure 2: *The star-forming region IRAS 08470-4321 in Vela, observed in stare mode. Top-left: H, 0.5″/pix; top right: K, 0.8″/pix; bottom-left: K, 0.5″/pix; and bottom-right: L, 0.5″/pix. Integration times were 5 × 60 sec at H and K, 64 × 1 sec at L. The brightest source has K = 9.3^{mag} and L = 7.2^{mag}.*

Table 2: *Photometric Zero Points*

Filter	Lens/Pixel scale			
	S1 1.6″	S2 0.8″	S3 0.5″	S4 0.3″
H			16.41(2)	
K	15.85(3)	15.85(3)	15.76(6)	15.50 (5)
L				14.52

Several images are presented in the Figures 1–4; details are in the captions. All images are shown with north to the top and east to the left. DITs of order 10–60 sec were used for the J, H, and K observations, while DITs of order 1 sec were used at L. Because of the large sky background, observations at L are not possible with pixel scales of 0.8″ and larger. Total integration times ranged from a few to a few tens of minutes. All images were sky subtracted and flat-fielded, and the remaining bad pixels were "fixed" by careful median filtering.

4. Photometric Accuracy

Photometric standard stars from the list of Bouchet et al. (1991, *AA,* in press) were observed throughout the runs. During the first run we noted that in the J, H, and K bands, bright stars observed with short DITs showed streaks similar to the ones associated with the hot pixels, with an unknown amount of signal lost in the streak. These data did not yield reliable calibration. During the second run, we therefore chose fainter standard stars (i.e. 7th magnitude), for which DITs of order 20 sec is appropriate, in order to integrate enough background to overcome the streaking. Unfortunately the J-band sky emission is so low that this technique was not totally satisfactory in that band, and we will not present calibration data for it. On the other hand, no streaking occurs in the L band, where the thermal background is always very high.

From the observations of the standard stars, nominal photometric zero points (ZPs) were obtained; these are summarized in Table 2, where the uncertainty in the last decimal is given in parentheses. At L we observed only with lens S4, and only one standard star was observed so that no estimate of the uncertainty is available there. Table 2 is only partially complete, but it does show the accuracy with which the ZPs can be determined: overall, an uncertainty of $\lesssim 0.05^{mag}$ can be achieved.

Table 3: *Net system efficiencies*

Filter/Lens	FDZM[1] W cm^{-2} μm^{-1}	η_{NEW} %	η_{OLD} %
H/S3	1.19×10^{-13}	5.9	6.2
K/S3	4.12×10^{-14}	6.3	3.3
L/S4	5.40×10^{-15}	4.9	–

[1]Flux density for 0 mag star.

5. Net System Efficiency

The observations of the standard stars were also used to determine the net (atmosphere + telescope + instrument) system efficiencies. The results are summarized in Table 3, where they are also compared to the old 32 × 32 Philips array. The nearly double efficiency at K results from a full coverage of that band. These numbers, however, are disappointing: with some reasonable assumptions for the atmospheric transmission, reflectivity of the telescope mirrors, and absorption by optical components within the camera, a net detector efficiency $\eta_d \approx 20\%$ at K is deduced.

6. Noise

When averaging together many observations of a given DIT, the IRAC acquisition software includes an option to calculate a noise frame that is stored together with the data. This frame has, for each pixel, the RMS variation determined from the individual read-outs. This option was used to measure the RMS noise under different background conditions and with different integration times. The noise was measured on parts of the array that are free of bad pixels, and hence these measurements reflect the behaviour of the good pixels. A plot of the measured noise as a function of the incident signal is shown in Figure 5. The horizontal line denotes the noise floor, i.e. the RON, while the diagonal line denotes the expected shot noise. There are two possible interpretations for the offset between the measured and the expected noise: (i) there is some excess noise in the system whose origin is unknown at present; and (ii) the preamplifier gain was overestimated, and the true value is closer to 100e$^-$/ADU. As a line through the measured points apperas to be parallel to the expected line, the latter seems more likely. Should this be the case, the net detector efficiency would be correspondingly lower (i.e. ~ 13%), as would the net efficiencies in Table 3.

7. Limiting Performance

In actual performance the noise that counts is the pixel-to-pixel noise in regions of the reduced image that contain pure sky. The improper subtraction of the bad pixels and of their streaks introduces a spatial noise which turns out to be the limiting factor under most conditions. Only at L, where the background is high enough that the streaking is totally overcome, is background limited performance achieved, though even there the odd bad pixel falling on top of the source of interest can seriously affect its measurement.

The pixel-to-pixel sky noise was measured on good parts of some reduced deep (e.g. 1 hour total integration time) frames, and from these measurements the limiting sensitivity was determined. These are summarized in Table 4 which gives both the background noise level (1σ/sec/pix) and the point-source sensitivity (5σ/sec/synthetic beam). The latter was determined for a pixel size of 0.5″ and an equivalent beam diameter of 4″, resulting in a beam area of 50 pixels. The measured sky brightness per arcsecond square (rather than per pixel) is also listed in Table 4. These are about 3 times larger than expected; about half of the excess can be ascribed to the oversized pupil stop which we hope to replace soon with a correctly sized one. The source of the remaining excess is not known at this time.

8. Conclusions

The results of the first runs of IRAC with the new Philips 64 × 64 array have been presented. This array is clearly better than the previous one, the main improvements being (a) larger size, (b) broader wavelength coverage, (c) better overall stability, (d) fewer bad pixels, and especially (e) lower read-out noise. There are several respects, however, in which the new array is disappointing: (a)

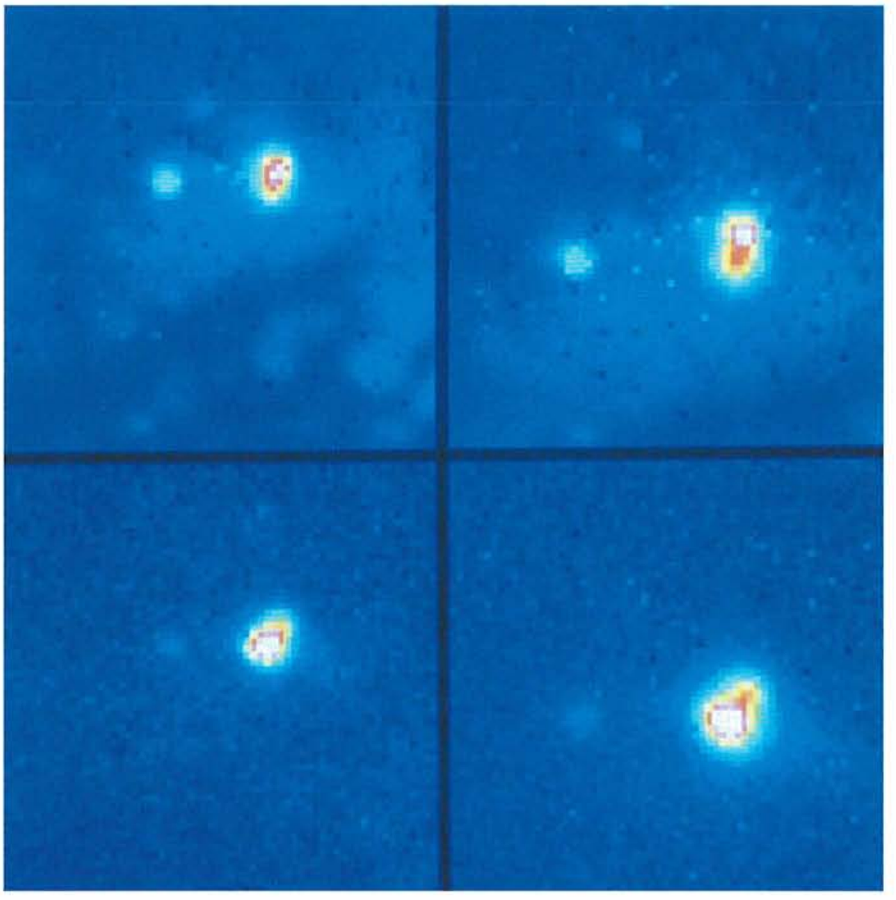

Figure 3: *The infrared source in RCW 57, observed in b/s mode. Top-left: K 0.5″/pix; top-right: K, 0.3″/pix; bottom-left: L, 0.5″/pix; and bottom-right: L, 0.3″/pix. From the S4 images the following photometry was derived: irs1-NW: K = 8.4^{mag} and L = 4.9^{mag}; irs1-SE: K = 8.8^{mag} and L = 4.3^{mag}.*

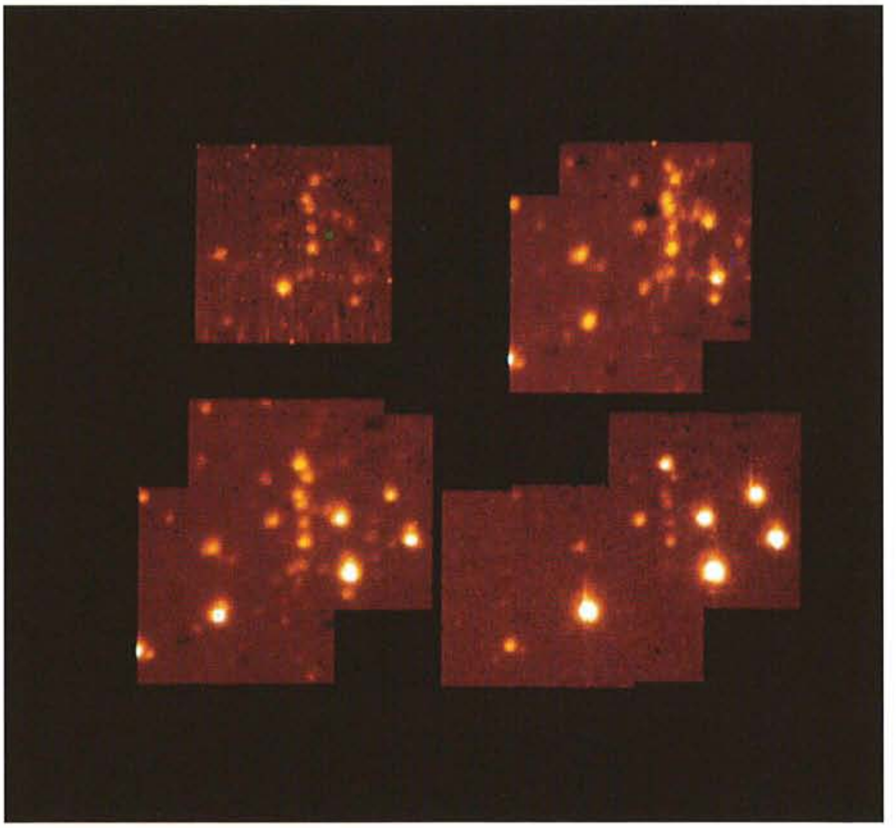

Figure 4: *The cluster associated with IRAS 17430-2848, near the Galactic centre, observed in b/s mode at 0.3″/pix. Top-left: J; top right: H; bottom-left: K; and bottom-right: L. A single frame was obtained at J, while a mosaic of several is presented at H, K, and L. The faintest objects at L are 9.8^{mag}.*

the net detector quantum efficiency is low, (b) the number of bad pixels is a function of detector integration time, and (c) the streaking effect. The limits in actual performance are imposed by improper subtraction of the bad pixels and of their streaks. The combination of these problems makes the new array unsuitable for work under low background conditions, e.g. in the J band, in the H and K bands when working at high spatial resolution, with the 1.5–2.5 μm CVF and eventually with a Fabry-Perot etalon.

Under high background conditions (K at low spatial resolution and L), where there is sufficient sky background to overcome most of the streaking problem, good results can be obtained. Here one is limited by (a) improper subtraction of the first few pixels of the streaks from the hot pixels, which add noise to the sky background, and (b) the source of interest falling on a bad pixel, thus increasing the uncertainty in the photometry.

Table 4: *Limiting sensitivities*

Filter	Sky (mag/sq. arcsec)	1σ/pix	5σ/beam
H	12.8	19.5	15.6
K	10.7	19.5	15.6
L	1.7	14.2	10.3

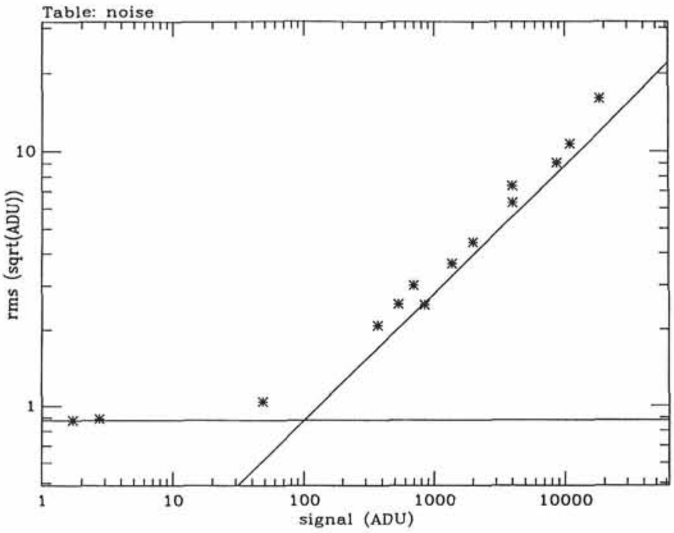

Figure 5: *Measured RMS noise vs. signal. The horizontal line indicates the RON, and the diagonal line shows the expected noise for background limited performance.*

Photographic Astronomy with MAMA

J. GUIBERT and O. MOREAU, Centre d'Analyse des Images, Observatoire de Paris, France

MAMA (Machine Automatique à Mesurer pour l'Astronomie) is a fast and accurate multichannel microdensitometer developped and operated by INSU and located at Observatoire de Paris. MAMA processes in a few hours photographic plates up to 14′ × 14′ with a positional accuracy of 1 μm (repeatability: 0.2 μm) and a photometric accuracy of 2 per cent over a dynamical range of 3 densities. The detector is a RETICON CCPD array with 1024 photodiodes. The plate can be digitized either in a systematic way by lanes 10.24 mm wide, or in a random access mode from a catalogue of preliminary positions. The basic

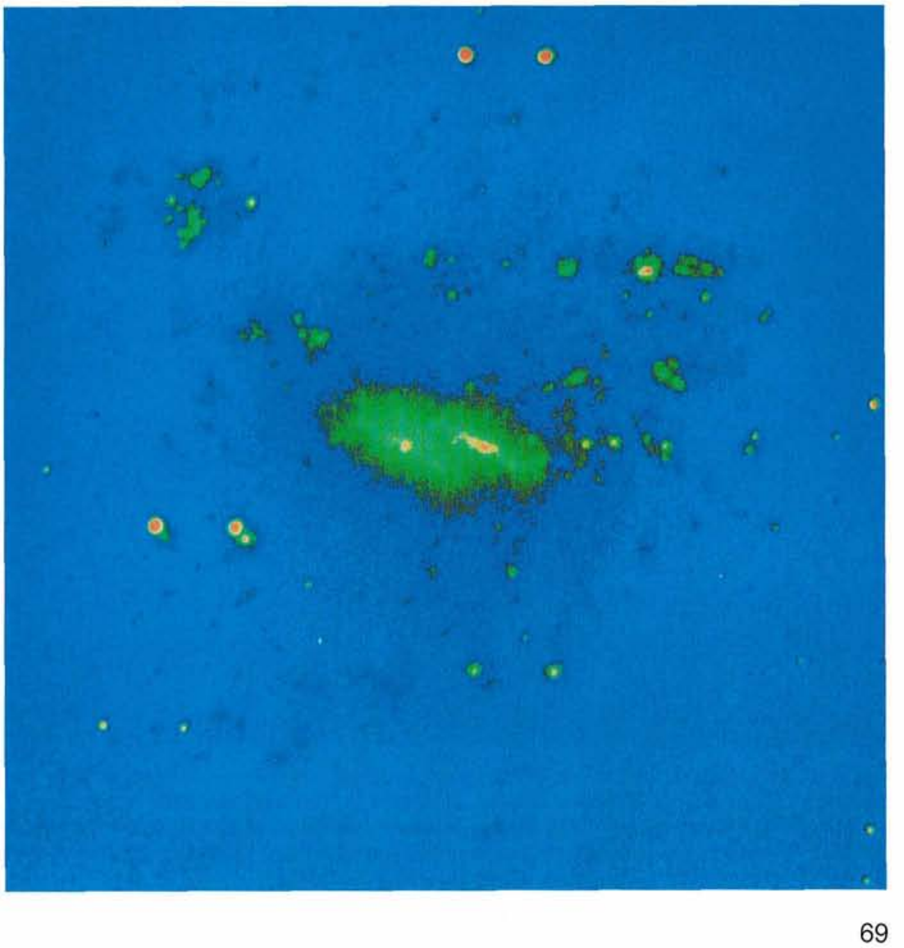

Figure 1: *Detection of at least three regions with intense star formation in a spiral galaxy. A combination of two exposures with the 1-metre ESO Schmidt telescope on IIIa-F emulsion: UV (80 min. behind a UG 1 filtre) and R (25 min. behind a RG 630 filtre). The upper images belong to the R exposure and the lower to the UV exposure; the offset is 30″. It can be seen that the lower (southern) UV images of the star-forming regions are significantly brighter than the R images. Digitized with MAMA for a programme conducted by G. Comte (Observatoire de Marseille). Plate 7922 obtained on March 13, 1989.*

pixel size (and sampling step) is 10 μm. Oversampling down to 2 μm can be used to digitize spectra; for some applications, pixels of 20, 30...80 μm can be synthesized in real time.

The digitized images can be processed according to three main modes. On-line processing leads, through a multilevel thresholding technique, to a catalogue of positions, areas, fluxes and second-order moments. Off-line processing is possible on the site using DEC-3100 or SUN SPARC 2 workstations, and a VAX 8250 computer; the available software includes MIDAS and a number of tools specially designed to extract the best from the astrometric and photometric capabilities of the machine. Finally, the user can of course take the pixels with him to process them with his own facilities.

A wide variety of scientific projects are currently being carried out using MAMA. Several long-term programmes dealing with solar physics are based on spectral images from Pic du Midi, Teide Observatory (Tenerife), Sacramento Peak, and Meudon where spectroheliograms have been accumulated since the beginning of this century. Works concerning the solar system, stellar populations and galactic structure as well as extragalactic astronomy are mainly based on Schmidt plates from Palomar, Siding Springs, Calar Alto, Tautenburg, CERGA, and of course ESO.

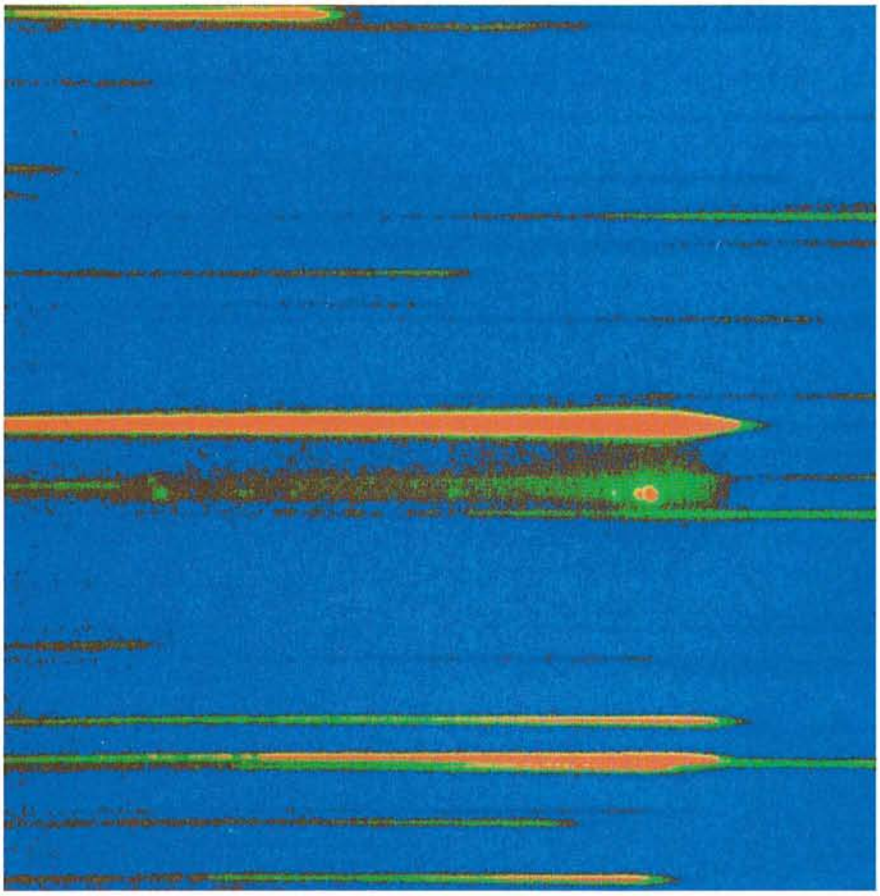

Figure 2: *Strong emission in the objective-prism spectrum of a galaxy, indicating intense star formation. The plate (no. 7906) was obtained on March 6, 1989 with the ESO 1-metre Schmidt telescope, equipped with a 4° UBK7 prism; dispersion 450 Å/mm at 4350 Å and 750 Å/mm at 5000 Å. Exposure: 100 minutes on IIIa-J emulsion without filtre. Digitized with MAMA for a programme conducted by G. Comte (Observatoire de Marseille).*

Galactic structure surveys conducted with MAMA take advantage of the astrometric accuracy of the machine. Using plates taken over 40 years, relative proper motions are obtained by C. Soubiran (1991) for high numbers of stars with an accuracy of 1.5 milli-arcsec/year, which compares favourably with the absolute accuracy of HIPPARCOS. This geometric accuracy of MAMA is also quite appreciable when reducing objective-prism images, since the quality of radial velocity determination strongly depends on the geometry of the measuring machine.

The photometric accuracy allows stellar magnitudes to be determined to within 0.05 mag., provided good sequences are available. This feature is of course interesting for the study of stellar populations as well as for extragalactic programmes. Among the latter, an extensive search for quasar candidates mainly based on multicolour photometry in the North Galactic Pole region; Schmidt plates taken at various epochs will also be used to investigate the variability of the detected galactic and extragalactic objects. Information about MAMA and reduction techniques can be found in the papers by Berger et al. (1991) (see also the paper by Guibert et al. (1990), and references therein).

Among the programmes currently on the way which are based on La Silla instruments let us quote an extensive project aimed at the search for baryonic dark matter in the Galactic halo. The technique consists in monitoring the magnitude of a large number of stars of the LMC, the light of which could be amplified by microlensing when passing close to small and massive halo objects, such as jupiters, brown dwarfs, or small black holes. The ESO Schmidt telescope is used to search for deflectors with masses in the range 10^{-1} – 10^{-4} solar masses; a companion programme, using an assembly of CCD detectors, is aimed at the detection of masses in the 10^{-4} – 10^{-6} solar masses range. In the galactic domain, we can also mention stellar-population studies and star counts.

In the extragalactic field, direct and objective-prism plates from the La Silla Schmidt telescope are, among others, used to detect and study galaxies with bursts of star formation. This will be the topic of a paper by G. Comte (Observatoire de Marseille) in a forthcoming issue of *The Messenger,* and is illustrated by two photographs accompanying this presentation. The first concerns a direct double U-R exposure; the second reproduces part of an objective-prism plate.

In planetology, we can mention, among others, the study of Neptune's arc rings through accurate trajectography of the planet and Triton, performed on Schmidt plates from La Silla.

Glass copies of both ESO-R and SERC-J surveys are available in the plate vault: they are extensively used for preparing observations with the La Silla instruments, as well as for the identification, astrometry and photometry of optical counterparts of sources detected at other wavelengths: radio, X, infrared. In particular, MAMA is being used for identification and photometry of faint IRAS extragalactic sources.

We have given some examples of the invaluable role of photographic material taken at different epochs in studies of proper motions as well as variability in solar, galactic and extragalactic astronomy. In addition, ground-based and space observations at various wavelengths require and will continue to require wide-field complementary investigations.

The TYCHO catalogue will contain about one million stars known to a few hundredths of a second of arc and a few hundredths of a magnitude. This will result in significant improvement of the calibration of Schmidt plates which are expected to remain, for a long time, irreplaceable supports for wide-field information.

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Access to MAMA: MAMA is available for visitor use.
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MIDAS Memo

ESO Image Processing Group

1. Application Developments

The Echelle package has been further upgraded with instrument independent wavelength calibration and better background correction.

Peter Stetson has implemented a new version of DAOPHOT during a visit to ESO in April. This version reads the image data directly from the MIDAS .bdf files. An interface between DAOPHOT and MIDAS enables exchange of the table data between the two systems and thereby makes DAOPHOT available for MIDAS users. The DAOPHOT package and the interface are not on the standard release tape of the 91MAY version but can be obtained on explicit request to ESO.

A set of adaptive filters based on the Haar transform was installed in MIDAS by Gotthard Richter. These filters are especially useful for surface photometry applications since they smooth selectively areas depending on the local gradient. They are available in the 91MAY release of MIDAS.

2. ESO-MIDAS Courier

The Image Processing Group will start a biannual newsletter on MIDAS-related matters. It is called the ESO-MIDAS Courier and is edited by Rein Warmels. It will contain significantly more detailed information than has been possible in the MIDAS Memo. Contributions to the Courier can be sent to the MIDAS E-mail address, attn.: MIDAS Courier.

3. Data Analysis Workshop

The 3rd annual ESO/ST-ECF Data Analysis Workshop took place April 22–24 in the ESO Headquarters. It consisted of 1½ day scientific meeting centred on reduction software for direct image data followed by one day with users' meetings for both MIDAS and ST-ECF. Approximately 90 people participated in the meeting where more than

Central Computer Facilities of ESO

The central computers of ESO, which now consist of a cluster of two VAX 8600 systems running the VAX/VMS operating system, will be replaced during the fall of 1991. The new systems will use the UNIX operating system and support the X11 window system. A small VAX/VMS system will be purchased to ensure compatibility with external sites using VAX/VMS systems. UNIX workstations are expected to replace the DeAnza image display systems now connected to the VAX's.

The electronic network connections to SPAN, Internet, BITNET/EARN and UUCP will be maintained whereas the VMS/PSI-mail option will be discontinued. Direct access to ESO through X.25 and modems will still be possible. After the exchange of computer systems, it is expected that electronic News, Bulletin Boards and anonymous ftp accounts will be made available to facilitate easy information exchange between ESO and its user community.

P. GROSBØL, ESO

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, Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where fourteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. The 3.5-m New Technology Telescope (NTT) became operational in 1990, and a giant telescope (VLT=Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, Germany. It is the scientific-technical and administrative centre of ESO where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to 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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30 papers and posters were presented. Proceedings of the scientific session will be published during the course of this year.

Next year the Data Analysis Workshop is expected to take place in May 1992 with the emphasis on reduction procedures for spectroscopic data.

4. MIDAS Hot-Line Service

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

- EARN: MIDAS@DGAESO51
- SPAN: ESO::MIDAS
- Eunet: midas@eso.uucp
- Internet: midas@eso.org
- FAX.: +49-89-3202362, attn.: MIDAS HOT-LINE
- 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 we ask users to use it in urgent cases only. To make it easier for us to process the requests properly we ask you, when possible, to submit requests in written form either through electronic networks, telefax or telex.

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