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BENGT STRÖMGREN (1908–1987)

Bengt Strömgren, former President of the ESO Council (1975–1977) died on 4 July after a brief illness. His presidency occurred at a particularly difficult moment in ESO's history. Thanks to his wisdom and the self-confident and decisive way in which he dealt with ESO matters, many perils were avoided and a high degree of harmony was established between the delegations of the member countries which has endured up to the present.

Bengt Strömgren was a distinguished scientist. He published his first results on Baade's comet 1922c in Astronomische Nachrichten (217, p. 345) in 1922 when he was fourteen years old. One of his last preprints appeared a few days before his death. The son of Elis Strömgren, Director of Copenhagen Observatory, Bengt obtained his Ph.D. in 1929 and became Professor of Astronomy in 1938 and Director in 1940. From 1951–57 he was Director of the Yerkes Observatory of the University of Chicago. The next ten years he was a member of the faculty of the Institute for Advanced Study in Princeton. In 1967 he returned to Copenhagen to occupy the "House of Honor", to be Professor of Astrophysics and for several years Director of NORDITA, the joint research institute of the five nordic countries. From 1970 to 1973 he was President of the International Astronomical Union. For more than a decade he was President of the Danish Cancer Committee, which shows the width of his interests.

The thread that runs through his research is an interest in the chemical composition of celestial bodies. In the thirties this led him to studies of the internal structure of stars in which he showed that hydrogen must be a major constituent. In 1940 he published an important article on the composition of the solar atmosphere in the Festschrift for Elis Strömgren. Later he perceived the need for efficient methods to determine stellar luminosities, temperatures and metal abundances in order to study the distribution of stars of different composition and age and thereby to probe the history of our galaxy. This led to the development of the "Strömgren photometric system", the four colour uvby system which is widely used. In this system the pass bands defining the colours have been selected with great care to maximize the information about the essential stellar parameters. Also to be mentioned are his earlier researches on the ionization of interstellar gas by hot stars. Such ionized regions are now known as "Strömgren spheres".

Bengt Strömgren was low key but decisive. If he strongly doubted what you told him, he would very mildly ask if you were quite sure. He was modest in claiming credit and generous in giving it to others. But if he felt it important to reach a particular aim, he was persistent. Most Danish astronomers are in some way his students, and many of us elsewhere have been influenced by him as post docs or associates. And very many have enjoyed the warm hospitality of Bengt and Sigrid Strömgren.

If it is the mark of a successful life for a scientist to have had a significant impact and to have made lasting contributions to science, then Bengt Strömgren has been a fortunate person, indeed. He will be missed by all who knew him.

L. Woltjer

CPD −71° 172, a New Binary with a Hot Subdwarf

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The Very Wide Field Camera (VWFC) is an experiment developed with, as a major aim, the detection in a range of faint magnitudes of the stellar objects showing a strong ultraviolet excess. It consists of an all reflection F/1.9 Schmidt camera which refocuses the image of the sky given by a hyperbolic mirror onto the photocathode of an image intensifier. It provides a useful field of about 66° in diameter with a resolution of about 5 arcminutes. Three UV interference filters centred at 168, 195 and 254 nm can be placed alternatively in the incident beam. The images are recorded on classical KODAK IIa-0 emulsion. The VWFC was flown aboard Spacelab-1 in December 1983 and 66 frames were obtained; because of orbital constraints, only twenty per cent of the celestial sphere could be covered by the deepest survey. Thanks to an adequate image data processing particularly well adapted to correct the images from straylight background, limiting magnitudes as faint as m (195 nm) = 9.3 were reached.

In the course of identifying stars around the Small Magellanic Cloud, a well-defined star-like object was found (Fig. 1) with no other counterpart than a cool star; according to the data provided by the Centre de Données Stellaires in Strasbourg and to the ESO/SRC Sky Atlas prints, the only possible candidate was CPD −71° 172, an F0 star with magnitudes $m_v \sim 10.5$ and $m_B \sim 10.9$. From these values, the expected 195 nm magnitude was normally expected at about 12.3 whereas it was estimated to be close to 8. A so large UV excess led us to suspect a hot subluminous companion to the cool primary. We confirmed soon the spectral type of the latter by help of a spectrogram obtained at ESO La Silla. At the same time, a first low resolution UV spectrum provided by the IUE satellite confirmed the existence of a very hot subdwarf companion. The binary association of both stars seems evident after their angular distance, which is likely less than 1 arcsecond (the pair is optically still unresolved), and after the distance inferred from the cool star (700 pc). The absolute magnitude deduced for the blue star, $M_v \sim 3$, is a common value for this kind of objects. We recall their great interest as they provide a direct means of testing the ability of models to reproduce the last stages of stellar evolution towards the white dwarf degenerates. In this connection and from a practical point of view, the interest of binary systems similar to CPD −71° 172 lies in the opportunity they offer to determine unambiguously the absolute magnitudes of hot subdwarfs, so long they belong to loose systems in which no significant mass exchange has occurred when the original primary was near the red giant tip.

Visible spectrography was performed on IIIa-J hypersensitized plates using the Boller and Chivens spectrograph attached to the ESO 1.52-m telescope, with a dispersion of 39 Å mm^{-1}. We classified the star as F 2.5 IV with an uncertainty of 1 subclass; no He I or He II lines were visible.

UV spectra at low resolution have been obtained in the range 120 to 320 nm with the IUE satellite; they are fully dominated, especially in the shorter wavelength region, by the flux of the hot component, showing a UV gradient similar to that of BD 75° 325, a well-studied sdO star.

Johnson, Cousins and Strömgren photometries were carried out at ESO and SAAO, with the aim of a photometric deconvolution between the components. The fitting of intrinsic colours of both components to so many colours was a puzzling task which required an iterative method. We found that a colour excess E (B−V) = 0.014 was necessary to reproduce the observed colours. The deconvolution implied a fit of the Kurucz (1979) model atmospheres normalized at V to the flux distribution in the IUE

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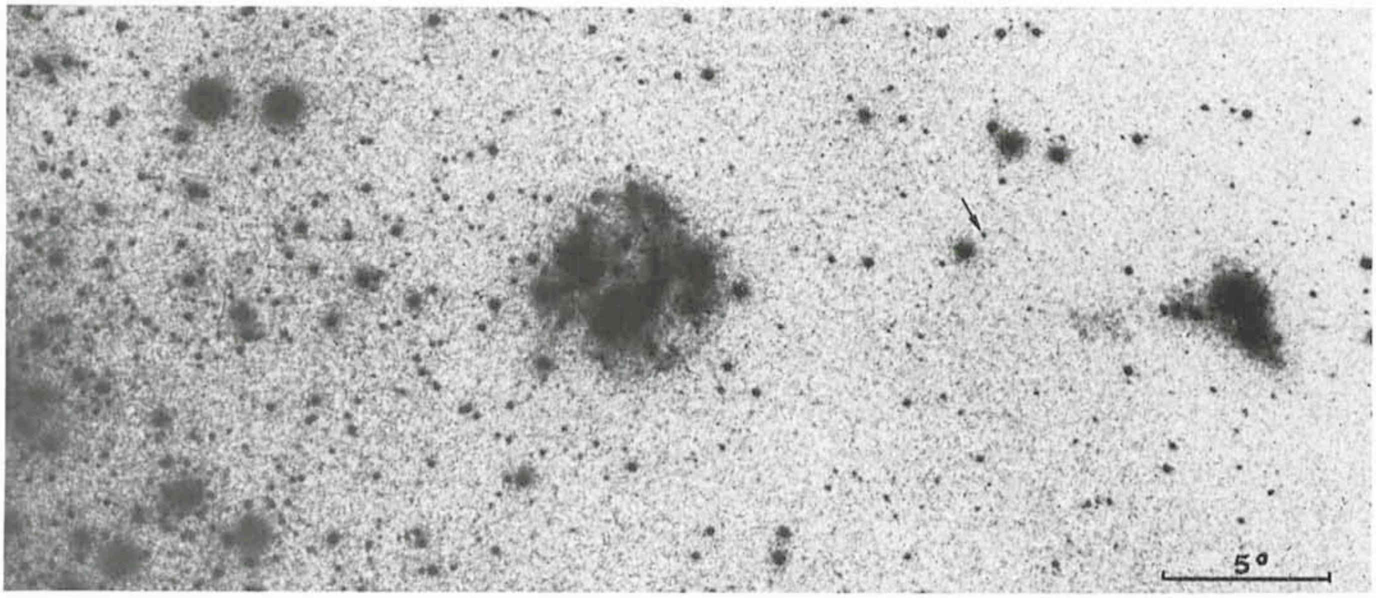

Figure 1: *Negative enlargement of part of a deep frame (195 nm filter, exposure time 304 s) of the VWFC in the region of the Magellanic Clouds: the LMC is at the centre, the SMC to the right (North is roughly up, East to the left). Four other newly identified objects showing UV excess have been found in this field.*

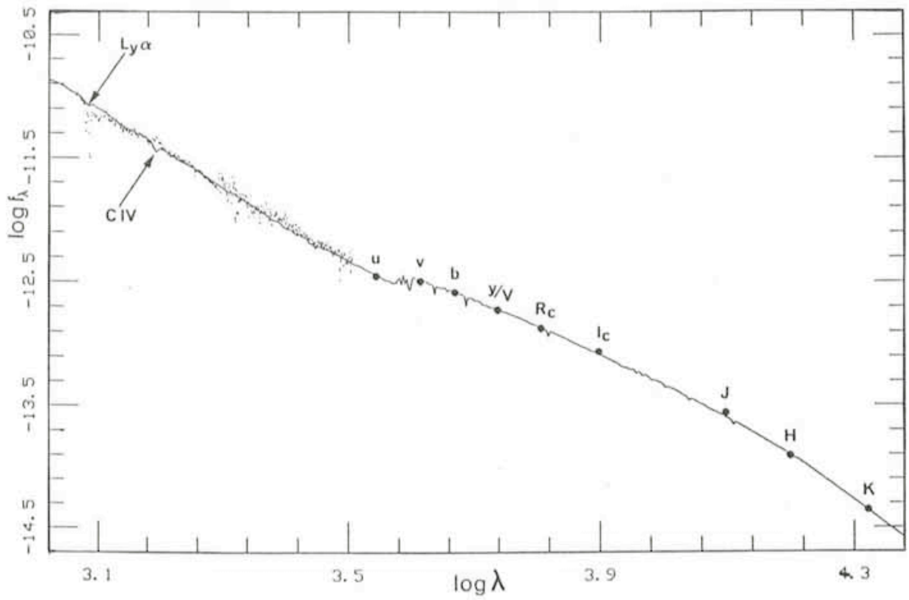

Figure 2: *Absolute flux distribution of CPD − 71°172AB from Lyman alpha to the Johnson K band (2.2 μm) expressed in erg (cm^2 s Å)$^{-1}$ versus the wavelength in Å units. Strömgren uvby, Cousins $R_c I_c$ and Johnson JHK fluxes are displayed by large filled dots. Small dots in the UV range represent the observations with IUE.*

range, following the method of Heber et al. (1984) and Heber (1986) though presently only LTE models were available. It provided a low estimate of the effective temperature T_{eff} ~ 50,000° K for the hot star, from which were derived its intrinsic optical colours; some iterations were necessary to adjust the V magnitudes and the reddening so that all colours of the primary would be those of an early F star. The adopted solution was the following:

Star	CPD −71° 172 A	CPD −71° 172 B
Spectral type	F 3–4 IV	SdOB
y or V	10.99	12.05
b−y	0.265	− 0.155
m_1	0.161	0.060
C_1	0.643	− 0.210
U−B	0.019	− 1.210
B−V	0.403	− 0.327
V−R_c	0.240	− 0.16
V−I_c	0.481	− 0.32
V−J	0.77	− 0.74
V−H	0.96	− 0.91
V−K	1.01	− 0.97

The visual absolute magnitudes of both stars were derived from the adopted spectral type and colours of the F component, using the Tables of Crawford (1975) and of FitzGerald (1970) to estimate its degree of evolution; the inferred intrinsic parameters were checked by means of the Barnes-Evans (1978) relation. We determined in that way:

Star	M_v	T_{eff}	BC	Log ($L/L_\odot$)	$R/R_\odot$	log g
CPD −71° 172 A	1.80	6,700	−0.10	1.15	2.80	3.7
CPD −71° 172 B	2.86	55,000	−4.80	2.70	0.24	5.4

Figure 2 shows the fit of the sum of the Kurucz models adopted for each component to the IUE and visible observed composite colours. As it can be seen, the overall agreement between models and observations is quite satisfactory. A subsequent check using the R index of Schonberner and Drilling (1984) yielded T_{eff} ~ 50,000 to 60,000° K.

We have compared CPD −71° 172 B to two well-known subdwarfs:

(1) BD 75° 325 is a field sdO with T_{eff} ~ 50,000° K, log g ~ 5.3, helium rich after Kudritzki et al. (1980). The short wavelength IUE spectra of both stars have revealed comparable ionization and excitation temperatures; the He II line at 164 nm is much stronger in the spectrum of BD 75° 325, suggesting that helium is moderately to fairly depleted in CPD −71° 172 B. The abundance of nitrogen is roughly normal while silicon and carbon are depleted like helium.

(2) The ultraviolet spectrum of LS II + 18° 9, which is a helium normal star with T_{eff} ~ 60,000° K, confirms both the normal abundance of nitrogen and the slight depletion of helium in the photosphere of CPD −71° 172 B. In case where these results would be confirmed by the analysis of IUE high resolution observations, this newly discovered subdwarf would be one of the first helium poor sdO's with T_{eff} > 40,000° K.

So far, 14 other potential candidates have been identified and spectrographic observations recently performed at ESO have revealed seven objects of various natures, for which a long-term general survey including multicolour photometry, radial velocity measurements and IUE observations is in progress.

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Tentative Time-table of Council Sessions and Committee Meetings in 1987

October 6	Council in Paris
November 17	Scientific Technical Committee
November 19–20	Finance Committee
Nov. 30–Dec. 1	Observing Programmes Committee
December 7	Committee of Council
December 8	Council

All meetings will take place in Garching unless stated otherwise.

List of ESO Preprints

506. V. Castellani and M.L. Quarta: The Oosterhoff Dichotomy Revisited. I. The Ranking of RR Lyrae Periods Versus Metallicity. *Astronomy and Astrophysics.* June 1987.
507. L.B. Lucy and M. Perinotto: Models for the Wind of the Central Star of NGC 6543. *Astronomy and Astrophysics.* June 1987.
508. A.F.M. Moorwood: IRSPEC: Design, Performance and First Scientific Results. Invited paper presented at the Workshop on "Ground-Based Astronomical Observations with Infrared Array Detectors", University of Hawaii at Hilo, March 1987. June 1987.
509. A. Renzini: Some Embarrassments in Current Treatments of Convective Overshooting. *Astronomy and Astrophysics.* June 1987.
510. P. Crane, A. Stockton and W.C. Saslaw: The Optical Spectral Index in the South Radio Lobe of 3C 33. *Astronomy and Astrophysics.* June 1987.

511. N. Epchtein et al.: Valinhos 2.2 Micron Survey of the Southern Galactic Plane. II. Near-Infrared Photometry, IRAS Identifications and Nature of the Sources. *Astronomy and Astrophysics.* June 1987.
512. M. Azzopardi, J. Lequeux and A. Maeder: The Number of Wolf-Rayet Stars in Local Group Galaxies. *Astronomy and Astrophysics.* June 1987.
513. M. Pierre and M. Azzopardi: Young Stellar Content of Nearby Galaxies. I. NGC 300. *Astronomy and Astrophysics.* June 1987.
514. A.F.M. Moorwood, M.-P. Véron-Cetty and I.S. Glass: Optical and Near-Infrared Observations of IRAS Galaxies. II. *Astronomy and Astrophysics.* July 1987.
515. F. Matteucci and A. Tornambè: Chemical Evolution of Elliptical Galaxies. *Astronomy and Astrophysics.* July 1987.
516. A.F.M. Moorwood, E. Oliva and I.J. Danziger: Infrared Spectroscopy of Supernova Remnants. Paper presented at IAU Colloquium No. 101, "The Interaction of Supernova Remnants with the Interstellar Medium", 8–12 June 1987, Penticon, Canada. July 1987.
517. G. Contopoulos: Escapes from Stellar Systems. Contribution to the Proceedings of IAU Colloquium No. 97. July 1987.
518. H. Dekker, S. D'Odorico and R. Arsenault: First Results with a Transmission Echelle Grating in EFOSC. *Astronomy and Astrophysics.* July 1987.
519. E.J. Wampler and W.L. Burke: Cosmological Models with Non-Zero Lambda. Paper presented at a Symposium celebrating the 60th birthday of Halton C. Arp, "New Ideas in Astronomy". July 1987.
520. D. Baade: From Low-Noise Observations to High-Quality Data. Invited talk at 27th Liège Astronomy Colloquium "Astronomy with High-Precision Data", June 1987, Liège. July 1987.
521. M. Heydri-Malayeri, T. Le Bertre and P. Magain: The SMC Compact Blob N 81: a Detailed Multi-Wavelength Investigation. *Astronomy and Astrophysics.* August 1987.
522. D. Lorenzetti et al.: Infrared Monitoring of Halley's Comet. *Astronomy and Astrophysics.* August 1987.
523. A. Tornambè et al.: Binary Systems as Supernova Progenitors (Some Frequency Estimates). Invited paper at the 4th Workshop on "Nuclear Astrophysics" of the Max-Planck-Institut für Astrophysik at the Ringberg Castle, Tegernsee, April 21–24, 1987. August 1987.
524. M. Rodríguez-Espinosa, R.M. Stanga and A.F.M. Moorwood: Near-Infrared Photometry of High Redshift Quasars. *Astronomy and Astrophysics.* August 1987.
525. M. Rosa and O.-G. Richter: On the Progenitors of Type II Supernovae in M 83. *Astronomy and Astrophysics.* August 1987.
526. G. Meylan and S. Djorgovski: A Preliminary Survey of Collapsed Cores in Magellanic Clouds Globular Clusters. *Astronomy and Astrophysics.* August 1987.
527. T. Le Bertre: Optical and Infrared Observations of the Carbon Mira R For. Dust Shell Modelling as a Function of Phase. *Astronomy and Astrophysics.* August 1987.
528. Studies of Dynamical Properties of Globular Clusters. IV. Detailed Structure of 47 Tucanae. *Astronomy and Astrophysics.* August 1987.

Luminous MS Stars in the LMC

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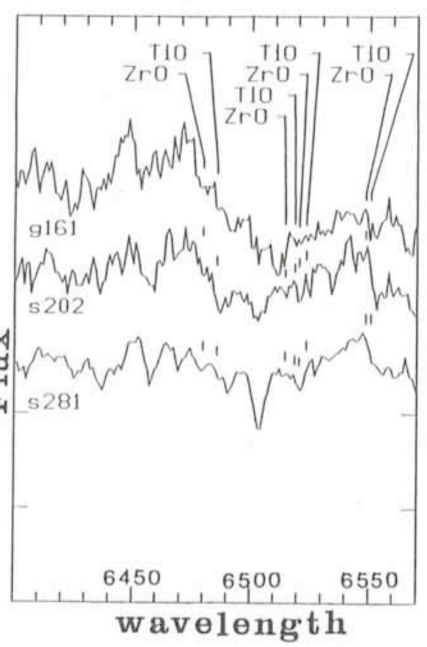
IDS spectra of a sample of stars selected from the M supergiant and M giant catalogue of Westerlund et al. (1981) have been obtained with the 3.6-m and 1.5-m telescopes. The sample covers the luminosity range from M(bol) = −9 down to M(bol) = −4. The most luminous stars are massive supergiants, while the less luminous ones are asymptotic giant branch (AGB) stars.

AGB stars are known to dredge up processed material to the surface. This produces carbon stars from oxygen-rich (M-type) stars. If the amount of material mixed to the surface is not large enough to transform the star into a carbon star, then the star becomes an MS, S or SC star. The spectral sequence M, MS, S, SC and C is an abundance sequence measuring the carbon-to-oxygen ratio. Thus MS stars have experienced some mixing and have a modified C/O ratio while M stars have not. For further details, the reader is referred to Iben and Renzini (1983) and references therein.

The MS and S classification is based on the strength of the ZrO bands, the strongest at 6473 Å. On the classification system of Keenan and Boeshaar (1980) the class MS is reserved for stars which have only slightly enhanced ZrO bands. Stars with stronger ZrO bands are called S-type. Abundance classes for S-type stars are determined from ZrO to TiO band-strength ratios.

When analysing the IDS spectra, particular attention was given to the strength of the ZrO bands. A number of S-type stars were easily found. To detect weaker enhancements in an unambiguous way, the strengths of the bands were measured by integrating the spectra in well-defined windows. Stars with luminosities around M(bol) = −6 and with types later later than around M2 were found to have slightly stronger 6473 (ZrO) features than more luminous M supergiants. Classification criteria used by Lloyd Evans (1983) indicate that this enhancement is enough to classify them as MS stars. Figure 1 shows spectra of three stars in the region of the 6473 band. The stars are from bottom to top: an M supergiant with M(bol) = −7.9, an MS star with M(bol) = −6.3 and an S star with M(bol) = −4.8. The strengths of the ZrO bands are seen to be stronger in the MS star than in the M star and, of course, much stronger in the S star. The stars are fairly close in temperature type.

In order to certify the MS classification, a number of classification standards of types M, MS and S were observed with the RETICON on the 1.5-m telescope in December 1986. The spectra cover the region from 5000 Å to 10000 Å. The dispersion is 228 Å/mm. The preliminary analysis of these spectra indicates that a few stars with 6473 features like the luminous MS stars in the LMC are found among the M-type classification standards. Thus, either the luminous MS stars are M-type or the M-type standards are actually type MS. Since MS and S-type stars frequently have a history of having once been



IDS spectra of LMC stars of spectral types M3 (bottom), M3S (middle) and S3/3 (top). The spectra are normalized to the same flux and the zero-points marked. The position of some TiO and ZrO features are indicated.

classified as type M and, when classifying in the blue spectral region, slight ZrO enhancements are easily overlooked, the latter explanation seems likely. To complicate matters further, the number of MS standards is very small and at least some of them have variable abundance class.

From their position in the colour-magnitude diagram, the MS stars are estimated to have masses around 5 $M_\odot$. Most of the carbon stars in the field investigated by Wood et al. (1983) were found to have pulsational masses around 1 $M_\odot$. The luminous J-type (^{13}C-rich) carbon stars (Richer et al. 1979) probably represent higher masses. The J-type carbon stars are known not to have enhanced s-process element abundances while the N-type, non-J, carbon stars have this enhancement. Unfortunately, s-process element abundances are not available for the MS stars but would be very useful in determining the relation between the two groups of carbon stars and the MS stars. This relation is at present not clear, but the MS stars are more massive than the bulk of ordinary N-type carbon stars and may be more closely related to the luminous J-type carbon stars.

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HD 187474: the First Results of Surface Magnetic Field Measurements

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1. Introduction

The upper main-sequence chemically peculiar stars (CP, see Preston 1974) were the first non degenerate stars definitely showing magnetic field with large scale structure. The magnetic field usually observed in CP stars is dipolar. More complicated structures are perhaps present, but their contributions are certainly smaller (Landstreet, 1980). As the star rotates, the visible hemisphere changes and magnetic field variations are observed. The magnetic field seems to play an important role in the physical phenomena occurring in the magnetic CP stars (diffusion, blanketing, structure of the atmosphere, . . .), and a better knowledge of it is therefore important for our understanding of the CP phenomenon.

The magnetic field is detected through the splitting of a line into several components: π components are symmetrically displaced around the central wavelength λ_o, while σ components are displaced to shorter or longer wavelengths. In the most simple case, the line is split into a triplet pattern with three components: one undisplaced π component and two symmetrically displaced σ components. These components are also polarized and their polarizations depend on the magnetic field orientation.

The mean displacement of the σ components from the central wavelength λ_o is given by:

$$\Delta\lambda = 4.67 \times 10^{-13} z B \lambda_o^2 \qquad (1)$$

for wavelength expressed in Å; z is the mean Landé factor of the σ component and B is the magnetic field in gauss. The mean Landé factor of the σ components z is also called effective Landé factor (geff). It appears immediately that this displacement is very small, of the order of 100 milliangström per kilogauss at 5000 Å for z = 1. Generally it is smaller than broadening due to other mechanisms (thermal, collisional broadening), the most important and unavoidable one is the rotational broadening.

The splitting measured in circularly polarized light gives access to the average longitudinal magnetic field, also called "effective" magnetic field (Heff). It is the average on the visible hemisphere of the magnetic field projection on the line of sight. One advantage of this method is that by recording separately the right and left circularly polarized light, small relative displacements of the same line, between the two spectra, can easily be detected. Several different methods of circular polarization measurement across spectral lines have been used to deduce stellar effective magnetic fields (Landstreet, 1980).

The splitting measured in unpolarized light gives access to the surface magnetic field (Hs), which is the average magnitude of the field over the visible hemisphere. The Hs value is then deduced from the displacement observed on classical spectra. It is difficult to measure and very often the Zeeman pattern of the lines are not resolved in stellar spectra.

It is a pity, because Hs values are more representative of the magnetic energy and less sensitive to the field geometry than Heff values. And Hs is certainly more suitable to study the influence of the magnetic field on other stellar characteristics (rotation, abundances, ...), or the correlation with parameters of interest in CP stars (photometric index of peculiarity for example). Moreover, the knowledge of Hs variation, in addition to that of Heff, is necessary to get a better idea of the field geometry.

2. Method and Data for Surface Magnetic Field Measurements

As said above, the displacement of the magnetic component is very small and Resolved Zeeman Pattern (RZP) can be observed only in the most favourable cases, at least in slowly rotating stars (Vsini < 10–20 km/s). Although CP stars rotate more slowly than main-sequence stars of the same spectral type, the sample where Hs can be measured directly from resolved splitting is limited.

Few CP stars (34) have been measured for Hs, among them only 12 show RZP (Didelon, 1983). Extensive Hs measurements along the whole period of variation are available for only 4 stars (Landstreet, 1980).

In order to go further and to measure Hs in a greater sample, the differential broadening due to magnetic field, must be studied. The first attempt to compare the widths of lines with different Landé factors was done by Preston (1971). More accurate analyses must compare similar lines which are formed under the same atmospheric conditions and have approximately the same strengths. So the lines must, if possible, belong to the same multiplet or super-multiplet, and must have approximately the same oscillator strength.

Several studies of that kind, more or less derived from the so-called "Robinson method" (Robinson, 1980), were undertaken, but have been applied to cool stars only. In fact, all these approaches used the comparison and/or the deconvolution of magnetic sensitive lines by magnetic null lines or lines less sensitive to the magnetic field (smaller z value).

One kind of procedure directly fits the profile of the magnetic line with 3 components. The parameters of these components are partially derived from the unsensitive lines (Marcy, 1984). Then the "deconvolution" is done iteratively and finally gives the field strength and the filling factor, which is the surface proportion covered by the field.

Other procedures study the division of the Fourier Transforms (FT hereafter) of the two lines with different magnetic sensitivity (Sun et al., 1987 and references therein; Gray, 1984). The FT of a sensitive line is given by:

$$Pz(\sigma) = P_o(\sigma) * (1 - A + A\cos(2\pi n \sigma_o \Delta)) \quad (2)$$

- $P_o(\sigma)$ is the FT of a magnetic null line,
- A is a function of the mean orientation of the magnetic field θ, and of the filling factor F : $A = 0.5\,F\,(1 + \cos^2\theta)$,
- Δ is the usual displacement of the components given by expression (1),
- σ_o is the smallest frequency obtained in the FT, which corresponds to the length of the spectrum analysed,
- n is an integer which gives the different frequencies of the discrete FT.

The division of two FT eliminates $P_o(\sigma)$ and the Zeeman signature corresponding to the Zeeman broadening is obtained. If the division is made by the FT of a magnetic null line, the theoretical Zeeman broadening function which must be used to fit the observational Zeeman broadening function is reduced to a simple form:

$$Z(\sigma) = 1 - A + A\cos(2\pi n \sigma_o \Delta)$$

Both methods use the same assumptions and seem to have the same limitations. They assume that the magnetic field is homogeneous on the visible hemisphere, that the Zeeman pattern can be analysed as a triplet, and they suppose that the lines are unblended. However, several attempts have been made to study the influences of these shortcomings (Gray, 1984; Gondoin et al., 1985).

It would be of interest to test the application of the different methods to CP stars, and to check if the magnetic field values can be derived in rapidly rotating magnetic stars. In that way, slowly rotating magnetic stars must be studied first to see if the different methods are consistent and reliable.

Surface magnetic field measurements with both methods require high resolution spectroscopy with high signal-to-noise ratio. In fact, one must be able to see Resolved Zeeman Pattern (RZP) in faint lines or make a fine profile analysis of lines with different Landé factors. The unique combination of the CES and Reticon at the CAT allows to obtain such data.

During two observing runs at this instrument, in December 1985 and October 1986, I observed several CP stars at several different wavelengths. I want to present here the first results concerning the very slow rotating CP star HD 187474, of the Si-Cr-Eu type. It has a rotational period of approximately 7 years, and is therefore a very good candidate to perform the first tests.

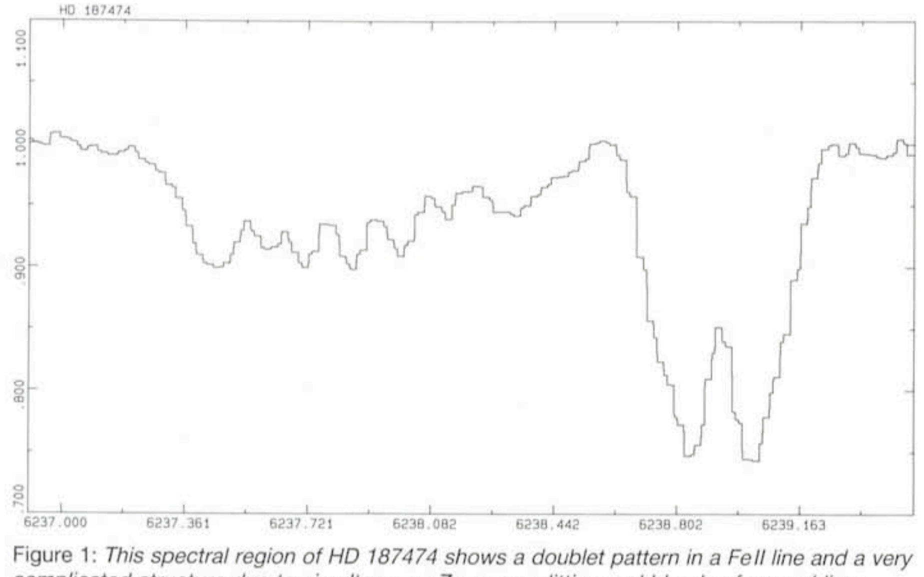

Figure 1: *This spectral region of HD 187474 shows a doublet pattern in a Fe II line and a very complicated structure due to simultaneous Zeeman splitting and blends of several lines.*

3. Some Difficulties in Surface Magnetic Field Measurements

It is obvious that people involved in Hs measurements try to observe lines with the greatest Landé factors possible, and which at the same time have a Zeeman pattern as simple as possible. I want to mention here some patterns of interest. The quasi triplet pattern occurs when the groups of π and σ components are widely separated. Otherwise, if π and σ components are blended together, the geff values listed in Beckers (1969) cannot be used, but taking into account the complete pattern and considering the magnetic subcomponents involved in the observed splitting, z can be calculated. Another interesting case is the doublet pattern; it is a special case of the quadruplet pattern. It occurs when the two groups of π components have the same displacement as the σ component groups. Then only two components are observed and they are more easily resolved than 3 or several components with the same z. As already seen above, complicated patterns will be difficult to analyse. This is illustrated in Figure 1, which shows a doublet pattern observed in a Fe II line of HD 187474 (the most simple pattern), and at the left of this line a very complicated structure. This feature is due to 2 nearby Si I lines with complicated Zeeman pattern, and possible additional blends with other faint lines.

It is also important to observe unsaturated lines. Otherwise, if they are too strong, they will be collisionally broadened, and information on the magnetic broadening will be more difficult to extract.

Moreover, as shown by expression (1), the displacement is related with the square of the central wavelength, and the splitting is more effective towards long wavelengths. That explains why people try to find suitable lines or line pairs in the red or even infrared region. But the choice is then limited by other constraints due to the earth's atmosphere. In fact, telluric lines of oxygen, water vapour or other species pollute large spectral regions which are then unsuitable for good measurements. For example a line pair of Fe II (73) at 7223 Å which would be very suitable for Differential Magnetic Broadening (DMB) study is disturbed by a forest of strong lines of atmospheric water vapour.

It therefore appears that the selection of lines to be studied is very important and very difficult. The choice is also important because the Reticon length limits the wavelength range available for each exposure to 50 Å.

This choice is not made easier by the great differences in abundance patterns

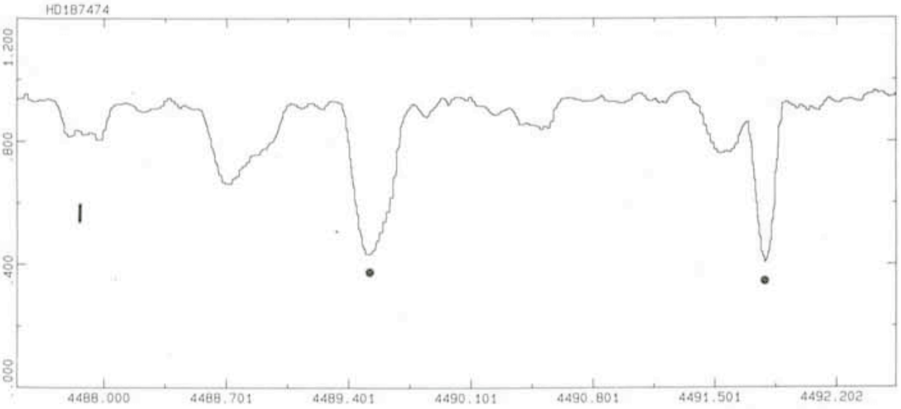

Figure 2: *A portion of a Reticon spectrum of HD 187474. The points indicate two lines of Fe II with different magnetic sensitivity. Note their different widths. The bar indicates a resolved Zeeman triplet in a Cr II line.*

encountered in CP stars. A strong, saturated line in one star, may be faint enough to be used, or may even disappear completely in other stars. Thus the choice depends not only on the lines themselves, but also partly on the selected stars to study.

Finally, I chose several spectral regions, in which lines with great z are present and can be observed in CP stars, and other regions with suitable line pairs for DMB analysis. The two lines of the pair must be located in the same 50 Å region, so they can be observed simultaneously with the Reticon.

All the problems mentioned above explain why clear RZP were usually not observed in the expected lines, but rather in unexpected faint lines (certainly with large z value) which appear in the chosen regions.

Another difficulty came from the line identification, but also from recognition and collection of the configuration, the Zeeman pattern and the z value.

The line identification in CP stars is not a trivial problem, even for strong lines (that is, those which are visible on photographic plates at high resolution 1–10 Å/mm, $W\lambda > 50$ mÅ). Such spectra of CP stars show unusual lines; lines from rare and heavy elements, or unidentified lines of common elements (i.e. Cr, Fe, . . .), usually not seen in normal stars. Even these strong lines are often not well studied in laboratory analysis, and atomic data are missing. The situation is worse at long wavelengths where atomic data are more likely to be missing.

In that way, the identification of faint (to very faint) lines detected in high resolution spectra with high S/N is a difficulty of first order. Moreover, the comparison of the strength or the presence of lines within a multiplet is not always possible due to the limited spectral range of 50 Å.

I want to point out that the lines analysed must be free of blends and must be as clean as possible, at least to perform DMB studies. It is obvious then that line identification is unavoidable for the best part, and that the choice of stars to be observed becomes more and more difficult. In fact, it is tempting to observe cool CP stars with strong overabundances. They would have many lines and the probability to see unexpected RZP is increased, but at the same time, blends will occur more often. This probability is also increased when the rotational velocity increases, due to the resulting line broadening.

All the above considerations show that the choices of the lines and of the stars to be observed are not independent. It is even more difficult to predict with certainty which lines will be suitable because the available atomic data are neither complete nor precise, even for common ions like Cr II, Ti II, . . . Only the observed spectra will show if the right choices have been made, and the experience will certainly bring up some useful and suitable lines or regions.

4. The Surface Magnetic Field of HD 187474 from RZP Study

In order to test and to compare the different methods of Hs measurement, the Hs first has to be determined from RZP, if possible. Five Reticon spectra of HD 187474 were obtained in October 1986. They cover the following wavelength regions: λλ 4488–4523, λλ 5000–5040, λλ 5274–5314, λλ6214–6265, λλ 7373–7426.

First of all, it is interesting to check by visual inspection if the Hs influence on the line profiles is noticeable. From the above-mentioned limitations and difficulties, it is obvious that DMB effects are certainly not easy to detect and analyse in some stars. However, effects are clearly visible in HD 187474. This is certainly due to the low rotational velocity and therefore the sharpness of the lines. This is illustrated in Figure 2 which reproduces a part of the spectrum in the lowest wavelength range. This range was chosen because it covers a region where 4 Fe II lines of the same multiplet (No. 37) are present. Moreover, they have approximately the same intensity but have different z values. Two of them are seen at 4489.5 Å and 4491.8 Å in Figure 2. Their z values are 1.5 and 0.4, respectively. The width difference is the signature of the DMB effect. A small blend is perhaps present in the red wing of the magnetic sensitive line. To the left in the same figure, a RZP is present. This triplet can be attributed to a Cr II line. This line has the same Landé factor (1.5) as the Fe II line at λ 4489.5. That one does not show a RZP, certainly because it is too strong ($W\lambda$ = 0.127 Å). This illustrates well the difficulty and the chance, which occurs in RZP observation, as stressed above. Two small and broad lines (certainly with high z values) are present at λ 4490.5 and λ 4491.5. The first one is definitely a Mn I line, but the second one cannot be identified with certainty. A broad blend of Ti II and Gd II is visible at λ 4488.7. Finally, this figure also gives an idea of the high S/N commonly obtained with the Reticon.

After this qualitative and visual check, the strength of Hs must be deduced from the observed RZP. But, as stressed above, RZP is seen mainly in faint lines that have to be identified.

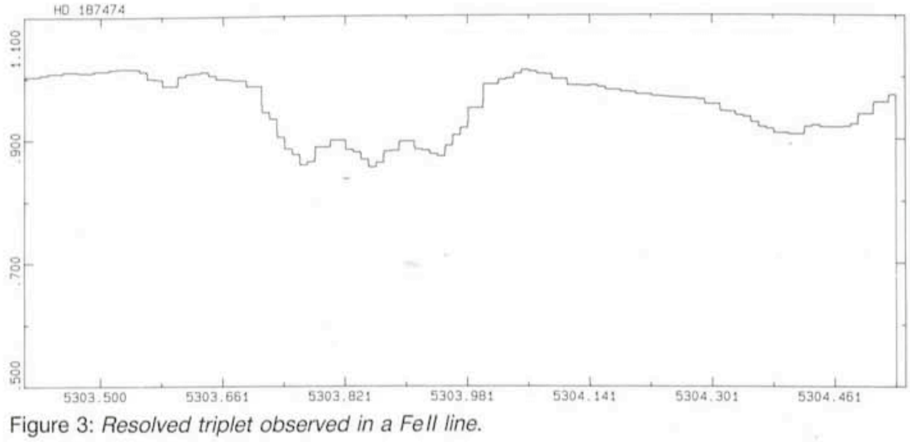

Figure 3: *Resolved triplet observed in a Fe II line.*

TABLE 1: *Resolved Zeeman pattern and Hs measurements*

λ obs.	ion identification		z	Δλ	B
4487.90	CrII	(63)	1.5	.078	5.5
4502.61	MnI	(22)	1.5	.065	4.6
4521.68	GdII	(44)	1.91	.0985	5.4
4522.34	GdII	(135)	1.19	.056	4.9
5011.80	?			.048	
5303.86	FeII	(225)	1.14	.0815	5.5
5306.34	CrII	(24)	1.63	.0845	3.95
6221.56	?			.122	
6227.17	CrII	(a)	0.6	.054	5.0
	(105)	(b)	1.8	.1525	4.7
6232.24	AlII	(10)	1.0	.109	6.0
6238.93	FeII	(74)	1.11	.10	4.97
6241.48	?			.130	
6243.67	AlII	(10)	1.17	.1285	6.05
6249.02	?			.117	
6249.40	FeII	Lund	1.5	.125	4.6
7420.32	?			.0955	

(a): case of the π components
(b): case of the σ components
"Lund" means that the identification comes from Johansson (1978) table.

I tried first to identify all the "strong" lines (residual intensity < 0.7) visible in the spectra. I used for this purpose the Moore table (1945) and the NBS table (Reader and Corliss, 1982). Moreover, for FeII, I used the line list prepared by Johansson (1978). The Moore table gives the configuration and then I can deduce the z value from Beckers table (1969). However, the NBS table does not give the configuration and then the identification is not useful for the study of Hs effects.

Once the identification of the strong line had been done, I selected the most "beautiful" and clear RZP. When the identification was possible I deduced from the observed Δλ a value for Hs. All these data are listed in Table 1. The magnetic field strength is given in kilogauss, and the displacement Δλ in A.

Figure 3 shows a typical triplet observed at λ 5303.8, which is due to a high excitation line of FeII (multiplet No. 225, z = 1.135).

Figure 4 shows an unusual RZP. This quadruplet is due to CrII (105). In this case it is possible to calculate an Hs value from the displacement of the σ components as usually, but also from π components. The two values are close together.

With the doublet pattern shown in Figure 1, the landscape of possible Zeeman pattern is well illustrated.

Now let us see what is the mean of the Hs strength. In Table 1, 16 RZP are listed, 5 have not yet been identified and 12 values of Hs can be calculated. They range from 3.95 to 6.05 kgauss, the mean value is 5.1 and the dispersion 0.6 kgauss.

The distribution of the Hs values are approximately the same for the different elements. So, if there is a patchy distribution of the element overabundances on the stellar surface, it does not greatly affect the Hs measurements. However, almost all the elements listed in Table 1 belong to the group of the iron peak or to the rare earths. They should have the same distribution and no differences are expected. The only different element (AlII) gives a slightly greater field (see below). Its distribution on the surface is perhaps not identical.

I want to point out that on the one hand the smallest value is very different from others, and does not fit the distribution very well. It is certainly due to a wrong measurement of the resolved pattern, which is not well defined, or to a bad z value. On the other hand, the two largest values (6., 6.05) came from the 2 AlII lines. If we eliminate these 3 values the distribution is restricted to the 4.6–5.5 domain. The mean does not change at all and the dispersion is only slightly reduced,

$$Hs = 5.0 \pm 0.4 \text{ kgauss.}$$

This is the first value of the surface field available for HD 187474. It should be compared to the Hs value of 2.3 kgauss deduced from the Geneva photometry. The disagreement is important and questions the validity of the relation established before (Cramer and Maeder, 1980; Didelon, 1984). Though the Hs value is close to the application limit of the relation, a better agreement would have been expected.

The good quality of the data allows not only to measure the displacement of the components, but also their individual intensities. This additional information will put some constraints on the field geometry (orientation). In fact the displacement is related to the field strength, but is not influenced by the geometry. On the contrary the intensities of the components are a function of the angle between the magnetic field orientation and the line of sight, but do not depend on the field strength. The relative intensities of the π and σ components are:

$$I\pi = a/2 \sin^2\theta$$
$$I\sigma = a/4 (1 + \cos^2\theta)$$

Then the ratio of their intensities permits the determination of the mean magnetic field orientation.

Visual inspection of the resolved triplet shows that π and σ components have approximately the same intensities. The measurements of their equivalent widths give the following ratio: $I\pi/I\sigma = 0.98 \pm 0.2$, which corresponds to $\theta = 55° \pm 5°$.

This angle is more or less related to γ, the inclination of the magnetic axis to the line of sight. It depends on the field geometry, but for dipolar field they are closely related.

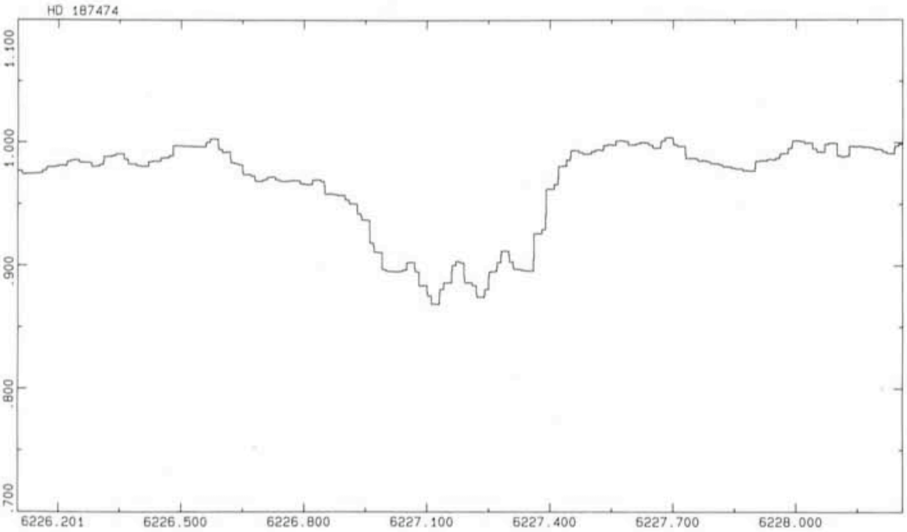

Figure 4: *Resolved quadruplet observed in a CrII line.*

In conclusion, the high quality of the data obtained with the CES and the Reticon allowed to make a fine analysis of the RZP observed in the slow rotation star HD 187474. So, the strength of Hs and its mean orientation were derived. This is one of the rare cases where the orientation of the magnetic field was possible.

I want to point out that it would be of great interest to follow HD 187474 during the whole period. On the one hand it will allow to determine the Hs variation and hence, put some constraints on the field geometry. If the inclination determination is possible at all the phases, it will also contribute to the study of the geometry. On the other hand, if the Hs variation is big enough it would be a good occasion to test the different methods of Hs measurement in slowly rotating stars and eventually determine their limitations towards small fields.

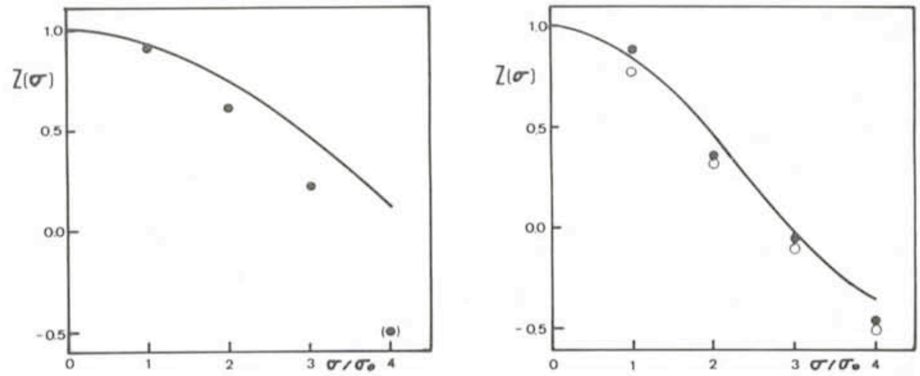

Figure 5: *Zeeman broadening functions associated with different magnetic sensitive Fe II lines and the unsensitive Fe II line (λ 4491, z = 0.4). The full lines give the functions calculated with the parameters deduced from resolved Zeeman pattern (B = 5 kgauss, A = 0.66). (a) The dots represent the observed broadening function associated with the sensitive magnetic line λ 4515 (z = 1.03). (b) Observed broadening functions associated with the magnetic sensitive line λ 4520 (full dots) and λ 4489 (empty dots). The two lines have the same z value (1.5).*

5. Differential Magnetic Broadening and Fourier Deconvolution

The strength of the field and its mean orientation can also be determined from the study of DMB effects. It is interesting to check if the Zeeman signature (also called Zeeman broadening function) can be described with the values determined above from RZP. The Zeeman Broadening Function (ZBF hereafter) is obtained by the division of the FT of two lines with different z values.

It is not obvious whether the Robinson method can be applied to CP stars. In fact, it has been developed to describe and study the magnetic field of late-type stars, which have a quite different field, similar to the solar one. The main problem arises from Doppler shift due to stellar rotation. Its combination with the surface field distribution on the visible hemisphere will distort the line profile. Then the magnetic effects would be more difficult to analyse. However, for slow rotating stars, like HD 187474, this difficulty is removed, and a test can be performed with good confidence.

I studied the DMB effects on Fe II lines present in the first wavelength range. I used the line at λ 4491 Å (z = 0.4) as an unsensitive magnetic line of reference. The three other lines have greater z values and are more sensitive to Zeeman broadening. Their wavelengths and z values are respectively; λ 4491 Å, z = 1.5; λ 4515 Å, z = 1.0; λ 4520 Å, z = 1.5. The division of the FT of one of these three lines by the FT of the "unsensitive" reference line gives the observational ZBF to be compared to the theoretical ones. The equivalent widths of these lines are not equal. The lines with large z are stronger than the line with z = 0.4. To compare "identical" lines by the division of FT, I scaled the reference line to the strongest line. (Marcy, 1984).

The expression (2) is used to calculate the theoretical ZBF for each line pair. As I extracted a region of 0.63 A to perform the FT of each line, the value of the smallest frequency σ_0 is given by 1.587 A^{-1}. The factor A is a function of θ, the mean orientation of the field, and F the filling factor. The θ value determined above is adopted (55°). The magnetic fields of CP stars cover the whole surface, so I assumed that F equals 1. Then the A value is 0.66. Δ is calculated for each line, taking for B the value of the field determined above (5 kgauss).

Figures 5a and 5b show the comparison of the observed and calculated ZBF. The full lines correspond to the calculated ZBF, with A = 0.66, the points give the observed ZBF. The ZBF obtained with the sensitive (z = 1.03) line λ 4515 is plotted in Figure 5a. In Figure 5b I plotted the ZBF obtained with the 2 other sensitive lines, which have the same z values (1.5). The observed ZBF of λ 4520, and λ 4489, are represented by dots and circles, respectively.

The large value of A gives a very sharp function. The ratio of Fourier amplitudes at high frequency is therefore small (see Figs. 1 and 2 in Gray 1984). The noise will be dominant and it will reduce the available points of the observational ZBF. Due to that limitation, only 4 points were useful in the data.

The agreement between the calculated and the observed ZBF of the lines with z = 1.5 is satisfactory (Fig. 5b). Moreover, the two observed ZBF have approximately the same values, which confirms the reliability of the data. The point of highest frequenccy (σ/σ_0 = 4) is a little bit off the curve. This is perhaps due to noise contamination, which appears already at that frequency. However, I try to better reproduce the observations. A best fit would be obtained with a greater A value or with a stronger field. In fact, the determination of A and B is not independent (Gray, 1984; Marcy, 1984). In the present case, I assumed that the magnetic field strength is well known, and to my point of view, the mean inclination determination is less satisfactory. A best fit would require approximately A = 0.7, which corresponds to θ = 51°. This value is still compatible with the adopted θ error.

The calculated ZBF of the line λ 4515 (z = 1.03) did not fit the observed one, which is much steeper. A better agreement would require at least A = 0.9 and so θ = 26°. This value is no more compatible with the inclination deduced from RZP. This effect is due to additional broadening of the line and the most probable explanation is the contamination by a small undetected blend.

I observed another line pair of Fe I at λ 7400 Å, suitable for DMB study. But the lines were too faint and the spectra too noisy for that purpose. So the ZBF of that pair cannot be used.

Finally, for the 2 lines with z = 1.5, a good agreement exists between the observational ZBF and the ZBF calculated with the values determined from RZP analysis. That shows that the Robinson method can certainly be used to determine Hs, at least in slowly rotating CP stars. Because even if they do not show RZP, it is possible to measure Hs. However, careful attention is required to choose suitable line pairs. Moreover, at least several ZBF are necessary to get a field value with a good confidence level and to avoid undetected additional sources of broadening or inaccurate atomic data.

6. Conclusion

A more extensive study, taking into account all the observed resolved Zeeman patterns, will be published later. I also plan to pursue the tests of the "Robinson" method and other methods of Hs measurements.

This preliminary study of Resolved Zeeman Pattern allowed the determination of the surface magnetic field strength of HD 187474, and its mean inclination on the line of sight at the time of observation.

Moreover, the comparison of observed and calculated Zeeman broadening functions shows that the "Robinson" method will be suitable to measure the surface magnetic field, at least in slowly rotating CP stars.

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The Clouds which Form the Extended Emission Line Region of NGC 4388

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Introduction

Since the discovery of Seyfert galaxies (Seyfert, 1943) and Quasars (Schmidt, 1963) most of the attention to these active galaxies has been directed towards understanding the physics of the nuclear non-thermal source, the structure of the inner emission line regions, (the so-called *Broad Line Region),* where the observed broad and variable emission lines are produced, and the coupling between both phenomena.

Further out, there exist extended emission-line regions with sizes up to a few kpc and where the observed strong optical, narrow forbidden lines are formed. These regions, usually called *Narrow Line Regions,* are considered as the link between the nuclear regions and the outer interstellar medium.

Work by Heckman and collaborators (Heckman et al., 1981) and subsequently by Whittle (Whittle, 1985a, b) showed the presence of a blue asymmetry as a general feature of the spatially unresolved [O III] λ 5007 Å line profile in Seyfert galaxies. This characteristic, not observed in the H II and starbust galaxies, was interpreted as a consequence of peculiar motions in the central regions of these active galaxies. Models considering outflowing emission clouds embedded in a dusty medium, i.e. the receding clouds being preferentially obscured, or infalling dusty clouds, producing the opposite effect, most likely explain these observations.

Direct correlations between the line width of the spatially unresolved narrow emission lines and the ionization potential or the critical density have been observed in Seyfert galaxies (De Robertis and Osterbrock, 1984, 1986). This indicates some kind of stratification in the physical conditions present in these regions, and covering a range which extends continuously from the Broad Line Region, $N_e \approx 10^9\ cm^{-3}$, through the Narrow Line Region, $N_e \geq 10^3\ cm^{-3}$.

Spatially resolved spectroscopic observations of the extended emission line regions in nearby Seyfert galaxies are crucial to understand how the physical, kinematical and ionizing structure of these regions evolve as a function of distance from the nucleus and position within the galaxy, how their structure is affected by the presence of the nonthermal nuclear source and which is the role of the interstellar medium.

Observations

Observations of NGC 4388 have been done at the Cassegrain focus of the La Silla 2.2-m telescope using the ESA Photon Counting System, the scientific model of the Faint Object Camera (see di Serego et al., 1985 for a detailed description). In the spectroscopic mode, the ESA PCD uses an array of 1,024 × 256 pixels (spectral x spatial direction) with a pixel size of 25 μm. The slit width was 1.5 arcsec and the scale along the slit was 1 $arcsec \cdot pixel^{-1}$ giving a total length of the slit of 256 arcsec on the sky.

Long-slit spectroscopy covered the spectral range [O III] λλ 4959, 5007 Å + H β at 21 Å/mm giving an effective resolution of 56 km · s^{-1} (FWHM at λ 5000 Å). Typical exposure times were 40 minutes divided into two periods of 20 minutes each. To monitor the geometrical distortion and to make the final wavelength calibration, HeAr comparison spectra were obtained after each single exposure. The observations in the various slit positions were optimized with respect to the position of the object on the sky in order to minimize the differential refraction effects. Finally, in each two dimensional spectrum, the signals of three adjacent spatial pixels were combined to increase the S/N ratio and to take into account the seeing effects.

Discussion

NGC 4388 is a highly inclined spiral galaxy located at the core of the Virgo cluster and classified as Seyfert 2 galaxy. Long-slit spectroscopy was obtained at position angles 23° and 152°. The slit at 23° was positioned to cover the direction at which a radio emission region extending over 40 arcsec was previously reported (Hummel et al., 1983). Emission on the [O III] lines was observed over a total extension of 24 arcsec symmetric to the nucleus.

Contrary to the general behaviour observed in the [O III] line profile of Seyfert galaxies, NGC 4388 shows a peculiar red-asymmetry (Fig. 1). The overall [O III] λ 5007 Å line profile is composed, both at *P.A.* 23° and *P.A.* 152°, of five clearly distinguishable components, separated by up to 600 km · s^{-1} (see Table 1). The main component, C_2, extends over the central region from 3 arcsec NE to 6 arcsec SE. The other two major components, C_3 and C_4, appear to extend over a region of ± 6 arcsec symmetrically with respect to the nucleus. Finally, the smaller components, C_1 and C_5, are concentrated at the centre. These components could be

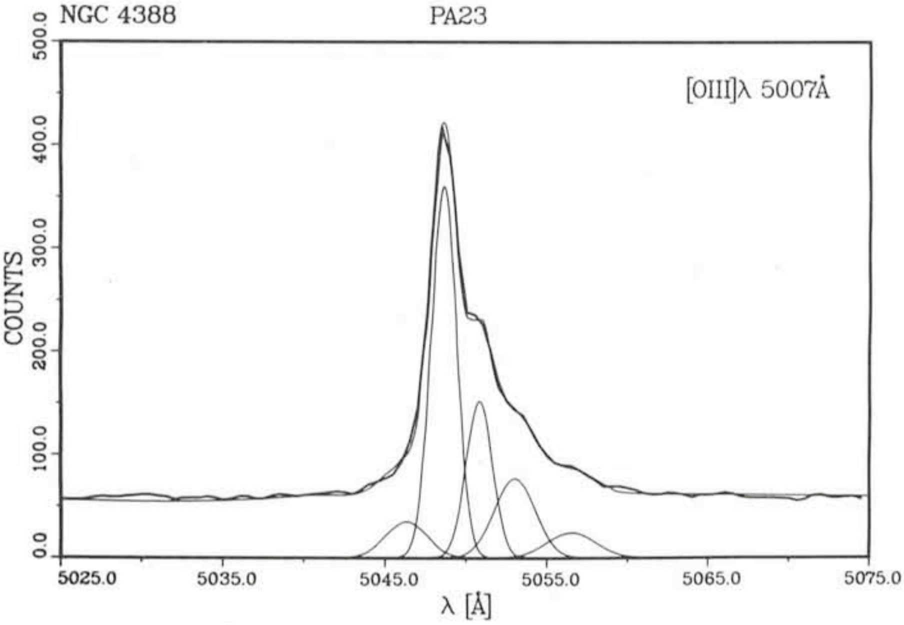

Figure 1: *[O III] λ 5007 Å integrated profile along the slit at P.A. 23°. The prominent individual components producing the observed red asymmetry are indicated as well as the obtained fit for the overall profile.*

associated with a system of giant clouds confined to the inner six arcsec from the nucleus. Considering the [O III] luminosity, L ([O III]) = $1.6 \cdot 10^{40}$ erg $\cdot$ s^{-1}, this gives a total mass M_T = 5,000 $M_\odot$ and energy $E_T = E_k$ *(kinetic)* + E_t *(turbulent)* = $3 \cdot 10^{51}$ erg for the system of clouds. This situation is similar to those observed in NGC 1068 (M_T = 186 $M_\odot$, E_T = $3.7 \cdot 10^{50}$ erg; Pelat and Alloin, 1980) and in NGC 4151 ($M_T = 1{,}100_\odot$, E_T = $4.7 \cdot 10^{50}$ erg; Pelat and Alloin, 1982) where a direct association between the nuclear radio emission and the clouds has been suggested (Wilson, 1983).

TABLE 1: *Emission line components in P.A. 23°. Derived parameters.*

Component	V ([O III]) $Km \cdot s^{-1}$	FWHM $Km \cdot s^{-1}$	I/I (tot.)
C_1	2352	140	0.06
C_2	2468	109	0.55
C_3	2604	110	0.23
C_4	2734	175	0.12
C_5	2942	175	0.04

The [O III] emission towards the NE of the nucleus at P.A. 23° is intriguing. In this region, Hummel et al., (1983) noted the presence of a radio elongation. A broader [O III] λ 5007 Å line, FWHM ≈ 300 $km \cdot s^{-1}$ and FWQM (full width at quarter maximum) ≈ 500 $km \cdot s^{-1}$, is observed. This line is broader at FWHM than the same line in the SW region by a factor two to three (see Fig. 2). The existence of such a relation between the radio emission and the emission line for large samples of Seyfert galaxies has been pointed out by different authors (Wilson and Heckman, 1985 and references therein) in terms of a [O III] luminosity and FWHM ([O III]) vs. 21 cm radio luminosity correlations. Also in 3 C 305 (Heckman et al., 1982), the same phenomena have been reported in the sense that the [O III] lines appear to be broader in the regions coincident with radio emission. This suggests a direct connection between the presence of anomalous motions, radial motions, turbulence, and the existence of radio synchrotron radiation, which needs further detailed studies.

A detailed study of the extended emission line region in NGC 4388 is contained in a forthcoming paper (Colina, L., Fricke, K.J., Kollatschny, W., Perryman, M.A.C., 1987, *Astron. Astrophys.* in press). A similar study, by the same authors, of NGC 2992 was published in *Astron. Astrophys.,* **178,** 51 (May (II), 1987).

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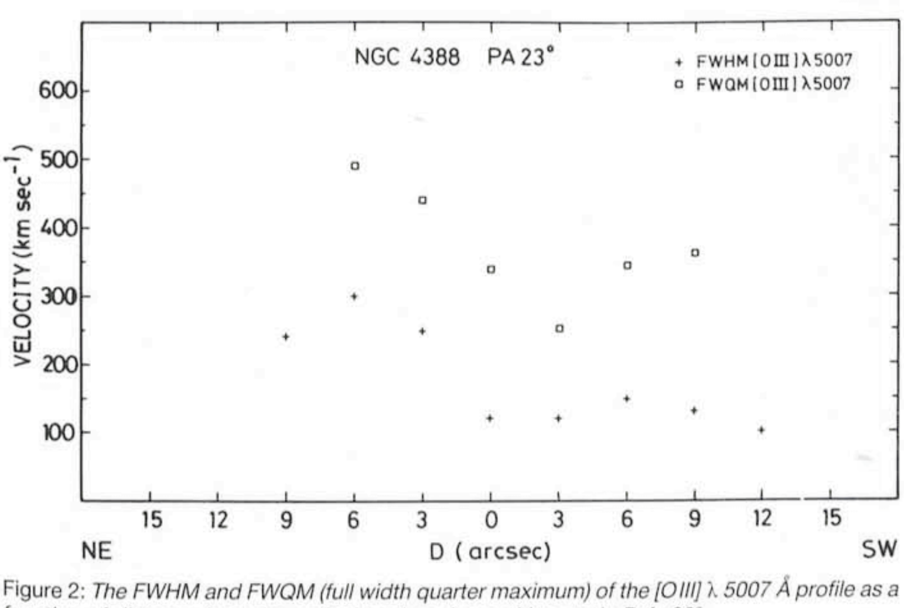

Figure 2: *The FWHM and FWQM (full width quarter maximum) of the [O III] λ 5007 Å profile as a function of distance from the optical nucleus for position angle P.A. 23°.*

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ESO Slide Sets

In the last issue of the *Messenger* ESO announced the publication of two slide sets: "Objects in the Southern Sky" and "Supernova 1987 A in the Large Magellanic Cloud".

Unfortunately, the price was not clearly indicated. It is DM 35.– for **each of the sets.**

Observations of the Shell Galaxy NGC 3923 with EFOSC

J.-L. PRIEUR, Observatoire du Pic-du-Midi et de Toulouse, France

NGC 3923 was observed at the 3.6-m ESO telescope in March 1985 with EFOSC, the ESO Faint Object Spectrograph and Camera (Dekker and D'Odorico, 1985). The results of these observations and other observations made at CFHT and AAT are described in more detail in Prieur (1987). NGC 3923 is an elliptical galaxy which exhibits peculiar arc-like structures or "shells" aligned with the major axis. They were first discovered by Malin (1977). Malin developed new techniques of photographic processing which are very efficient for detecting faint outer extensions around galaxies ("contrast enhancement") or inner structures superimposed over a bright background ("unsharp masking"). At present such shells have been seen around more than 140 elliptical galaxies. NGC 3923 appears as the richest system among the shell galaxy catalogue of Malin and Carter (1983). As an aligned system, it could be representative of the class of "aligned" systems which represent about 35 % of shell galaxies (Wilkinson et al., 1988). As it seems that at least 17 % of isolated elliptical galaxies are shell galaxies (Malin and Carter, 1983), the understanding of the origin of these structures is important for our knowledge of ellipticals and galaxies in general.

Quinn (1984) proposed a model to account for the properties of the shells. In his model, shells are the remnant of the merging of a small galaxy within a large elliptical. In phase space the location of the infalling stars wraps around the origin with time. Shells are density waves formed by stars near the apocentre. Another model was proposed by Williams and Christiansen (1985). The origin of the shells is internal to the elliptical galaxy. Stars form within an expanding blast wave of matter ejected from an active nucleus in an early phase of the history of the galaxy. But according to the authors themselves such a model cannot account for the large number of shells observed around NGC 3923.

Sandro D'Odorico included the observations of NGC 3923 in a technical run of EFOSC in March 1985 as a way to test the photometric accuracy and the speed of the instrument. EFOSC was used in direct imaging mode as an F/2.5 focal reducer with a B filter. The detector was a thinned, back-illuminated RCA CCD with 320 × 512, 30μm pixels. The resulting field was 3'.6 × 5'.7 with a scale of 0".67/pixel (seeing ≈ 1".9).

A series of 5 pictures were taken with the same orientation, moving the telescope slightly between each exposure. Each image was corrected following the usual procedure by subtracting a bias model and dividing by a mean flat field. The cosmetic defects of the chip (mainly a bad column and some "hot spots") were removed by interpolation on the surrounding pixels. We noted a slight light concentration in the centre of the frames (Cf. Fig. 1). We used these pictures for determining shell profiles and worked on thin slices. Since shells are thin we could interpolate the value of this light gradient in the profiles (in the same way that we computed the residuals of the background of the galaxy). Comparing the results from ESO frames with AAT images we could verify that there was a good agreement. Therefore for our purpose, this light gradient did not affect our measurements. The actual shift of each image was determined by measuring the centres of unsaturated stars. Then the images were shifted back and added. The result was checked by comparing the F.W.H.M. of some stars before and after the operation. One of the major advantages of this

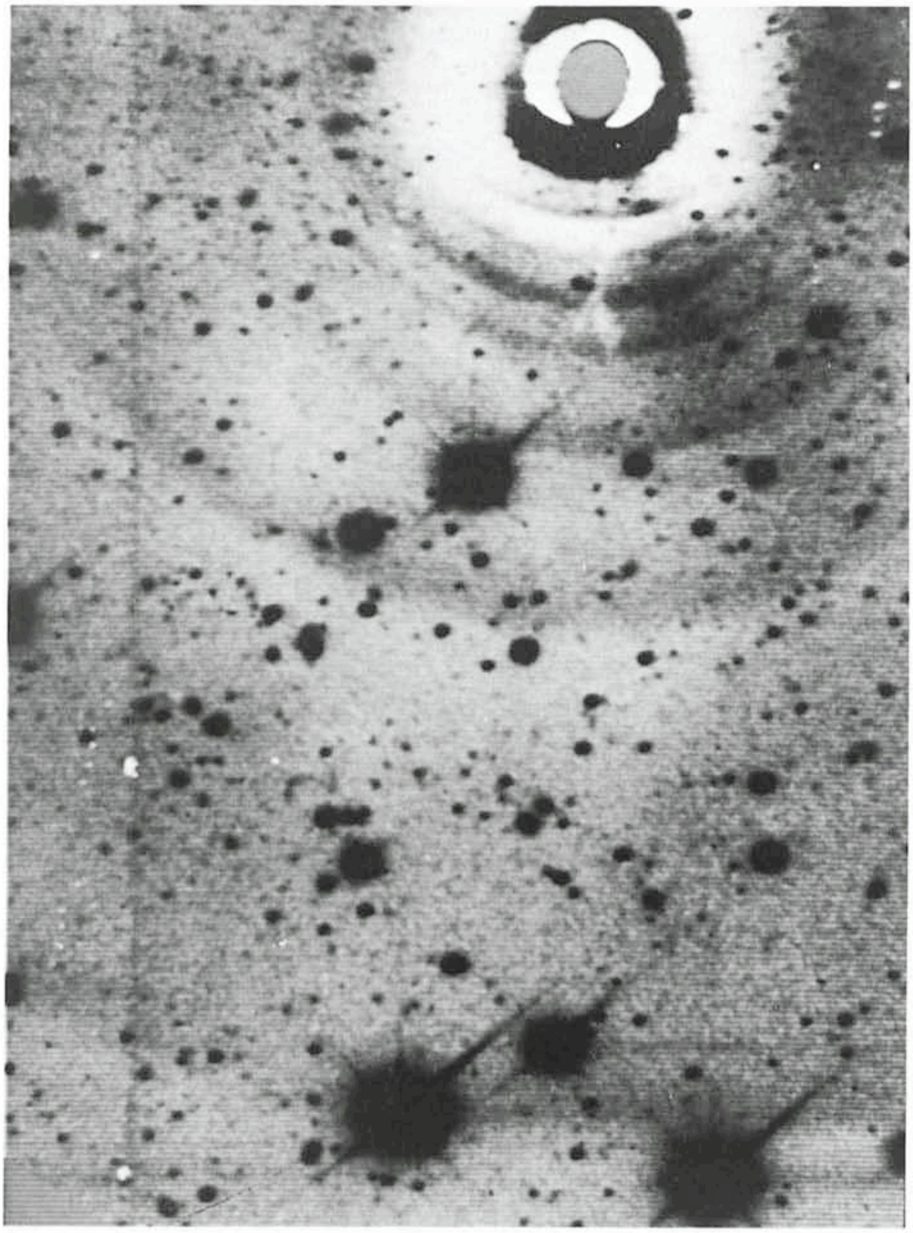

Figure 1: *South-Western part of NGC 3923. This picture was obtained by adding up five 7-min EFOSC CCD exposures and subtracting the background of the galaxy as described in the text. Seven shells and a faint dust lane are visible here. As the centre of the galaxy was saturated, our procedure for removing the galaxy was perturbed in the very centre.*

technique is to increase the intensity range of the images avoiding the problem of electronic saturation of long exposures.

Shells around NGC 3923 are faint and it is difficult to distinguish them from the bright background of the galaxy. Except for the outer shells the galaxy background had to be removed for our study, as we did to compute the shell colours in a previous paper (Fort et al. 1986). A luminosity profile of NGC 3923 was computed and used to construct a model for the galaxy, assuming a simple geometry of concentric ellipses. This background was subtracted and shells appeared clearly as shown in Figure 1. Following Malin (1977) we also used unsharp masking filtering which was effective for the inner shells.

The Shells Around NGC 3923

NGC 3923 seems a normal elliptical with no unusual features apart from the shells. Our estimate of the central M/L ratio, $M/L = 13. \pm 2.$ ($h = 0.75$), is compatible with most elliptical galaxies.

The galaxy is surrounded by about 22 shells aligned with the major axis. The dynamical range in radius is very large with a distance of about 100 kpc for the outermost shell and about 1.7 kpc for the innermost shell ($h = 0.75$). They are regularly spaced in the outer parts, but not in the inner parts where some can be associated in pairs of the same distance. The interleaving of the outer shells gives strong support to Quinn's model with wrapping in phase space. In the centre the system is as regular. This needs to be investigated with numerical simulations.

The shells have a roughly constant ellipticity, $E = 1. \pm 0.4$, and a roughly constant angular extent of about 60°. Dupraz and Combes (1986) suggested that the shape of the shells could be related to the equipotentials of the main galaxy. A brief study of the shape of current models of ellipticals shows that the shells have ellipticities of the same magnitude as the expected ellipticities for the equipotentials. But the uncertainties are rather large and the graphs do not show any obvious relationship. The shape of shells has still to be studied in theory.

New shells were found in the outer parts and very close to the centre of the galaxy (less than 2 kpc). To account for the presence of shells very close to the centre a dissipative process has to be invoked. This argument gives support to current models with a progressive launching of stars from an infalling galaxy which is slowed by dynamical friction.

Profiles were computed for 19 shells. Shells do not appear as "plateaus" as predicted by Hernquist and Quinn (1987 c). But we think this is linked to the fact that these authors did not use an angularly limited shell for the projection onto the line of sight. We used a simple 3-dimensional model with a gaussian radial distribution and limited angular extent, and obtained good agreement with the observed profiles. The shell thickness parameter appears to be roughly constant for the inner shells $r_g = 0.17\ kpc \pm 0.11$.

The total luminosity of the shells is about 5 % of the luminosity of NGC 3923. In the merging scenario the number of stars actually in the shells is only a fraction of the total number of orbiting stars. Therefore the luminosity of the infalling companion is expected to represent more than 5 % of the total luminosity of NGC 3923.

The outermost shells are much brighter than the inner ones and contribute a large part of the total luminosity. Shell 1-N is three times as bright as the sum of the 17 inner shells. Therefore it seems that the infalling galaxy lost most of its stars in the first few oscillations. The remaining core was slowed down by dynamical friction and progressively disrupted but at a slower rate. Because of this loss of energy caused by dynamical friction, it sank deeper and deeper into the potential well, eventually forming shells at less than 2 kpc from the centre. From the total luminosity of the shells and the study of Dupraz et al. (1987) it seems that in such a scenario dynamical friction alone cannot account for the observed distribution of the shell distances and luminosities. But it is likely to reduce significantly the previous estimates of the mass of dark matter needed to account for the shell radial distribution.

The Discovery of a Dust Lane Aligned with the Major Axis of the Galaxy

On the ESO CCD images a dust lane aligned with the major axis is visible in the South Western part of the galaxy, from about 30 arcseconds from the centre to about 80 arcseconds. The inner limit is probably underestimated since the galaxy background is very bright in the inner regions. This dust lane is rather faint and is best visible on processed images (Fig. 1). It is likely to go through the centre and also be present on the North Eastern side but unfortunately we do not have very deep exposures for the North Eastern side.

Preferred planes in different models of ellipticals have been studied in detail by many authors (see for example Habe and Ikeuchi [1985]) who have shown that only the equatorial plane of the potential is stable in a prolate potential or in an oblate potential. Dust lanes aligned with the major axis of bi-axial galaxies are stable only in oblate galaxies. Thus if this dust lane is in a stable configuration, NGC 3923 is not prolate. Such an observation seems to disagree with the conclusions of Dupraz and Combes that NGC 3923 was the archetype of prolate systems (Dupraz and Combes 1985, 1986). Of course, we must be careful in our interpretation of these observations since the possibility of an unstable configuration of the dust lane cannot be excluded.

In triaxial systems dust lanes in stable configuration can be observed aligned with either the longest or the shortest axis. Therefore NGC 3923 could also be a triaxial system.

Tumbling prolate systems could also have a dust lane aligned with the major axis but only at large distances from the centre where the orbital time is large compared to the tumbling period (Tohline and Durisen 1982). In that case the dust lane would only "feel" a smoothed potential which is oblate for a prolate galaxy tumbling around its minor axis. There are two objections to this hypothesis. First the outer shells would also feel an oblate potential and their geometry would be affected. It is shown by Dupraz et al. (1986) that outer shells

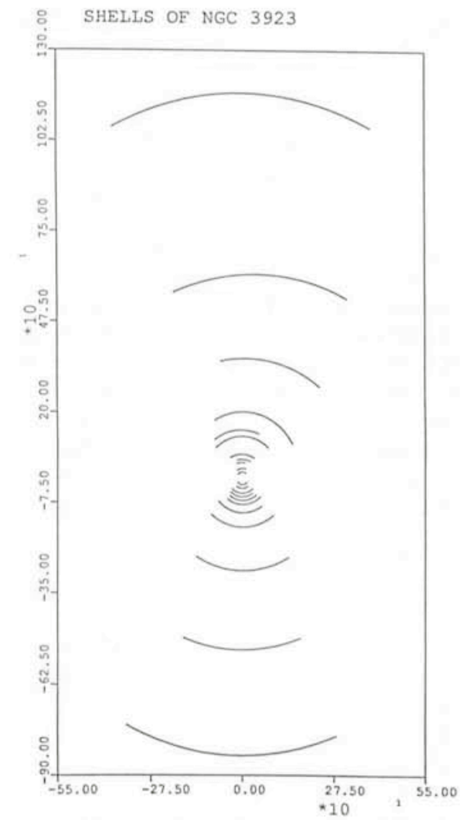

Figure 2: *Schematic diagram of the shells around NGC 3923. This diagram was obtained with observations from CFHT, AAT, and ESO.*

are randomly distributed in angle in a tumbling bar with aligned inner shells since in the inner parts the orbital time is smaller than the tumbling period, and the inner shells can feel a prolate potential. Secondly the dust lane is too close to the centre of the galaxy to feel a "smoothed" potential when all the shells feel a prolate potential.

Conclusions

The complementary observations made at ESO brought a decisive contribution to the comprehensive study of NGC 3923 which is about to be published (Prieur 1987). With other observations from AAT and CFHT they allowed us to obtain accurate positions of faint shells around the galaxy, and measure physical parameters which can be directly compared to theoretical models and numerical simulations. It was found that models published until now do not fully account for the properties that we have observed. Among the current models the merging model seems to be the more likely to be able to solve the problem. The main theoretical problem is the modelling of dynamical friction in the centre of the galaxy (which is far from being negligible as some authors thought). This study provides new parameters which had never been measured and which go further than what numerical simulations or theoretical studies have been able to predict until now. We hope that this work will stimulate new theoretical developments on this field.

These observations with EFOSC as a focal reducer demonstrate that this instrument can also be a very efficient and powerful tool for photometry of extended objects. The decisive data used in this paper came from only a few 7-minute exposures!

Acknowledgements

I am very grateful to Sandro D'Odorico for obtaining the CCD pictures of NGC 3923.

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Visiting Astronomers

(October 1, 1987–April 1, 1988)

Observing time has now been allocated for Period 40 (October 1, 1987–April 1, 1988). As usual, the demand for telescope time was much greater than the time actually available.

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

3.6-m Telescope

October 1987: Moorwood/Oliva, Danziger/Moorwood/Oliva, Bergvall/Johansson, Moeller/Kjaergaard Rasmussen, Pickles/van der Kruit, Soucail/Fort/Mathez/Mellier/D'Odorico, Mellier/Soucail/Fort/Mathez, Bergeron/Boissé, Maccagni/Vettolani, Danziger/Gilmozzi, Benvenuti/Porceddu.

November 1987: Benvenuti/Porceddu, Kudritzki/Humphreys/Groth/Butler/Steenbock/Gehren/Fitzpatrick, Wolf/Stahl/Davidson/Humphreys, Reitermann/Bascheck/Scholz/Krautter/Wolf, Richtler, Surdej/Courvoisier/Magain/Swings, Butcher/Mighell/Buonanno, Ellis/Couch/D'Odorico, Schwarz/Larsson, Chincarini/Manoussoyanaki, Breysacher/Azzopardi/Lequeux/Meysonnier/Rebeirot/Westerlund, di Serego Alighieri.

December 1987: Westerlund/Azzopardi/Rebeirot/Breysacher, Azzopardi/Lequeux/Westerlund, Pottasch/Pecker/Karoji/Sahu, Zadrozny/Leggett/Perrier, Kern/Merkle/Lacombe/Léna, Nesci/Perola, Westerlund/Lundgren/Edvardsson, Kunth/Schild/Arnault, Melnick, Cristiani/Barbieri/Clowes/Iovino/Nota, Melnick, Wampler, Reimers/Schröder/Toussaint.

January 1988: Reimers/Schröder/Toussaint, Becker/Appenzeller/Wilson/Schulte-Ladbeck, Koornneef/Israel, Bouvier/Bertout, Giraud, Bignami/Caraveo/Vigroux, Renzini/D'Odorico/Greggio/Bragaglia/Federici, Östreicher/Ruder/Seifert/Wunner, Mathys/Maeder, de Loore/David/Hensberge/Verschueren/Blaauw.

February 1988: de Loore/David/Hensberge/Verschueren/Blaauw, Rosa, Danziger/Cristiani/Guzzo, Meylan/Djorgovski, Röser/Meisenheimer/Perley, Trinchieri/di Serego Alighieri, Bianchi/Grewing/Bässgen M., François/Matteucci.

March 1988: François/Matteucci, Kudritzki/Méndez/Husfeld, Ruiz/Maza/Méndez, Jakobsen/Perryman, Pottasch/Manchado/Mampaso, Jarvis/Martinet, Le Bertre/Epchtein, Dennefeld/Bottinelli/Gouguenheim/Martin, Krautter/Mundt/Hessman/Ray, Israel/van Dishoeck.

2.2-m Telescope

October 1987: MPI time, Schwarz.

November 1987: Schwarz, Landi Degl'Innocenti/Landolfi/Pasquini, Bues/Pragal, Gouiffes/Cristiani, Surdej/Courvoisier/Kellermann/Kühr/Magain/Swings/Refsdal, Cayrel/Tarrab, Butcher/Mighell/Buonanno, Christensen/Sommer-Larsen/Hawkins, Westerlund/Azzopardi/Rebeirot/Breysacher.

December 1987: Gouiffes/Cristiani, Fusi Pecci/Buonanno/Corsi/Greggio/Renzini/Sweigart, Fusi Pecci/Buonanno/Corsi/Ferraro/Bragaglia, Meylan/Djorgovski, Paresce/Burrows/Viotti/Lamers, Weigelt/Baier/Fleischmann.

January 1988: Lyngå/Johansson, Le Bertre/Epchtein, Courvoisier/Bouchet/Robson, Tanzi/Bouchet/Falomo/Maraschi/Treves, Pakull/Stasinska/Testor/Motch/Heydari-Malayeri, Wouterloot/Brand/Stirpe, Reipurth/Zinnecker, Rodríguez Espinosa/Stanga, MPI time.

February 1988: MPI time, Schwarz/Larsson.

March 1988: Schwarz/Larsson, Schwarz/Aspin/Magalhaes/Schulte-Ladbeck, Durret/Boisson/Bergeron, Krautter, Galletta/Bettoni, Ulrich/Pierre, Tosi/Focardi/Gregio, Piotto/Capaccioli, Capaccioli/Held/Nieto, Aurière/Koch-Miramond/Cordoni, Ögelman/Aurière/Alpar, Gouiffes/Cristiani.

1.5-m Spectrographic Telescope

October 1987: Lortet/Testor, Danziger/Fosbury/Lucy/Wampler, Schwarz, Johansson/Bergvall, Dettmar/Barteldrees, Maccagni/Vettolani, Herczeg/Drechsel.

November 1987: Herczeg/Drechsel, Pasquini/Schmitt, Bues/Müller/Rupprecht, Bertola/Buson, Sauvageot/Dennefeld, Balkowski/Maurogordato/Proust/Talavera, Danziger/Fosbury/Lucy/Wampler.

December 1987: Danziger/Fosbury/Lucy/Wampler, Courvoisier/Bouchet, Pottasch/Pecker/Karoji/Sahu, Mantegazza, Lundgren, Rafanelli/Marziani, Divan/Prévot-Burnichon, Danziger/Fosbury/Lucy/Wampler.

January 1988: Danziger/Fosbury/Lucy/Wampler, Tanzi/Bouchet/Falomo/Maraschi/Treves, Bica/Alloin, de Ruiter/Lub, Alloin/Baribaud/Pelat/Phillips, Tarrab, Thé/Westerlund/Vardya, Danziger/Fosbury/Lucy/Wampler.

February 1988: Möllenhoff/Bender/Madejsky, Arsenault/Durand, Duerbeck, Danziger/Fosbury/Lucy/Wampler, Gerbaldi/Faraggiana/Castelli.

March 1988: Gerbaldi/Faraggiana/Castelli, Friedjung/Bianchini/Sabbadin, Alloin/

Baribaud/Pelat/Phillips, Acker/Stenholm/Lundström, Alloin/Baribaud/Pelat/Phillips, Bertola/Buson/Vietri, Vettolani/Fairall/Da Costa/Chincarini, Drechsel/Andreae, Danziger/Fosbury/Lucy/Wampler, Courvoisier/Bouchet.

1.4-m CAT

October 1987: Solanki/Mathys, Holweger/Gigas/Lemke, Gratton, Spite F./Spite M.

November 1987: Spite F./Spite M., Benvenuti/Porceddu, Waelkens, Lagrange/Ferlet/Vidal-Madjar, Ferlet/Andreani/Dennefeld/Vidal-Madjar, Andreani/Ferlet/Vidal-Madjar/Grenier, Ferlet/Vidal-Madjar/Gry/Lallement, Lagrange/Ferlet/Vidal-Madjar, Barbuy/Arnould/Jorissen.

December 1987: Barbuy/Arnould/Jorissen, Grenon/Barbuy, Pottasch/Sahu, Barbuy, Pallavicini/Giampapa, Stahl/Schwarz/Wolf/Zickgraf, de Vries/van Dishoeck/Habing, Stahl/Schwarz/Wolf/Zickgraf.

January 1988: Reimers/Toussaint/Schröder, Stahl/Schwarz/Wolf/Zickgraf, Gustafsson/Edvardsson/Magain/Nissen, Gustafsson/Saar/Vilhu, Cayrel de Strobel.

February 1988: Cayrel de Strobel, Vladilo/Beckman/Crivellari/Molaro, Gillet/Pelat, Lundgren, Lenhart/Grewing/Neri.

March 1988: Lenhart/Grewing/Neri, Vreux/Magain.

1-m Photometric Telescope

October 1987: Hesselbjerg Christensen, Johansson/Bergvall, Böhnhardt/Vanysek/Beißer, Di Martino/Zappala/Cellino/Farinella, Wolf/Stahl/Davidson/Humphreys.

November 1987: Wolf/Stahl/Davidson/Humphreys, Catalano F.A./Kroll, Liller/Alcaíno, Bues/Pragal, Bues/Müller/Rupprecht, Chini/Krügel.

December 1987: Chini/Krügel, Heske/Wendker, Courvoisier/Bouchet, Busso/Silvestro/Scaltriti/Persi/Robberto, Mattila/Schnur, Barucci/Fulchignoni/Harris/Zappala/Binzel/Di Martino/Lagerkvist/Burchi/Dipaoloantonio, Lyngå/Johansson.

January 1988: Lyngå/Johansson, Courvoisier/Bouchet, Kaelble/Kappelmann/Grewing, Le Bertre/Epchtein, Reipurth/Zinnecker, Spinoglio/Persi/Coe/Ferrari-Toniolo, Westerlund/Pettersson, Balkowski/Arimoto/Boisson/Durret.

February 1988: Balkowski/Arimoto/Boisson/Durret, Thé/Westerlund/Vardya, Greenberg/Thé/Chlewicki, Courvoisier/Bouchet, Le Bertre/Epchtein, Schoembs/Barwig/Mantel, Poulain/Davoust/Nieto, Kohoutek/Martin.

March 1988: Kohoutek/Martin, Le Bertre/Epchtein, Courvoisier/Bouchet, Mermilliod/Claria, Antonello/Conconi/Mantegazza/Poretti, Moneti/Stanga.

50-cm ESO Photometric Telescope

October 1987: Group for Long Term Photometry of Variables.

November 1987: Wolf/Stahl/Davidson/Humphreys, Poretti/Antonello, Pospieszalska-Surdej/Surdej/Taylor, Cutispoto/Rodono/Ventura/Catalano F./Butler.

December 1987: Cutispoto/Rodono/Ventura/Catalano F./Butler, Mattila/Schnur.

January 1988: Debehogne/Di Martino/Zappala/De Sanctis/Lagerkvist/Magnusson, Waelkens/Cuypers.

February 1988: Waelkens/Cuypers, Thé/Westerlund/Vardya, Greenberg/Thé/Chlewicki, Kohoutek, Barrera/Mennickent/Vogt.

March 1988: Barrera/Mennickent/Vogt, Group for Long Term Photometry of Variables.

GPO 40-cm Astrograph

October 1987: Böhnhardt/Vanysek/Beißer.

November 1987: Scardia.

January 1988: Debehogne/Machado/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Mourao/Protitch-Benishek/Javanshir.

February 1988: Elst/Ivanova/Shkodrov/Geffert, Mermilliod/Heudier.

March 1988: Ferreri/Zappala/Di Martino/De Sanctis/Debehogne.

1.5-m Danish Telescope

October 1987: Gammelgård, Jørgensen et al., Hansen et al., Helmer et al., Lindgren/Ardeberg.

November 1987: Lindgren/Ardeberg, Griffin R.F./Griffin R.E.M./Mayor/Clube, Imbert, Imbert/Maurice/Prévot/Andersen/Nordström/Ardeberg/Lindgren/Mayor, Richtler, Leibundgut/Tammann, Noergaard-Nielsen/Hansen/Joergensen, Sauvageot/Dennefeld, Alcaíno/Liller, Jönch-Sørensen/J. Knude.

December 1987: Jönch-Sørensen/Knude, Reipurth, Jönch-Sørensen/Knude, Becker/Appenzeller/Wilson/Schulte-Ladbeck.

January 1988: Becker/Appenzeller/Wilson/Schulte-Ladbeck, Gouiffes/Cristiani, Giraud, Melnick, Della Valle/Rosino/Ortolani/Cappellaro/Turatto, Westerlund/Pettersson, v. Paradijs/v. d. Klis/Charles, Andersen/Nordström.

February 1988: Anderson/Nordström, Møller/Rasmussen, Hansen et al., Reiz et al., Andersen/Nordström/Mayor/Olsen.

March 1988: Andersen/Nordström/Mayor/Olsen, Lindgren/Ardeberg, Mayor/Duquennoy/Andersen/Nordström, Galletta/Bettoni, Ortolani/Piotto, Ortolani/Gratton.

50-cm Danish Telescope

October 1987: Olsen, Grenon/Lub.

November 1987: Grenon/Lub, Lindgren/Ardeberg.

December 1987: Lindgren/Ardeberg, Group for Long Term Photometry of Variables.

January 1988: Group for Long Term Photometry of Variables, Olsen/Gray.

February 1988: Olsen/Gray, Pellegatti Franco, Lindgren/Ardeberg, Clausen et al.

March 1988: Clausen et al., Helt/Clausen/Giménez/Vaz.

90-cm Dutch Telescope

November 1987: Grenon/Lub, v. Amerongen/v. Paradijs.

December 1987: v. Amerongen/v. Paradijs.

January 1988: de Geus/Lub/Blaauw/de Zeeuw, de Ruiter/Lub, de Loore/David/Blaauw/Hensberge/Verschueren, de Ruiter/Lub, Thé/Westerlund/Vardya.

February 1988: Thé/Westerlund/Vardya.

March 1988: Heynderickx, Caspers, Brand/Wouterloot.

IC 3370: a Box-Shaped Elliptical or S0 Galaxy?

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I. Introduction

It has now been established that a significant portion (≥ 1 per cent, Jarvis 1986) of disk galaxies have box- or peanut-shaped bulges. However, until fairly recently, it was generally believed that no elliptical galaxies existed which possessed these same box- or peanut-shaped characteristics. If such ellipticals do exist, then they would be interesting for several reasons. The May et al. (1985) models for box- and peanut-shaped bulges required a large amount of rotation in order to support these shapes. However, we know that most bright elliptical galaxies ($M_B \leq -21.0$) rotate slowly. Hence, a possible dichotomy may exist if bright box- or peanut-shaped "elliptical"-like (i.e. no disk) galaxies could be found which rotate as rapidly as the current models require. Such galaxies may also provide important formation, evolutionary and dynamical links between classical elliptical and disk galaxies. Fairly recently, several galaxies classified in the literature as ellipticals have indeed been found which do show strong box-like features. We report here some of the most interesting results of one of these galaxies, IC 3370.

The southern galaxy IC 3370 is classified as an E2pec in the Revised Shapley Ames Catalogue of Bright Galaxies and an E2 in the Second Reference Catalogue of Bright Galaxies.

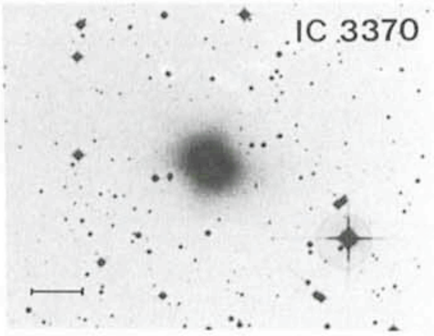

Figure 1.

The ESO/SERC J Survey (see Fig. 1) shows IC 3370 as a moderately bright elliptical galaxy with a "bow-tie" or "crossed-streamers" appearance not unlike the peanut-shaped bulge of NGC 128. On the shallower ESO B survey, IC 3370 resembles a normal elliptical galaxy.

II. Photometric Observations

The Johnson B, V and R surface photometry of IC 3370 was obtained with an RCA CCD (512 × 320 pixels) aligned E-W at the f/13 Cassegrain focus of the 0.9-m telescope at C.T.I.O. with an image scale of 0.495 arcsec pixel^{-1}. The raw data frames were reduced in the standard manner for CCD observations using the ESO MIDAS system. Figure 2 shows the isophotal contour map of IC 3370 on the Johnson B magnitude system. The V and R isophotal maps are very similar. The most important feature to note is the strong box shape of the isophotes. This shape extends over more than 3.5 magnitudes of surface brightness to the faint limit of the photometry ($\mu_B \simeq 25.0$ mag arcsec^{-2}). Moreover, Figure 2 strongly suggests that the trend of extreme "boxiness" extends to much greater distances and hence lower luminosities than can be seen within the CCD field.

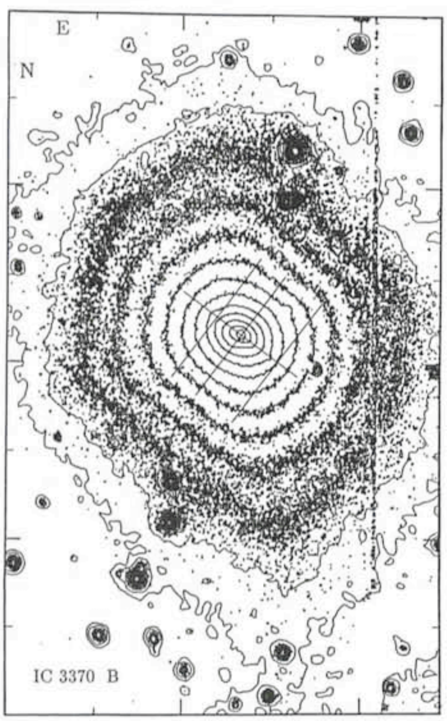

Figure 2.

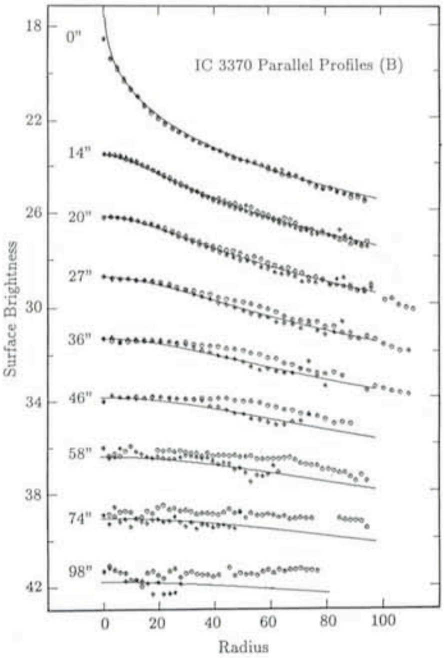

Figure 3.

Both the major and minor axis luminosity profiles in all colours are well fitted by a de Vaucouleurs $r^{\frac{1}{4}}$ law, similar to what is observed in "normal" ellipticals and the bulges of most disk galaxies. However, the minor axis luminosity profile shows a very steep decrease of luminosity with radius: $I_B \propto z^{-4.4 \pm 0.2}$. Most ellipticals have indices closer to that of a Hubble law ($I \propto z^{-2}$). Figure 3 shows the perpendicular luminosity profiles of IC 3370 at selected distances from the minor axis as labelled on the plot. Apart from the 0″ cut (minor axis) which closely follows an $r^{\frac{1}{4}}$ law as noted earlier, the remaining perpendicular profiles are different and are unlike both classical spheroidal bulges and normal elliptical galaxies. All show a remarkably constant luminosity for $z < 50''$, especially the 50″, 60″ and 70″ cuts before sharply decreasing, strongly indicating the box-shaped nature of the isophotes.

The total magnitude of IC 3370, uncorrected for galactic absorption is $B_T = 12.02 \pm 0.10$. Assuming a distance of 54.1 h^{-1} Mpc ($h = H_0/50$ km.s^{-1}.Mpc^{-1}) for IC 3370, the absolute B magnitude is $M_B = -22.1$. Few if any bulges are known which are significantly more luminous than IC 3370. This luminosity is more typical of elliptical galaxies.

IC 3370 also shows a significant amount of isophotal twisting amounting to a total rotation of about 25° between r = 0″ and r = 70″. This is quite puzzling in the light of our current understanding of the bulges of disk galaxies especially if the "bulge" is close to edge-on as discussed below. Classical bulges are generally believed to be nearly oblate (eg. Jarvis and Freeman, 1985) in which case no isophotal twisting should be observed at any inclination. Isophotal twisting in galaxies is most commonly interpreted as due to triaxiality. The large change of PA observed in IC 3370 is more akin to what is seen in some elliptical galaxies than in the bulges of disk galaxies. We may be forced to resort to some external process to explain this twisting such as the merger of two or more parent galaxies which simultaneously formed the box shape (see discussion below). Alternatively, we may be observing the effect of a past tidal interaction much like what NGC 205 is undergoing today.

III. Kinematic Observations

Most of the long-slit spectroscopic data for IC 3370 were obtained with the Boller and Chivens spectrograph and CCD at the ESO 3.6-m telescope. Typical exposure times for each slit position were 2 hours using a 2″ slit and a spectral resolution of about 2.4 Å. Spectra of several early K-type giant stars were also observed to form a template for measuring the galaxy velocity dispersions and rotation. The geometric stability was very good with a total shift of less than 0.2 pixels (20 km s^{-1}) over five hours of hour angle. The reduction procedures for long-slit spectroscopic data followed standard procedures and will not be discussed further here. The velocities were determined by cross-correlating the galaxy spectra with the standard star spectra. The observed velocities V and velocity dispersions σ along the various cuts in IC 3370 are shown in Figure 4. An internal consistency check on the data was made from the points where the slit positions intersected. These points, plotted as plus signs gave two independent measurements for the velocity and velocity dispersion. An external check on the instrumental setup and reduction procedures was afforded by obtaining a short exposure of the major axis of the bright galaxy NGC 4594 and comparing the observed rotation curve with that observed by Kormendy and Illingworth (1982). The results, shown in Figure 5, indicate a good agreement. It is interesting to note that the sharp turnover in the rotation curve at about 5″ on either side of the nucleus was not seen in the KI or Faber et al. (1977) data.

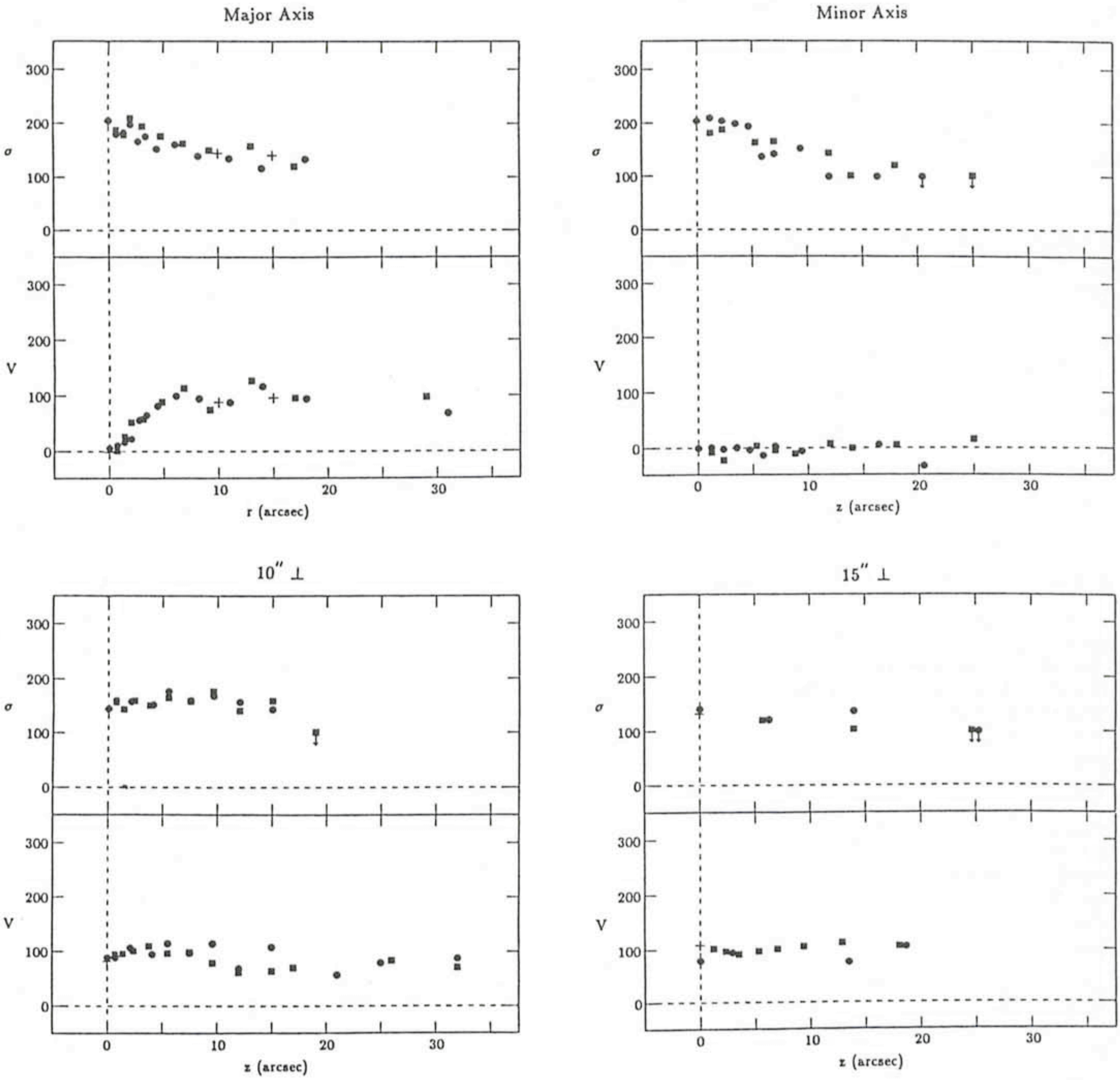

Figure 4.

Evidence for a stellar disk in IC 3370

Figure 6 shows the inner 20″ of IC 3370 divided by the same image spatially filtered with a circular Gaussian filter of FWHM = 4.9″. We can clearly see a faint luminous stellar disk totally enveloped within a much more luminous bulge. The disk is also convincingly revealed by least-squares fitting ellipses to the isophotes of the inner 20″ of IC 3370. This argues in favour of IC 3370 being an S0pec galaxy and not an E galaxy by classical definition. The large aspect ratio of the disk suggests that IC 3370 is seen very nearly edge-on. Moreover, all the Jarvis (1986) sample of 41 disk galaxies with box- or peanut-shaped bulges also had inclinations greater than about 80°. This can be no coincidence. Therefore we conclude that the presence of an observable box shape with an observable luminous high aspect ratio disk suggests an inclination for IC 3370 of $i \geq 80°$.

The observed heliocentric velocity of IC 3370 was measured to be 2959 ± 30 km s^{-1}. The inner 7″ of IC 3370 along the major axis is rotating like a solid body, reaching a maximun velocity of about 100 km s^{-1}. Beyond this point the rotation curve is quite flat. The minor axis rotation curve shows no significant mean rotation and indicates that IC 3370 is not tumbling.

The kinematically most interesting cuts are those perpendicular to the major axis and offset from the minor axis at distances of 10″ and 15″ from the nucleus. These are also shown in Figure 4. Their most striking feature is the near constancy of the velocity and dispersion with z to z ~ r_e (8h^{-1} kpc) for the 10″ ⊥ cut and z ~ 0.6r_e (4.8h^{-1} kpc) for the 15″ ⊥ cut. Therefore, *IC 3370 is strongly cylindrically rotating to large z distances above and below the plane of rotation.* In fact, it is cylindrically rotating to significantly greater z distances than have been observed before in disk galaxies with box- or peanut-shaped bulges.

IV. Implications for Formation

A natural question arises as to how these galaxies formed. What evidence is there to suggest that IC 3370 had a mostly dissipative formation much like disk galaxies or alternatively, a weak

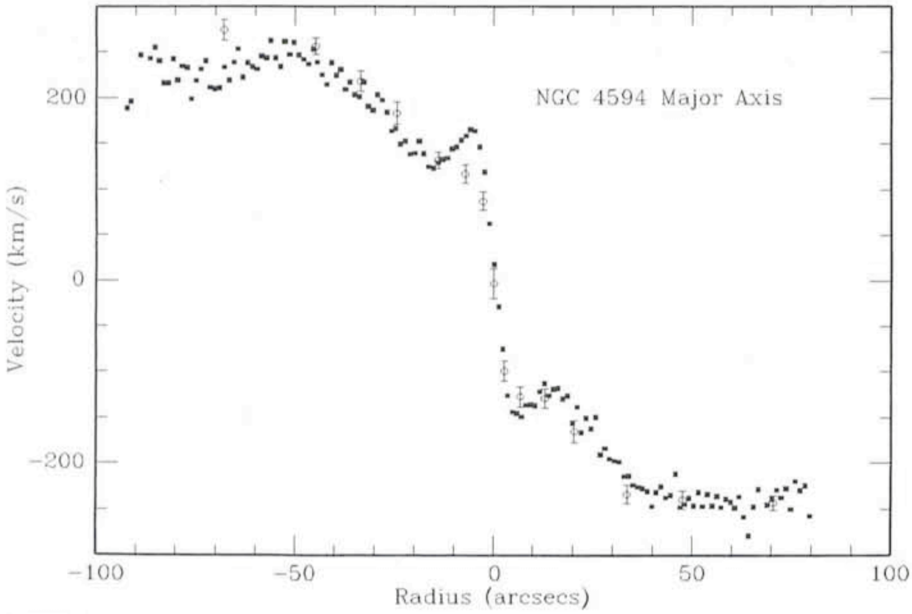

Figure 5.

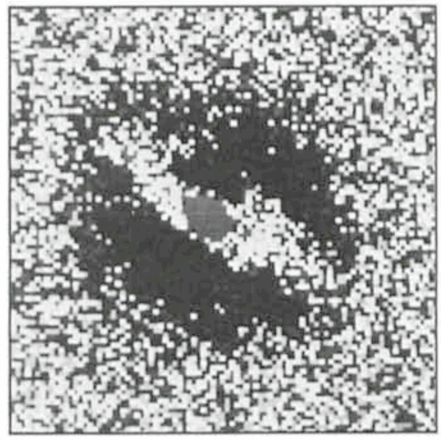

Figure 6.

dissipative history as is generally believed for the bright ellipticals? The small colour gradient in IC 3370 argues against a strongly dissipational collapse. This is also supported by the lack of a significant amount of highly dissipated material in the form of a disk. These and other more subtle points require us to look for a non-dissipative type model for IC 3370.

One alternative possibility may lie with mergers as these have been shown to be capable of producing the characteristic box and peanut shapes (Binney and Petrou, 1985). Their models showed that the slow accretion of a satellite galaxy by a more massive host can lead to the box or peanut shapes with the proviso that the mass of the bulge must not amount to more than a small fraction of the overall mass of the host system. However, for IC 3370, the ratio of the bulge mass to total mass is almost unity. Also, the satellite capture hypothesis cannot work well in the case of the host system being highly triaxial, a possibility in view of the large amount of isophotal twisting observed. Slightly triaxial or oblate elliptical galaxies with an approximately axisymmetric potential cannot be excluded however. Thus it seems that the most likely merger possibility for IC 3370 proposed by Binney and Petrou is the slow collision of two massive disk galaxies which have appropriately inclined total angular momentum vectors. The absence of a significant amount of dust in IC 3370 would tend to argue in favour that the merging progenitors were S0 galaxies unless the merger process triggered efficient star formation depleting nearly all of the gas. These proposals have no sound physical basis at present and can only be tested by adequate n-body experiments.

V. Conclusions

The main conclusions reached in this study of IC 3370 are as follows:

1. IC 3370 is an S0pec galaxy and not an elliptical as previously classified. The strongest supporting evidence for this is the discovery of a faint luminous stellar disk.

2. IC 3370 is highly cylindrically rotating to much greater z distances than have previously been observed in box- or peanut-shaped bulges.

3. The kinematic data show that IC 3370 has as much rotation as an oblate isotropic model flattened by rotation alone.

4. There is an unusually large amount of isophotal twisting in the bulge of IC 3370 amounting to a total shift of about 25°. Merger or tidal processes may offer the only satisfactory explanation for its occurrence.

5. The bulge of IC 3370 is very luminous with $M_B = -22.1$, making it one of the most luminous bulges known.

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Upgrading of the ESO 1.52-m Telescope

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A Few Words of History

At the time the ESO Convention was signed, two telescopes 1 metre in size were foreseen, one dedicated to photometric observations, the other to spectroscopic work. The latter however, was soon turned into a 1.52-metre telescope, a modified twin-brother of a telescope then under construction at the Haute-Provence Observatory. A rather large building was planned to house the coudé spectrograph and an aluminizing plant for up to 2 metre diameter mirrors, and was erected in 1968.

The 1.52-metre spectroscopic telescope was first offered to visiting astronomers for the period September 1st 1969 to March 1st 1970. The instrumentation then available consisted of the coudé spectrograph and a Cassegrain spectrograph from Marseille Observatory, aimed at radial velocity measurements. Later, an echelle spectrograph was installed at the coudé focus, working with an electronographic device and providing a resolution down to 0.015 nm. This spectrograph is present-

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ly being modified so as to receive a CCD detector and be remotely controlled. A Boller and Chivens spectrograph was purchased for the Cassegrain focus. It was first equipped with an Image Tube, then with the Image Dissector Scanner (1978) and a reticon device, and since March 1987, works with a CCD detector. A set of gratings allows to reach resolutions from 0.1 to 1.35 nm for an entrance slit of 3 arcsec.

The Need for an Upgrading

Firstly, an instrument twenty years old has necessarily suffered from ageing: some mechanical and optical parts in particular must be replaced. Secondly, the technology for telescope building and the observing conditions have changed rapidly: no doubt that a short tour at the various telescopes on La Silla would convince you of this fact. And finally, requirements of the astronomers have changed according to technological progress. Remember that a pointing accuracy of about 2 arcmin was seen as acceptable by the time the 1.52-metre telescope was planned, while now we are all looking for much better performances . . .

As far as possible, all instruments on La Silla should meet these requirements which aim at a better efficiency and reliability. Along this line of thinking, an upgrading of the 1.52-metre telescope appeared to be necessary and was initiated recently. In a similar way the 1 metre photometric telescope has benefited by a complete check-up and has been modernized at the same time.

It should be realized that such a task is not as easy as it looks at first sight: precisely because the technological aspects have changed so much! Modernizing a telescope from the sixties can be time consuming and expensive. However, many interesting results are to be expected from small to medium size telescopes if these are efficient and well equipped. Indeed, they can provide the large amounts of data which are requested to perform serious research on variability projects or survey projects. To be competitive these telescopes need an accurate computer-controlled pointing, a precise and automatic guiding and must be equipped with fast and high quality instrumentation.

What Do the 1.52-m Telescope Users Think?

In order to estimate which support to this upgrading could be expected from the users community, an inquiry was sent around last April to the 55 astronomers having observed at the 1.52-metre telescope during the period April 1, 1986 to April 1, 1987. This inquiry consisted of a set of questions regarding (i) the telescope itself and the general observing conditions, and (ii) more specifically the Image Dissector Scanner because this detector recently showed serious signs of degradation. A total of 43 astronomers replied to this inquiry, i.e. 78 %: we thank them very much for their help. From their answers the following conclusions could be drawn:

Regarding point (i), 65 % of the observers are not satisfied with the present observing conditions. The rating for suggested improvements went as: 93 % are in favour of a computer-controlled pointing, 74 % would appreciate the access to an automatic guiding system, 58 % also favour a computer-controlled dome motion and 58 % see the need for observing from a side-room. Finally, an impressive proportion of observers, 90 %, would accept a close-down of the instrument during two months if this could speed up the upgrading – even if this close-down disturbs temporarily their scientific programmes.

As far as point (ii) is concerned, only a subset of the astronomers sample answered this part of the inquiry, those having used the detector on the Boller and Chivens spectrograph (24 of them). The answers are strongly dependent on the epoch at which the IDS was used, since its impressive failures started last December 1986. Most IDS users from December 1986 to March 1987 notice stability problems, an increase of the noise, the appearance of spikes and a spectacular loss in sensitivity. To the suggestion of replacing the dying IDS by a CCD detector, 83 % of the users agree while 17 % raise arguments in favour of the IDS (real-time data display, small size files, homogeneity of data . . .) although they have no serious objection to the CCD.

This inquiry has shown, if necessary, that the astronomical community strongly supports the upgrading of the 1.52-metre telescope and that a speeding up of the action would be welcome.

Which Improvements Have Been Implemented Already?

On the side of the telescope, up to now the modifications have been mainly of mechanical nature and are related to the modernization of the telescope drive.

Additional improvements have been achieved for the auxiliary functions: (i) a new mirror 3 support has been implemented which does allow for easy and well aligned optical configuration changes between Cassegrain and cloudé focii, (ii) four motorized sliding counter-weights are now along the delta tube (iii) one motorized offset counter-weight is for the hour angle axis, (iv) a balancing counter-weight ring has been installed below the mirror cell (v) there is a new motorized rotator for the Cassegrain instrumentation and, (vi) telescope blocking devices have been mounted in order to ensure safer and faster instrument exchanges.

On the side of the instrumentation, a new CCD detector has been attached to the Boller and Chivens spectrograph.

Future Upgrading

The telescope will get new servo-motor drives at both axes. These will allow for accurate tracking and off-setting. A high resolution encoder with an absolute position read-out feature will be installed. Automatic telescope and dome presetting will be implemented. An automatic guiding system for Cassegrain observing and possibly coudé as well, will be available. It is intended to develop an autonomous safety system for the telescope, in order to prevent collision with the pillars and the platform. The telescope and instrumentation cabling will be renewed and a cabling twist system will be incorporated. Finally, a new control room will be installed at the floor below the telescope. Regarding the instrumentation, the optics of the Boller and Chivens spectrograph will be improved in order to overcome the geometrical aberrations. It is also planned to reactivate the echelec spectrograph with a CCD detector.

While you are reading these lines, part of this *future* upgrading has allready become past upgrading . . . .

Thinking of the future of small or medium size telescopes, one route is towards modernized efficient instruments with only a few high quality equipments. One might direct the effort, at the 1.52-metre telescope, in having the echelle spectrograph equipped with a CCD at the coudé focus, and the improved Boller and Chivens spectrograph at the Cassegrain focus, also with a CCD detector. This would lead to a better set-up of the instrumentation because of less frequent change-over. This whole upgrading is intended to raise the 1.52-metre telescope to the same quality standard as now found on the site.

A large fraction of the TRS staff at La Silla is presently involved in this task, particularly W. Eckert and his workshop crew for the mechanical modifications, M. Maugis for the new encoder interfaces, J. Alonso for the servo-drives and G. Andreoni for the telescope control software.

La Silla, June 29th 1987

A New Distance Indicator for Spiral Galaxies?

E. GIRAUD, ESO

1. Introduction

With an observed dispersion of 0.45–0.55 mag, the Tully-Fisher (T-F) relation between the maximum rotation velocity V_M, deduced from H I profiles at 21 cm, and the luminosity of spiral galaxies is a good method for determining relative distances of clusters of galaxies. However, the scatter in the relation is larger than can be accounted for by observational errors only. In particular the B-band T-F relation is probably not single-valued (i.e. an Sb with a maximum rotation velocity equal to that of an Sc is fainter in the blue than the Sc). It is generally thought that the use of infrared magnitudes (H band at 1.6 μm) tends to reduce the scatter. But a major disadvantage at H is the absence of a system of diameters (H magnitudes are measured within a standard aperture ratio, fixed at ~ 31 % of the isophotal blue diameter at 25 mag arcsec^{-2} [Fig. 1]).

In view of this, it was expected that significant improvement would be obtained if isophotal magnitudes could be measured in a band where:

(a) the sensitivity of CCD detectors is good

(b) the corrections for galactic and internal reddening are quite small

(c) the luminosity is a reliable indicator of the mass in stars.

The red I-band was chosen as a compromise between these constraints. One of its disadvantages is the brightness and the noise of the sky background. But this is not a major problem because accurate sky subtraction can be made on CCD frames. A programme of CCD surface photometry in the I-band was started for this initial purpose.

2. Observations

Nine nights in two runs (September 1986 and May 1987) at the 1.5-m Danish telescope were allocated to the project. Unfortunately, poor weather conditions were encountered during a large fraction of the observing time. Useful observations under photometric conditions could be performed in I and B or V for about $2\frac{1}{2}$ nights. The data were acquired with CCD # 1 in September 1986 and CCD # 3 in May 1987. Series of dome flat fields were taken for every filter at the beginning of each night. Standard stars from the catalogue of Landolt were observed alternately with galaxies.

3. Reduction

The reduction of raw data was carried out with IHAP at ESO, Garching. The sky background was measured by taking the mean of pixel values within disks of specified centres and radii. The disks were centred to avoid stars and extended galaxy light. Isophotic levels were deduced for each frame from the standard stars. Then elliptical isophotes were obtained visually by overlaying ellipses of given centre, major axis, position angle and ellipticity onto high contrast images. Most often the isophotes can be fairly well approximated by ellipses, but in general not all of them have the same centre, ellipticity and position angle. An example of the shift of the isophotes is shown in Figure 2 for NGC 4522. Non-concentric isophotes were encountered in the case of very dusty galaxies. This is illustrated in Figure 3 for the edge-on galaxy I3322A. For this galaxy bright contours were forced on a symmetric profile. The apparent magnitudes were measured within various isophotal diameters and the magnitude–line width relation was tested for each of them.

4. Results

It turned out that the reduction of the spread in the Tully-Fisher relation is only marginal. However, the surface brightness was identified as an irreducible source of scatter. More precisely it was found that the surface brightness of galaxies of similar line widths can be different. At this point one possibility would be to consider that kinematic and photometric data describe a plane given by $L \propto V_M^x S^y$ where the luminosity L and the mean surface birghtness S are measured at some isophote. The pend-

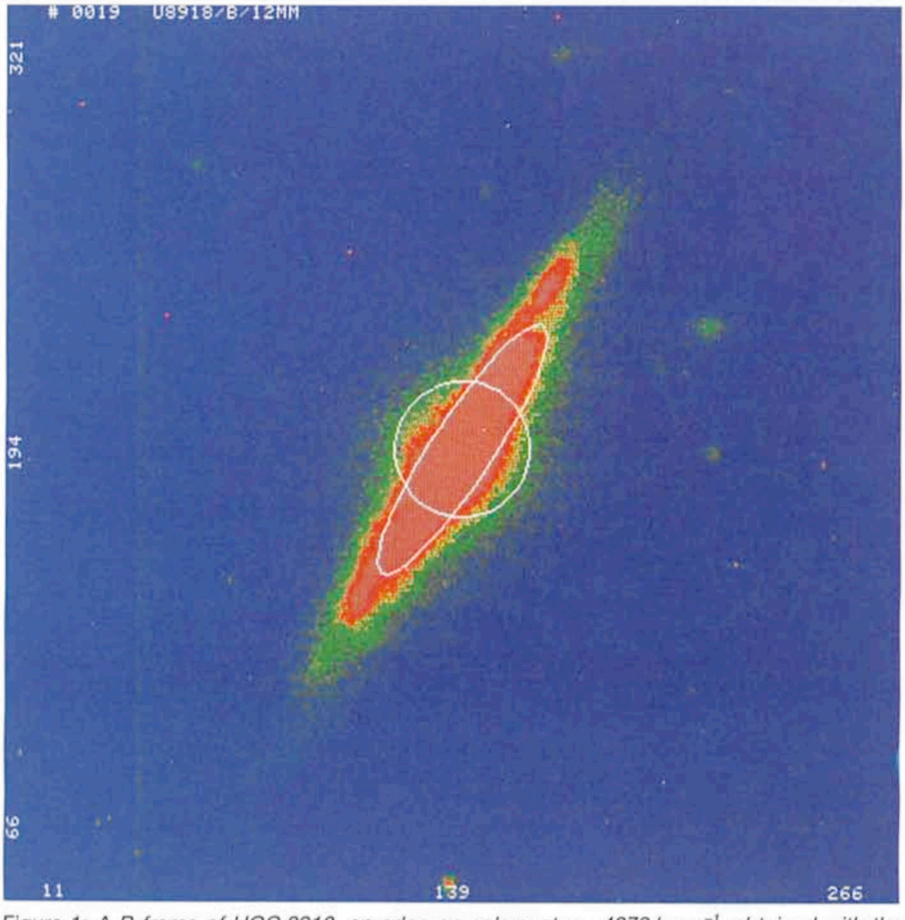

Figure 1: *A B-frame of UGC 8918, an edge-on galaxy at v = 4070 km s^{-1}, obtained with the 1.5-m Danish telescope at La Silla (exposure time 12 minutes, CCD # 3). Superimposed are the standard circular aperture at log A/D (O) = – 0.5 of the infrared system and the elliptical contour used in the I-band (in the case of a rotation velocity V_M = 167 km s^{-1}).*

Detailed Spectra at z = 4.11

The hitherto most distant known object in the Universe is Q0000-26, a 17.5-mag quasar in Sculptor with redshift 4.11. Spectra by J. Webb with the ESO 3.6 m + CASPEC (480–660 nm, 0.06 nm resolution, >12 hr integration time) show many absorption lines around z = 4 and an intervening galaxy at z = 3.39 (ESO PR 13/87).

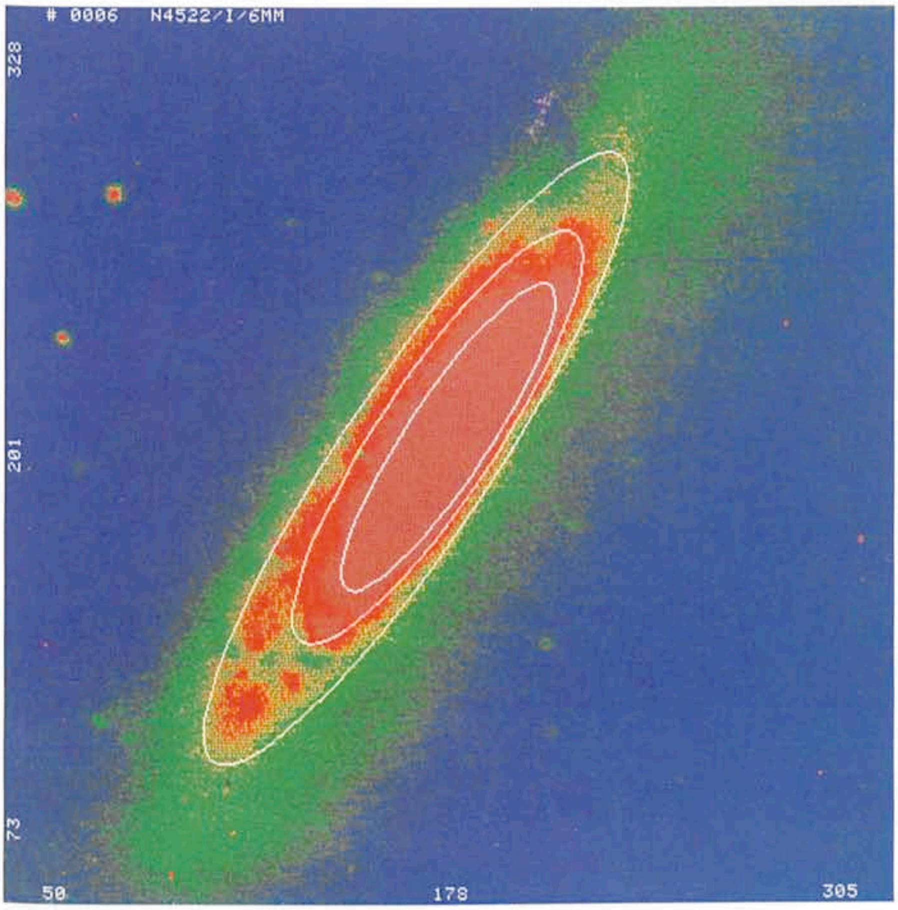

Figure 2: *An I-frame of NGC 4522, a galaxy in Virgo, showing a shift in the isophote contours. (1.5-m Danish telescope, CCD # 3, exposure time 6 minutes.) The luminosity and the surface brightness of this galaxy were measured near the outermost elliptical contour.*

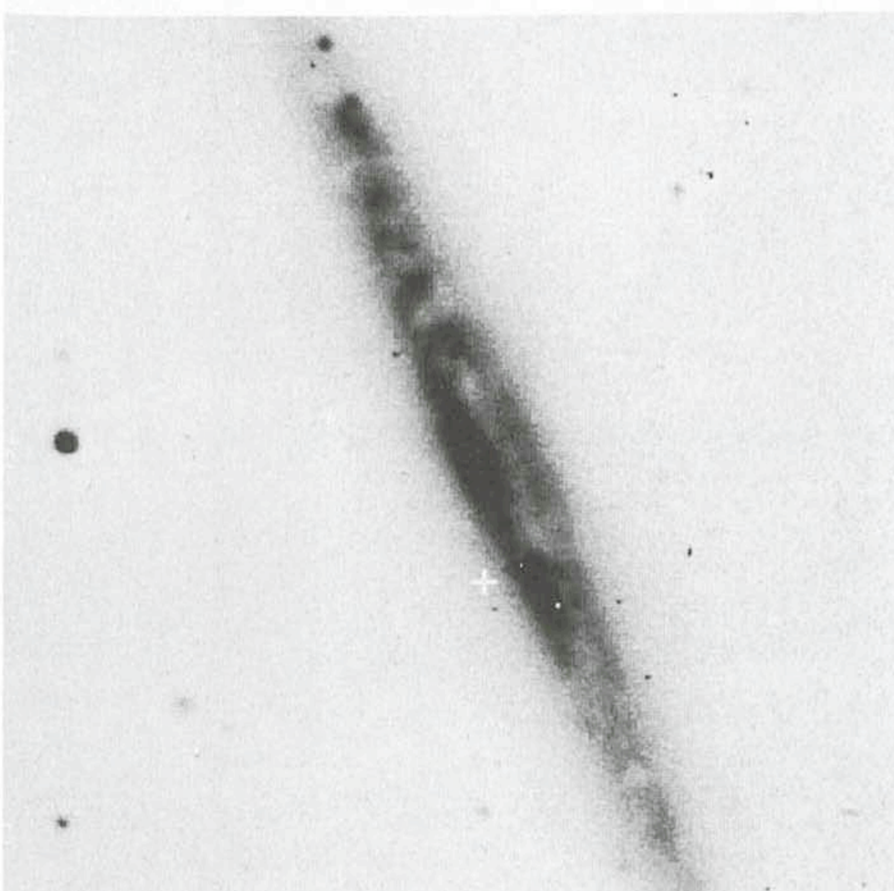

Figure 3: *Image of the edge-on Scd(?) galaxy I3322A in Virgo showing a strong line of dust in its plane.*

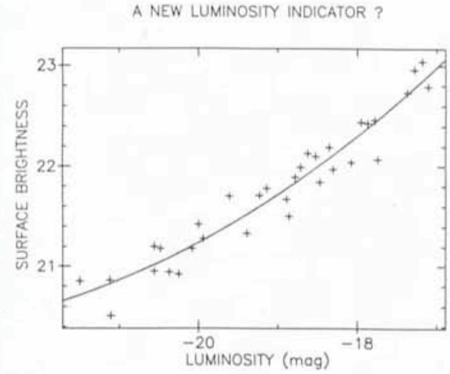

Figure 4: *The luminosity-surface brightness relation.*

ing question would be to determine it. In fact, the synthetic rotation curves pictured by Rubin et al. (1985) indicate that the maximum rotational velocity of bright galaxies is generally reached within a small fraction of their diameter, while for small galaxies the rotation velocity increases more slowly along the radius. From this argument, a relation between luminosity, rotation velocity and surface brightness would not involve a single isophote for all galaxies.

To take full advantage of the surface photometry the luminosity and the surface brightness have been measured within isophotes deduced from an empirical linear relation where brighter isophotes are used for galaxies of progressively higher rotation velocity. Apparent magnitudes and diameters were corrected for galactic absorption and internal reddening by using the equations of the RC2 with a maximum of $A_I = 0.28$ mag for edge-on galaxies and $A_I/A_B = 0.35$.

The relative distances have been derived from the Hubble flow by assuming that the motion of the Local Group in the frame of the cosmic microwave background is the composition of the infall of the Local Group toward Virgo and of the L.S.C. toward Hydra-Centaurus.

The basic result of this approach is illustrated in Figure 4 which presents the luminosity-surface brightness relation.

From this first test, I get a dispersion of 0.18 mag in the relation luminosity → surface brightness and 0.35 mag in the relation surface brightness → luminosity.

This result, which is much better than the Tully-Fisher relation, is quite impressive because the spatial distribution and the environment of the set of data are very heterogeneous. (There are some objects in Virgo, Pegasus I, Z 74-23 and

(Continued on page 24)

The area around the Horsehead Nebula, reproduced from a 120-minute ESO Schmidt plate (IIIa−F + RG630). Contrast control by B. Dumoulin and J. Québatte, ESO. ▸

in the field!) In particular, if this sample is representative of the real world, the cosmic scatter must be very small. Moreover it seems possible to improve the accuracy of the method by balancing the weight of the errors in each photometric variable. A solution is to choose brighter isophotes for massive galaxies in order to increase the range in surface brightness. A more complete analysis of the data is now in progress.

To conclude, an accuracy level of 12–15 % in extragalactic distances seems to be within arm's reach by this new luminosity indicator. It would be very important to confirm the result with a sample of ~ 100 galaxies, to calibrate the zero-point of the relation and to start the study of galaxy streamings at kinematic distances smaller than 8,000–10,000 km s^{-1}.

References

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A New Device for Performing High-Speed Polarimetric Measurements

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Introduction

The explosion of the supernova SN 1987A in the LMC on February 23, 1987, was such an exceptional event for the present generation of astronomers that all possible efforts are justified that could allow a deeper insight into the somewhat spectacular results obtained for the supernova. It is not our purpose to review here the descussions that were triggered by the observation of two different neutrino showers that raised the question as to whether the precursor of SN 1987A is now a black hole or a neutron star. If we assume the latter, it should be possible to carry out linear as well as circular polarization measurements synchronous with the perhaps fast rotating central star, as soon as the pulsar becomes visible. With respect to the distance modulus of SN 1987A, which is of the order of $18^{m}.5$, it is evident that we cannot directly observe in the visible domain the polarization of a central object in the supernova. However, it will perhaps be possible to measure the interaction of a strong and quickly varying magnetic field with the shell surrounding the pulsar. To derive a correlation between polarization and magnetic field, it must be possible to measure the polarization synchronously with the rotation of the neutron star. This can be implemented in a simple way also in the relatively slow ESO polarimeter PISCO. The intended modification has to be carried out in such a way that absolutely no interferences with the usual functions of the instrument can occur (Stahl et al., 1986). Therefore the proposed changes mainly have to be shifted onto the software facilities of the instrument. Since it requires much work to prepare the requisite programmes at a computer we have to start our modifications immediately and therefore at a time we are by no means certain about the usefulness of our efforts. However, once created, the intended modification can also be used for measuring fast varying objects like polars of DQ Her type.

Performance of the Modification

The multichannel analyzer described by K. Metz (1984) will be replaced by the ESO Time Series System (TSS) that allows data to be collected in four channels each msec and to write them in a special way onto a magnetic tape. For synchronizing the channels, the system additionally provides a 1 kilohertz signal from a CERME clock display unit that is connected with the ESO Universal Time to read out the UT. In describing the principle of the proposed modification of PISCO, all details of the phase plates and the polarizing prism that were described by K. Metz (1984, 1986) shall be omitted for the moment. Then the count-rates of the photomultipliers are proportional:

$$I +/- (Q \times \cos(4\delta(t)) + U \times \sin(4\delta(t)) \qquad (1)$$

I, Q, U are the Stokes parameters to be measured (if the quarterwave instead of the half-wave plate of the compensator is used, Q, U describe the circular polarization of the signal), +/– stands for the two multiplier channels 1 and 2 respectively, $\delta(t)$ is the instantaneous position angle of the optical axis of the continuously rotating phase plate.

Since the two channels of the polarimeter can work independently, only one channel (with sign +) will be considered for the following:

for $\delta(t)$ =

0°.0	the multi-	I+Q	(a)
22°.5	plier count	I+U	(b)
45°.0	rate is	I–Q	(c)
67°.5	proportional	I–U	(d)

Since one rotation of the modulating half-wave plate yields four identical measurements of the polarization, the Stokes parameters measured for a certain angle $\delta(t)$ repeat modulo 90°.

The basic idea of the modification is then very simple: If one wishes a polarization measurement for a certain phase position X of the pulsar than one has to wait for a coincidence of the pulsar phase X and the necessary half-wave plate position angles (a), (b), (c), (d), each modulo 90°. The times of the coincidences are indicated by the clock pulses of the TSS and the 32 pulses generated in the polarimeter in order to indicate the instantaneous position angle of the rotating half-wave plate.

Time Resolution

The time resolution of the proposed modification cannot be described in a general way since it depends not only on the fixed rotation frequency of 6 Hz of the modulating half-wave plate but also on the period of the pulsar in question. Since the rotation of the half-wave plate cannot be adjusted to a fractional number of the pulsar period two entire compromises have to be met:

(1) For the selected pulsar phase X a certain deviation has to be tolerated (however, the deviation should not far exceed 10 % of the pulsar period).

(2) The positions (a), (b), (c), (d) of the axis of the rotating phase plate can be selected only with an accuracy of $11^{\circ}.25$, corresponding to the distance of two subsequent clock pulses generated in the polarimeter during one rotation of the modulating phase plate. If P is the period of the pulsar, d = 5.21

La Silla Slide Set

ESO announces a new Slide Set, with pictures of La Silla and the telescopes there. The set, which comprises 20 slides, may be obtained at a cost of DM 3.– from the ESO Information Service (address on last page).

msec the time that is needed for the phase plate to move through an angle of $11^\circ\!.25$ and $T_{90} = 8 \times d = 41.68$ msec the time for the phase plate to run through 90° we have:

$$\delta(t) = 11^\circ\!.25 \times n \times P/d \qquad (2)$$

where $\delta(t)$ repeats modulo 90° and $n = 1, 2, \ldots$ is the number of rotations of the pulsar.

Therefore, if $P \approx 2 \times d/k$, $k = 1, 2, \ldots$ (extremely fast rotation of the pulsar), or if $P \gg 8 \times d$ (extremely slow rotation of the pulsar or observation of a polar like star) one single polarization measurement would need $6 \times 5.21 = 31.26$ msec. Presumably it can be expected that P is of the order of the time necessary for one rotation of the phase-plate. One polarization measurement would then last for a time of $4 \times P$. Naturally the compromises described above are fully valid in that case and therefore a fast computer with a sufficient great memory is required.

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ESO Press Releases

The following Press Releases have been published since July 15, 1987, the date when *Messenger* 48 went to press.

PR 11/87: Astronomers and Physicists Meet at ESO at the First Full-Scale International Conference on Supernova 1987A (8 July).

PR 12/87: Discovery of a Binary Quasar (13 July), with one B/W photo.

SN 1987A (Continued)

The ESO Workshop on SN 1987A took place on July 6–8, 1987 in Garching with almost 200 participating scientists. It was the first, full scale international meeting on this exciting object and it was followed with great interest, not only by the participants, but also by the media which reported extensively about the results. The summary talk by S. van den Bergh is reprinted in this issue of the *Messenger* on page 32.

Since the ESO meeting, SN 1987A has continued to behave differently from most other supernovae. From magnitude 4.5 in early July, it has decreased to about magnitude 5.0 in early September; this is unusually slow. In fact, it almost looks as if the brightness has become nearly constant since mid-August.

Attempts to detect X-ray and gamma radiation have so far been unsuccessful. It was announced on July 14 that no significant gamma-ray emission from SN 1987A had been observed with the gamma spectrometer on-board the Solar Maximum Mission satellite (SMM) and neither the Japanese Ginga satellite nor the Quant instrument on the Soviet Mir station has detected any X-ray emission. Dramatic confirmation of the extreme weakness of short-wave radiation of SN 1987A came from a rocket experiment by the Max-Planck-Institut für Extraterrestrische Physik on 24 August. On this date, an X-ray detector on a rocket launched from Woomera in Australia was unable to register any signal in the 0.1–2 keV region, thereby setting an upper limit at 1/6000 of the X-ray strength of the Crab Nebula. However, theoreticians expect that a signal should be detectable during the coming months, as the shell of ejected material becomes less dense and when the material collides with the surrounding interstellar medium.

Radio astronomers in Australia have failed to confirm the observations of radio emission at 22 GHz, reported from Brazil in late June. However, the uncertainty of the Brasilian measurements may be larger than first thought.

Observations of SN 1987A are therefore still limited to the UV, visible and infrared spectral regions. At ESO, pictures in the light of doubly ionized oxygen were obtained (see page 34 in this *Messenger* issue) and the other types of observations continue. The "mystery spot" reported earlier apparently was of transitory nature and is no longer seen. It may have been a light echo in a nearby cloud.

The editor (September 8, 1987)

Sun Rings over La Silla

Sun rings were seen from La Silla during several days in late February 1987. This photo, which was obtained by Claus Madsen with a 35 mm camera (f = 28 mm), shows two sun rings with radii around 23 and 45 degrees. This atmospheric phenomenon is caused by refraction of sunlight in ice crystals, probably of hexagonal form. It is described in the famous book by M. Minnaert on "The nature of light and colour in the open air" (Dover, 1954).

FIRST VISITOR EXPERIENCE WITH PISCO:

Phase Dependent Polarization Variations of Southern Galactic WR + O Systems

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Scientific Rational

Wolf-Rayet (WR) stars are the likely descendents of the most massive stars before they explode as supernovae. Their distinguishing features are their extremely intense, broad emission lines of high ionization level. These lines arise in hot, fast, dense winds, which are rich in the products of centrally burned Hydrogen and Helium.

Three ionization sequences are encountered. From hot to "cool", these are: WN2 . . . WN9, in which the products of CNO-cycle H-burning appear in the winds; WC4 . . . WC9, in which the products of He-burning appear; and WO1 . . . WO4, a rarely observed stage of He-burning, in which Oxygen becomes enhanced. Although several unsolved, fundamental problems relating to WR stars remain, the relatively simple task of determining the absolute masses (as well as the mass loss rates) is tractable now, thanks to the advent and perfection of precision polarimeters.

Polarization arises in WR stars via the basically simple process of scattering of photons off free electrons, which abound in the hot, highly ionized winds of these stars. However, in the case of a single WR star with a homogeneous, spherically symmetric wind, the polarization due to electrons on any one side is expected to cancel with the polarization of similar electrons located at right angles to this. The net polarization is therefore zero (cf. Fig. 1a).

In the case of a binary star (or some other asymmetry, either in the light source or electron distribution), full cancellation does not occur and we expect to see some level of net non-zero linear polarization, which varies systematically with orbital phase (cf. Fig. 1b). This has indeed been seen in several *bright* WR + O binary systems:

V444 Cygni (Rudy and Kemp 1978; Robert et al. 1987);

CQ Cep (Drissen et al. 1986);

γ^2 Vel, HD 97152 and HD 152270 (St-Louis et al. 1987a; Luna 1982, 1985).

The full amplitudes of the phase-dependent variations in the degree of polarization range from about 0.2 to 0.8 %. The remaining 99.2 to 99.8 % of the light is unpolarized, i.e. the vibration direction of the electric vectors of individual photons are completely uncorrelated.

Typically in a binary, the degree of polarization varies mainly in a double wave per orbit as the cloud of fleeing electrons around the WR star scatters and polarizes the light from the O-type companion. Note that the wind of the O-type star is normally at least a factor ten weaker than the WR wind and can essentially be neglected. The reason for the double wave is simple: scattering electrons around the WR star when it is on one side of the O-star will produce the same polarization as when the the WR star is located on the diametrically opposite side (cf. Fig. 1b).

It can be easily shown that the manner in which the polarization varies depends, among other parameters, on the inclination of the orbital plane in the sky, i (cf. Brown, McLean and Emslie 1978). For orbits seen edge-on ($i = 90°$), the intrinsic polarization angle remains constant with orbital phase, while the amplitude varies from a maximum at quadrature, when scattering tends to occur at right angles, to zero at conjunction, when forward or back scattering occurs. For the other extreme, $i = 0°$, the polarization angle oscillates through 360° per orbit, while the amplitude remains constant. In general, one will, of course, find intermediate values of i. Once the value of i is known, one can then calculate the true stellar masses from the spectroscopic radial velocity orbits, which yield $M \sin^3 i$ only, i.e. one gets

$$M = (M \sin^3 i)_{spectrosc.}/(\sin^3 i)_{polarim.}$$

The mass is clearly the most fundamental parameter of a star. Unless the systems eclipses, it appears that the variation of polarization is the most reliable way to obtain i and hence M.

From the amplitude, A, of the phase-dependent polarization variations, one can also obtain a reliable estimate of the mass loss rate $\dot{M}$ of the WR star. It can be shown that A depends mainly on the total number of scatterers located in the WR wind out to near the orbit of the O-type star. Assuming total ionization of the dominating element, Helium, in the WR wind, as well as a simple wind law, one can use A to derive $\dot{M}$ (cf. St-Louis et al. 1987b). The mass loss rate is also a very important parameter for WR stars, which are able to expose more and more exotic products of nuclear burning, the higher $\dot{M}$ is. This gives us a good view of the processes that take place deep inside the stellar interior.

Use of the Instrument

In order to increase our sample of objects, we decided to request the use of the ESO polarimeter at the 2.2-m Max-Planck telescope. The instrument is fondly known as PISCO – "Polarization with Instrumental and Sky Compen-

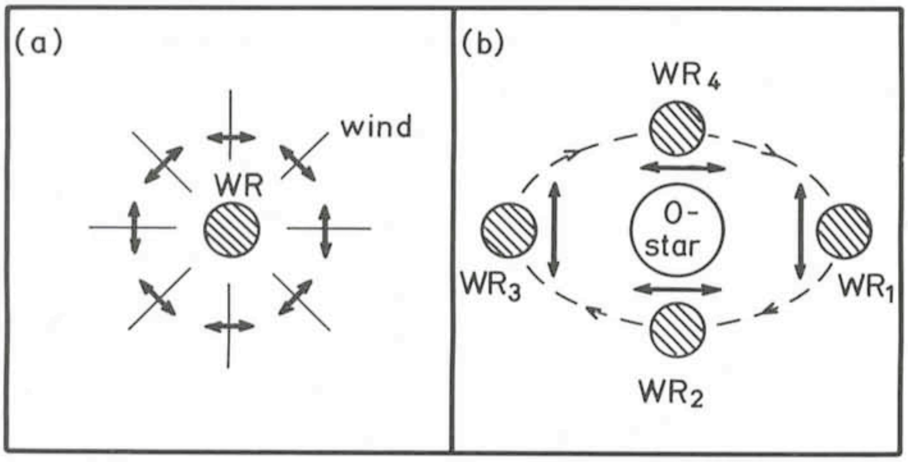

Figure 1: *Electric vectors of polarization seen*
(a) simultaneously in a spherically symmetric wind and
(b) in succession in a WR + O binary system.
Note that in reality both stars in (b) will orbit about a common centre of mass.

sation". For a more detailed description of PISCO, we refer to last December's *Messenger* (Stahl et al. 1986).

We used PISCO during six nights in early May 1987 to observe a half dozen southern Galactic WR + O systems below the 9^{th} magnitude limit of a previous more general polarization variability survey of southern WR stars (cf. St-Louis et al. 1987a and Drissen et al. 1987). For the latter work, it was much easier to obtain a much longer run on a smaller telescope! Later, we hope to be able to study WR + O binaries in the Magellanic Clouds in order to test the effect of lower metallicity on the mass loss rates.

Since electron scattering is wavelength independent, we decided to save an enormous amount of time by monitoring for polarization variation in *one* bandpass only. We chose the *visual* broad band in order to reduce the effects of moonlight and wavelength-dependent atmospheric extinction, compared to, say, the broad *blue* band. We used PISCO in its full sky and instrumental compensation mode for observing linear polarization, i.e. with a rotating half-wave plate as variable retarder and a Foster prism as analyzer. A double diaphragm with 10 arcsecond holes allowed us to keep the bright moonlit sky to a tolerable level, while capturing most of the starlight.

As usual, we had to calibrate the efficiency of measuring the polarization. From observations of bright non-polarized stars through a 99.99 % polarizer, as well as from direct observations of standard stars, we found an efficiency factor of 90.4 % ± 0.4 %. While quite good, we wonder if this could not be improved to the *upper* 90 %!

From observation of various non-polarized stars, we found and eliminated a residual telescope polarization of $P_{tel} \simeq 0.056$ % in a direction $\theta_{tel} \simeq 99°$ (angles here are expressed in the conventional way from celestial north through east). The zero-point of the polarization angle was established on the basis of polarized standard stars. The zero-point tended to drift in one sense by about 1° each night at the beginning of the run, but remained constant later.

Since the expected amplitudes of orbital polarization modulation are small (< 1 %), it is necessary to obtain high precision for each data point. From previous experience, a scatter of $\sigma_{pol} \lesssim 0.02$ % per observation is necessary. To reach this level, one must collect about 25 million photons. This is based on Poisson statistics; the real errors are always somewhat larger due usually to hidden systematic effects. Exposure times of 30 minutes were necessary to

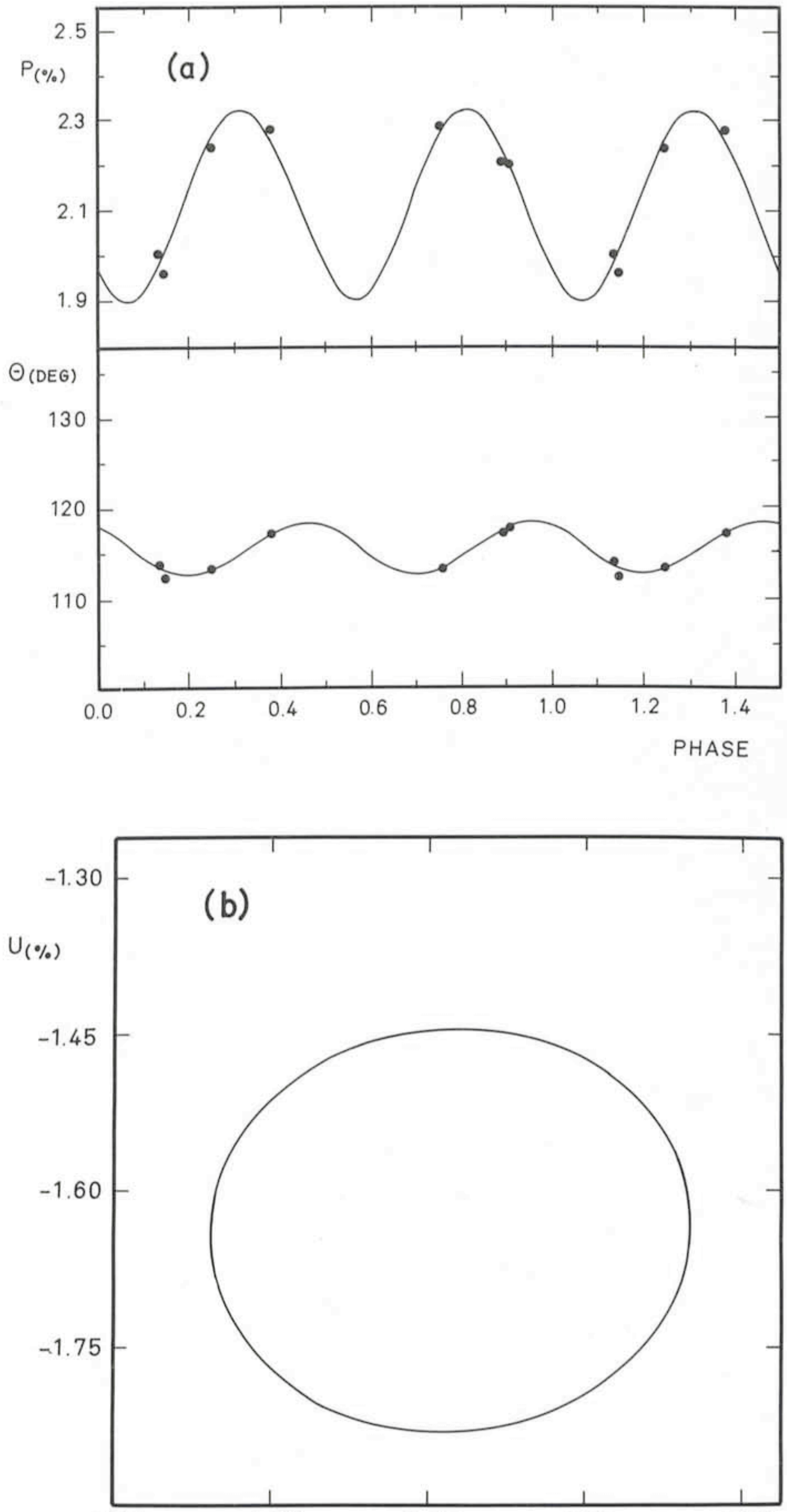

Figure 2: *(a) Linear polarization P and equatorial position angle θ versus phase θ of the spectroscopic orbit for the WN4 + O4-6 binary HD 90657 (period 8.255 days, WR star in front at JD = 2443923.7). The curve is a forced double-wave sinusoidal fit made to the Stokes parameters Q(θ) and U(θ). Note that Q = P cos 2θ and U = P sin 2θ.*
(b) The Q-U locus from the double-wave fit for HD 90657. The curve results in the orbital inclination $i = 56\overset{\circ}{.}5 \pm 6\overset{\circ}{.}3$ *and the position angle of the line of nodes* $\Omega = 5\overset{\circ}{.}4 \pm 16\overset{\circ}{.}3$.

reach this precision at V ≃ 11 mag. The brightest star observable without adding a neutral density filter had V ~ 7.8 mag, yielding a mean count rate of ~ 300,000 counts per second in one of the channels; the other channel counted photons at only slightly more then half this rate.

Luckily, about 80 % of the six nights were clear. The data were completely reduced at La Silla before departure. (It appears that AFJM now owes Hugo Schwarz a bottle of Champagne because of this.) This required some extreme effort to modify and debug the reduction programme; we are very grateful to the ESO mountain staff for this, as well as for their help at the telescope.

For the most part, PISCO works very well. The only major problem remaining in our view is the inadequacy of the on-line reduction during the night. This allowed us to get barely a rough feeling for the real quality of the data as they were being obtained. If not already done, the efficiency of using PISCO could be considerably enhanced if one could walk away from the telescope each morning with definitive (or nearly so) data!

Some Results

We wish to terminate this brief exposé by illustrating the results for some of the six WR + O binaries and one test O + O binary that were observed. The WR + O systems ranged in brightness from V ≃ 9 to 11 mag. An additional WR + O system at V = 11.2 mag turned out to be unmeasurable due to the proximity of the full moon (≲ 30°). This sample of stars is complete as far as southern WR + O binaries of V ≤ 11 mag are concerned, although a six-night run is only a start especially for the systems with longer periods (P ≳ 10 days).

In Figures 2 and 3 we show plots of P and θ versus spectroscopic orbital phase, and the Stokes parameters $Q = P \cos 2\theta$ versus $U = P \sin 2\theta$ for two WR + O systems:

(1) HD 90657, WN4 + O4-6, P = 8.255 d (Niemela and Moffat 1982), and

(2) HDE 311884, WN6 + O5, P = 6.239 d (Niemela 1987; Niemela, Conti and Massey 1980).

Note the double wave per orbit. The observed modulation in θ is considerably reduced due to the dilution from a moderately strong but constant component of interstellar polarization. From the shape of the Q-U figures traced out during the orbit we deduce $i = 56\overset{\circ}{.}5 \pm 6\overset{\circ}{.}3$ and thus $M_{WR} = 9\ M_\odot / \sin^3 i = 16\ M_\odot$ for the first system and $i = 76\overset{\circ}{.}9 \pm 1\overset{\circ}{.}7$ and hence $M_{WR} = 40\ M_\odot / \sin^3 i = 43\ M_\odot$ for the second

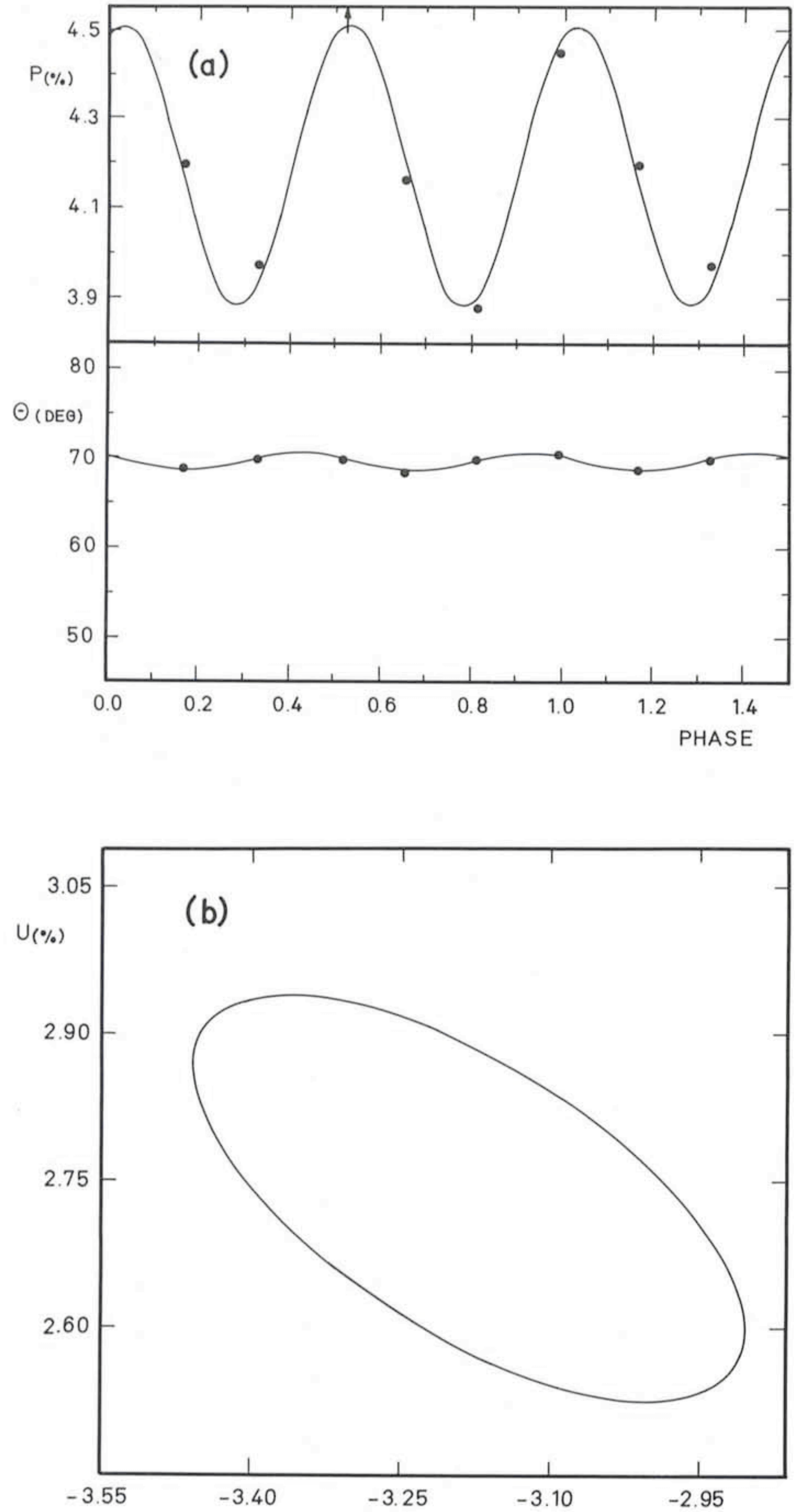

Figure 3: *(a) P and θ versus orbital phase for the WN6 + 05 binary HDE 311884 (period 6.239 days, WR star in front at JD = 2443918.4). The curve is a forced double-wave sinusoidal fit to Q and U (compare Fig. 2a).*
(b) The Q-U locus from the double-wave fit for HDE 311884. The results are $i = 76\overset{\circ}{.}9 \pm 1\overset{\circ}{.}7$ and $\Omega = -32\overset{\circ}{.}8 \pm 4\overset{\circ}{.}0$. Note how the more elongated shape here compared to the curve of Fig. 2b leads to a higher orbital inclination.

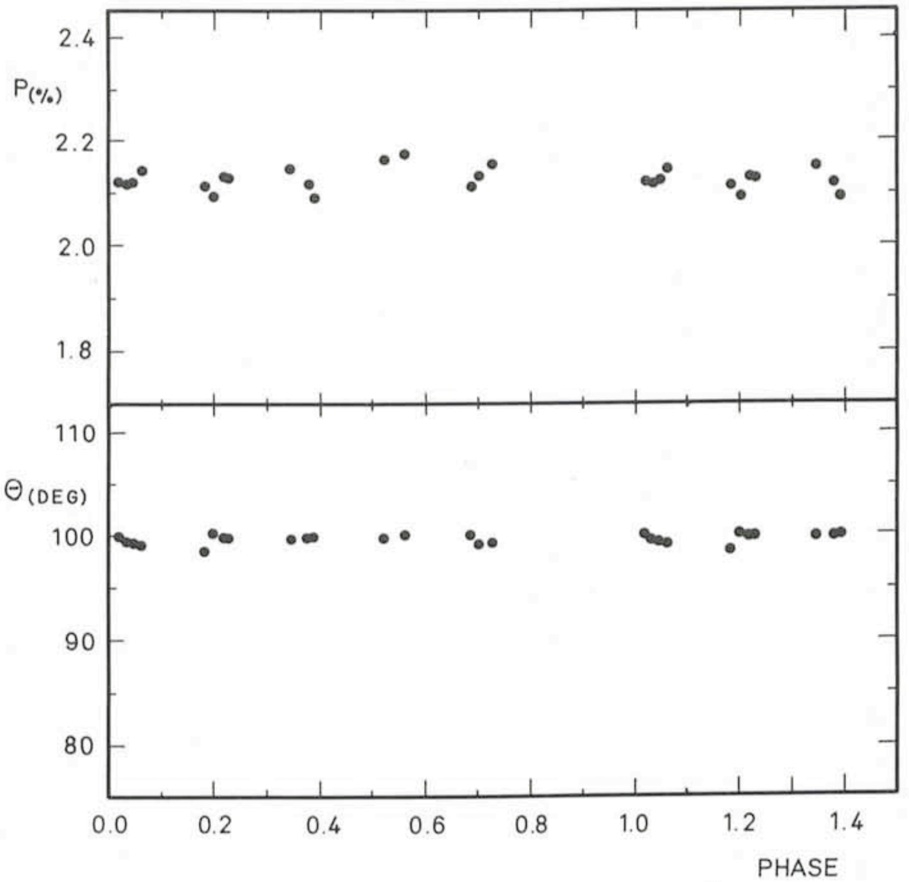

Figure 4: *P and θ versus orbital phase for the 03 V +08 V binary HD 93205 (period 6.0810 d). Periastron passage occurs at phase 0.0 ± 0.1.*

system. These masses are in line with previous suspicions that the hotter WN stars tend to be less massive on the average than the cooler ones. In fact, HDE 311884 is the most massive known WR star. We will save deriving mass loss rates $\dot{M}$ for these stars until we have a more substantial data base with more stars.

For the sake of comparison, we show similar observations for a double O-type binary, HD 93205, in the central part of the bright Carina Nebula (cf. Conti and Walborn 1976). This system, of type O3 V + O8 V, with a period of 6.0810 d in an eccentric orbit (e = 0.49), contains the earliest main-sequence star known in a binary. It is of great importance to estimate its mass. Our results, shown as plots of P and θ versus spectroscopic orbital phase in Figure 4, were somewhat disappointing to say the least, since they failed to reveal a significant modulation. Contrast this with the WR binary HDE 311884 in Figure 3, of similar period and thus similar orbital separation! In retrospect however, it may not be too surprising that the amplitude of HD 93205 is so small, since O-type stars (even the hottest ones) especially near the main sequence, are known to have mass loss rates that are generally a factor ≳ 10 less than the mass loss rates of WR stars. Our polarization data here confirm this. Hence, the mass of the O3 V star must remain as a lower limit on the basis of the spectroscopic orbit: $M_{O3V} \sin^3 i = 39 M_\odot$.

Acknowledgements

We wish to congratulate K. Metz and his team for the fine work in constructing such a superb instrument. We are very grateful to ESO for observing time, and to the ESO mountain staff, especially our introducing astronomer Hugo Schwarz, for able assistance at the telescope and the reduction terminal. AFJM acknowledges financial support from the Natural Sciences and Engineering Research Council of Canada, WS from the Deutsche Forschungsgemeinschaft.

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HR 4049: an Old Low-Mass Star Disguised as a Young Massive Supergiant

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Preface

Scientific collaborations can be triggered by fortuitous circumstances. The common project we report on here started in a bizarre way. Two of the authors (HL and CW) first met during a third-cycle course in Han-sur-Lesse in the south of Belgium, where HL was lecturing on mass loss in massive stars. During a conversation it turned out that we were both puzzled by results we had obtained on a southern late-B super-

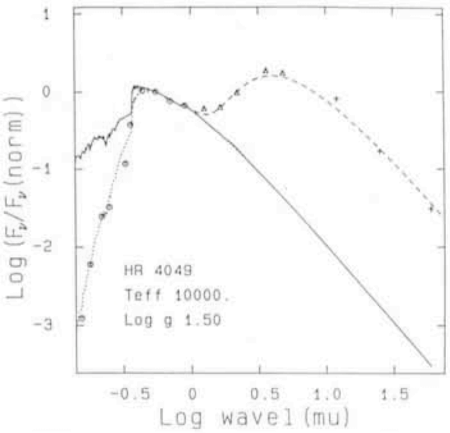

Figure 1: *Observed energy distribution of HR 4049 and model fit as described in the text.*

giant. HL was involved in a study of the most unusual UV deficit and IR excess of the object HR 4049 while CW had been monitoring for several years the large-amplitude and long-time-scale photometric variability of HD 89353. Knowing that there are approximately 9,000 stars in the Bright Star catalogue and 225,000 in the HD catalogue, and realizing that

$$4049/9120 \approx 89353/225000 \quad (1)$$

we considered it probable that we were actually discussing the same object, but we had no Bright Star Catalogue at our disposal to check this conjecture. So, CW decided to drive back to his home institute in Leuven the same evening and could verify that the conjecture was true. That exciting moment was the beginning of a collaboration on HR 4049 and possibly similar stars, in which several colleagues have joined now. Eventually, we must confess that, two years later, equation (1) still led to about the only confirmed prediction we could make concerning our star: indeed, the star has yielded continuous surprises. But we always have our Bright Star Catalogue with us when we travel!

Energy Distribution of HR 4049

The fifth-magnitude star HR 4049 has been classified as B9.5 Ib–II. One may wonder how the peculiarity of such a bright object was noticed only now, after about one century of monitoring of the southern sky. The answer is that the exotic nature of some objects only becomes apparent from observations in space, at wavelengths outside the visual range. HR 4049 is in that respect a typical case. Although we shall see below that the visual behaviour is by no means normal, it is at shorter and longer wavelengths that HR 4049 most markedly revealed its peculiar nature. With respect to normal stars with the same spectral type, it is severely underluminous in the ultraviolet, and it presents an impressive excess in the infrared. It partly was the detection of this excess with the IRAS experiment that started interest in this star. Accordingly, UBV and near-IR observations were obtained at ESO, by Mario Perez. UV data were also available, as the star had been measured by both the S2/68 space experiment and the ANS Orbiting Ultraviolet Telescope.

The observed energy distribution of HR 4049 is plotted in Figure 1. The star is located at intermediate galactic latitude, so that interstellar reddening is small. Various determinations led to a most likely value for the reddening E (B–V) of 0.10 mag. This value is somewhat uncertain because of the colour variability (see below). However, the uncertainty does not affect the main conclusion, which is that the energy distribution of HR 4049 is characterized by three components:

(1) A model atmosphere flux with low gravity and a temperature of about 10^4 K (the continuous line on the figure). The visual energy distribution thus agrees well with the spectral type, so that it is not so surprising that the peculiarity of the object was not noted earlier.

(2) A circumstellar absorption component, which is very pronounced in the UV and which causes additional reddening of B–V by about 0.15 mag. Shortwards of 5000 Å the absorption scales as $1/\lambda$. The energy deficit with respect to the model atmosphere amounts to 5 mag at 1550 Å. Of course, adopting a lower temperature would lessen the deficiency. It is not possible, however, to account for the whole UV spectrum of HR 4049 by merely changing the effective temperature of the model. The $1/\lambda$ absorption law indicates that the size of the absorbers is smaller than about 500 Å.

(3) A circumstellar dust component which manifests itself through emission in the infrared. The excess flux can be represented accurately by a black-body spectrum with a temperature of 1250 K. From the flux at maximum of the excess it is found that the effective area of the IR source is 800 times as large as the stellar disk. A black-body is not the only possible model for the excess IR flux, but the order of magnitude of the temperature and size given here is realistic.

The Spectrum

The energy distribution of our star in the visual may be not markedly peculiar, but the spectrum surely is. The main criterion for classifying HR 4049 as B9.5 Ib–II was the appearance of the Balmer lines. However, H. Abt (see Morgan, 1984) found that the other spectral features do not fit the MK classification: while the narrow Balmer lines suggest an A0I-type, the Ca II lines are very weak for this type, the He I line at 4021 Å is absent, as are the expected lines of Fe II and Mg II.

We have obtained several coudé spectra of HR 4049 at ESO, using the 1.52-m and 1.4-m CAT telescopes. A 12 Å/mm spectrum in the range 3622–3900 Å is shown in Figure 2. The spectrum is remarkably regular and shows nothing but the Balmer lines from H9 to the Balmer limit. In fact, we had problems to convince some colleagues that we were showing them a stellar spectrum and not a hydrogen spectrum made in the laboratory! The last line of the series that can be identified is H30. Such a large number of Balmer lines is typical for low-density atmospheres and is the main reason for the classification of HR 4049 as a supergiant.

Describing the other characteristics of the visual spectrum is easy: it is essentially cataloguing lines that are absent.

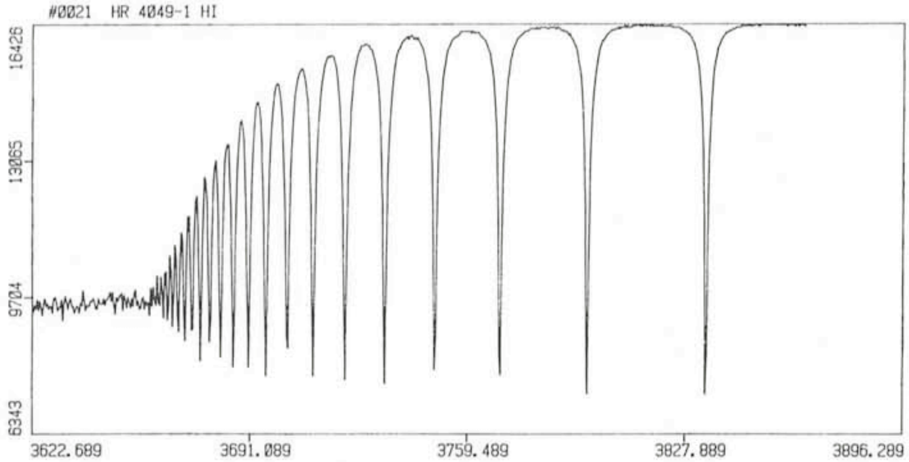

Figure 2: *A blue spectrum of HR 4049 taken with the ESO 1.52 coudé. The ordinate is expressed in arbitrary units.*

None of the stronger helium lines are seen, even at the high resolution of the CES. On our 12 Å/mm spectra there is no trace of lines of Mg II, Fe II, or Cr II, lines that tend to be prominent in early-A supergiants. Some weak features are present, however. The Ca II H and K lines and Na D lines show a weak stellar component, besides several interstellar ones. The most prominent lines besides the Balmer lines belong to neutral carbon. These lines, which arise from metastable levels with rather high excitation potential, imply a very strong overabundance of carbon. The only other lines we have identified are two weak lines of O I.

The difference between HR 4049 and normal early supergiants is still more prominent in the UV. An IUE low-resolution spectrum was kindly obtained for us by Dr. A. Cassatella from Vilspa in Madrid. Many spectral features are seen, but nothing in common with spectra of typical late-B or early-A-supergiants. Had we not seen the visual spectrum, where line identification is not so difficult, first, we would never have been able to interpret the IUE spectrum. But now it appears that almost all lines in the UV spectrum can be identified with C I or C II. So both the UV and the visual spectrum indicate that HR 4049 is a very metal-deficient star with a high C-abundance.

HR 4049 as a Post-AGB Star

Anticipating other observational results, we may already make a guess on the nature of our star. Unlike normal supergiants, it is certainly not a massive star. Massive stars are young and therefore metal-rich. Moreover, they tend to be confined to the galactic plane, near the place where they were born, while HR 4049 is located at a galactic latitude of 26°. The only known possibility for a low-mass star to appear with $T = 10^4$ K and a low gravity is the rapid transition in the upper part of the HR-diagram that a star undergoes when it has terminated its evolution as a red giant.

At the end of its evolution as a red giant – on the so-called asymptotic giant branch or AGB – a star less massive than five solar masses has a degenerated CO core and is burning helium and hydrogen in shells around the core. In its cool and tiny outer layers molecules and dust are formed. Because of instabilities in the envelope these outer layers are gradually expelled from the star and eventually decouple from it. As long as the energy production by H and He burning shells is not influenced by what is going on in the outer layers, the star evolves at constant luminosity. But it shrinks as the envelope mass decreases and so the surface temperature increases. The star thus evolves leftwards in the HR diagram, at a luminosity of 10^3 to 10^4 solar. Once the temperature exceeds about 25,000 K, the outcoming photons are energetic enough to ionize the ejecta that now form an ionized shell far from the star. This shell, having been invisible at visual wavelengths so far, now shines through emission lines: a planetary nebula is born.

How then does HR 4049 fit into this picture? The very low metallicity indicates that the star is an old object of initial mass less than a solar mass. The high carbon abundance is probably due to dredge-up processes as a result of thermonuclear flashes in the He-burning shell when the star was still on the AGB. The temperature of 10^4 K indicates that the star has left the AGB and evolves to higher effective temperatures. In fact, we can locate the position of HR 4049 on the calculated evolutionary tracks for post-AGB stars by Schönberner (1981) and thus derive its mass. From a study of the wings of the Balmer lines we found that the surface gravity of the star is 100 cm/s^2. Since the post-AGB stars have a unique relation between gravity and temperature on the one hand, and between mass and luminosity on the other hand, we can derive a mass of 0.544 $M_\odot$ from T and g, and a luminosity of 1.3 10^3 $L_\odot$ from this mass. The luminosity and the apparent visual magnitude indicate a distance of 400 pc. So, despite its original classification as a massive early-type supergiant, the star consistently turns out to be an old low-mass star!

Although we are confident that the post-AGB scenario applies for our star, several problems remain. First, it turns out that HR 4049 is abnormally bright in the visual, compared with other post-AGB stars. Usually the post-AGB stars are embedded in a thick dust cloud ejected on the AGB, and the ratio of visible to infrared luminosity is very small. In contrast, HR 4049 suffers only little extinction in the visual. Second, the dust temperature of 1,250 K is fairly high and seems to contradict the hypothesis that this dust was ejected on the AGB. If the dust was ejected on the AGB, it would have reached a distance of the order of 1 pc, and have a temperature close to 30 K.

The first problem is probably related to the low mass of the star. The duration of the transition from the AGB to the left of the HR diagram is a strongly decreasing function of mass. So the dust which was ejected during the AGB phase may now be at such a large distance that it hardly affects the visual luminosity. In fact, we are not at all sure that our star eventually will manage to become a planetary nebula. When the lowest-mass stars finally reach the 25,000 K temperature necessary for ionizing their circumstellar component, this component is already too far away and too dispersed to be seen as a planetary nebula. Interestingly, some excess flux at 100 micron was detected by IRAS: there is evidence that an additional cool dust component which no longer behaves as a point source is present. Probably, this component is the dust shell ejected on the AGB.

As for the second problem, the high temperature indicates that the dust which emits the bulk of the IR radiation is still relatively close to the star. Maybe it is presently formed by mass loss from the star. But what can be the physical cause of this mass loss?

Will Variability Provide the Key?

So far we did not focus on the other way our interest arose in HR 4049: the variability. The photometric variability was detected in the Bright Star survey that was carried out in the Geneva system with the Swiss telescope at La Silla. Thanks to the generous awarding of telescope time for this long project by Professor Rufener, the star has been monitored with Swiss precision continuously since late 1982. The visual-magnitude data are shown in Figure 3. HR 4049 stands out among variable

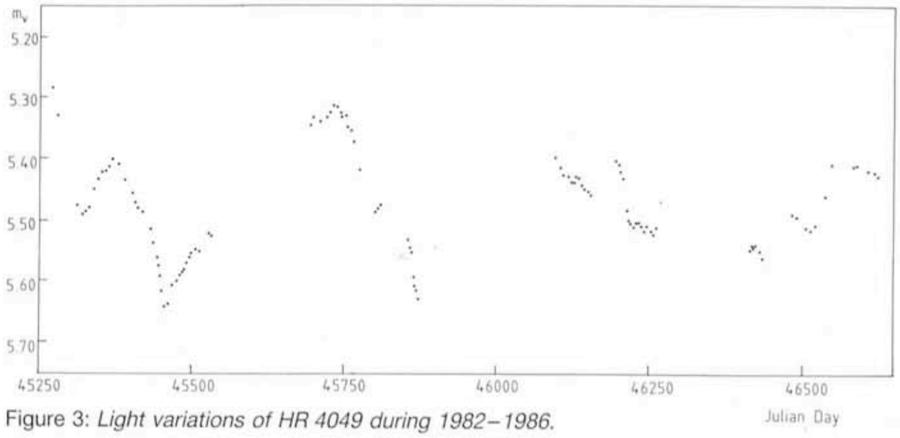

Figure 3: *Light variations of HR 4049 during 1982–1986.*

early supergiants by its large amplitude (up to 0.65 mag in U, 0.50 mag in B, and 0.35 mag in V) and its very long time scale (440 days). Since 1985 the star was also observed repeatedly in the infrared by ESO staff astronomer Thibaut Le Bertre. The variability is seen until 3.4 micron, where it amounts to 0.03 mag. Light curves are in phase over the whole spectral range observed. The amplitude roughly follows a $1/\lambda$ law.

It seems established that the variability is due to intrinsic variations of the underlying star, but what is going on is not clear at all. The period is much too long for radial pulsation, and colour variations are very large for nonradial pulsation. During the brightening of the star in early 1987 a series of high-resolution observations of the Hα-profile was obtained. There is a correlation between the photometric and spectral variability. The Balmer lines Hα and Hβ show (variable) emission components with central absorptions, and are best interpreted in terms of a decelerated outflow of mass from the star.

HR 4049 thus being a mass-losing variable star, it may indeed be that the dust envelope which is observed was not expelled during the AGB, but is of more recent origin. That could explain the high temperature of the dust and may be compatible with the faintness of the envelope relative to what is seen in candidate-proto-planetaries. This possibility raises the interesting questions whether other post-AGB stars also undergo a HR 4049-like phase, and, if so, how this phase does contribute to the planetary nebula.

More about the Dust of HR 4049

Unraveling the peculiarities of HR 4049 will need more observational efforts. These efforts may be rewarding in a broader scope than originally aimed at. As an example, it turns out that HR 4049 is a very interesting laboratory for the study of the interstellar medium. In general, interstellar dust contains various components which are not easily deconvolved. On the other hand, the composition of HR 4049 is so peculiar, that its dust may be expected to be peculiar as well. Indeed, although the UV deficiency of the object is extremely severe, there is no trace of the 2200 Å feature which is normally prominent in interstellar dust. On the other hand, the dust features at 7.4, 8.6, and 11.6 micron are clearly seen in the IRAS low-resolution spectrum. These last features have recently been attributed to the so-called "polycyclic aromatic hydrocarbons" or PAH's. The presence of PAH's in the dust of HR 4049 is not surprising, since hydrogen and carbon are so prominent; in fact the dust may be remarkably devoided of impurities. It is interesting to point out that the PAH's do not produce a significant 2200 Å absorption feature in the UV energy distribution of HR 4049. This supports the idea that PAH's are not responsible for the interstellar 2200 Å feature.

A Quest for Similar Objects

When an astronomer has encountered a strange object, he studies it, but also searches for other similar ones. If he is lucky enough and succeeds in finding a second one, he defines a class. Very soon, he has a class and some exceptions. That was also our experience. We think that it is probable that HR 4049 is related to some other supergiants with infrared excesses. Most of these stars are variable, many of them are high-latitude objects, some of them are metal-deficient. One of the most interesting stars in our sample may be the high-latitude ($b = 56°$) faint ($m_v = 8.8$) early-A supergiant HD 213985 (Waelkens et al., 1987). This star has an energy distribution not unlike that of HR 4049 and shows similar photometric variations; however, HD 213985 does not seem to present obvious spectral peculiarities. In fact, the more similar stars we find, the more pronounced does appear the peculiarity of HR 4049. So we found a class, but the exception is the very star we started with.

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Supernova 1987A

A Summary of the ESO Workshop held from 6–8 July 1987

S. VAN DEN BERGH, Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, Victoria, Canada

This has been a really exciting meeting! Not only have we heard many new results, but it has also provided a fine example of how science should be done. In particular we had vigorous interplay between theory and observation, contributions from a variety of wavelength regions and intense international collaboration.

In his introductory paper West showed that astrometry of SN 1987A places this object within $\Delta\alpha.\cos\delta = 0''.00 \pm 0''.04$ and $\Delta\delta = -0''.04 \pm 0''.05$ of the star Sk −69°202. This close positional agreement, plus the disappearance of Sk −69°202 in recent IUE spectra (Gilmozzi, Kirshner) shows beyond reasonable doubt that the B3I star Sk −69°202 was the progenitor of SN 1987A.

Sk −69°202 (star 1) has close companions (White and Malin) with V = 15.3, d = 2''.65 (star 2) and V = 15.7, d = 1''.4 (star 3). The a priori joint probability that Sk −69°202 should have two such close companions is $\sim 10^{-5}$ i.e. it is virtually certain that Sk −69°202 was a member of a physical multiple system. Since members of such a system are coeval, the progenitor of SN 1987A must have had a larger mass than the relatively unevolved star number 2. Assuming this star to be a main sequence object its magnitude $M_V = -3.6$ places a lower limit of $\sim 10\ M_\odot$ on the main sequence mass of the supernova.

A pre-outburst objective prism spectrum of Sk −69°202 (Wamsteker et al.) shows that N II λ3995 was significantly stronger in the supernova progenitor than in the B3Ia star Sk −67°78. Furthermore Kudritzky reported finding that Sk −65°21 and Sk −68°41 have helium abundances (by number) y = 0.35 ± 0.05 and y = 0.23 ± 0.05, respectively. This high helium abundance shows that at least some LMC blue supergiants are highly evolved post red giant objects. This conclusion is greatly strengthened by Cassatella's recent IUE spectra of SN 1987A which show that [N/C] ~50 to

80 and [N/O] ~2. This indicates that C has been converted almost entirely into N. A similar result had previously been found in the type II-L supernova 1979C.

The following is a summary of some of the photometric and spectroscopic properties of the supernova progenitor obtained by various Workshop participants: The star Sk −69°202 had V = 12.33 (after the contribution of stars 2 and 3 has been removed). From inspection of plates in the Harvard plate files Hazen finds no evidence that the SN progenitor exhibited significant variability during this century. From UBV photometry Sk −69°202 is found to have had E(B-V) = 0.17 ± 0.02. Objective prism spectra of the SN progenitor show no evidence for Hα emission. Finally IRAS scans of this part of the LMC do not show a signal at the position of the supernova indicating that there was no bright dust-shrouded object present at the position of the supernova. Polarization observations reported by Cannon, Menzies and Schwarz exhibit a constant foreground polarization of ~0.5% on which variations of up to ~1% are superimposed. This result suggests some patchyness in the expanding shell. Nevertheless, high-speed photometry by Helt shows no evidence for random brightness variations ≳0.005 mag on timescales of minutes to hours.

The most peculiar feature of SN 1987A remains its light curve. The supernova luminosity increased slowly for 3 months before finally reaching maximum between 1987 May 20 and 25. No other supernova has ever been observed to have a light curve quite like that of SN 1987A. The most likely explanation for this peculiar behaviour and for the low luminosity [M_V(max) = −14.9] of SN 1987A is that an unusually large fraction of its energy went into expansion of its atmosphere because the precursor was a blue supergiant at the time of core collapse. The idea that a supernova with a low-density envelope (i.e. a red supergiant) will emit more optical radiation than one with a denser (blue supergiant) atmosphere was, I believe, first proposed by Virginia Trimble. A possible problem with this view is that one might expect late-time (T ≳ 100 days) evolution of SN 1987A to be similar to that of other SN II. This does not appear to be the case since SN 1987A has B-V = 1.7, compared to 0.7 ≲ -V ≲ 0.9 for the 4 other supernovae of type II that have been well observed at T ~ 100 days.

Cassatella and Kirshner find that narrow emission lines, which may be due to excitation of material at a distance of ~1 × 10^{18} cm, began to develop in late May. Moneti showed that recent observations over the range 1 < λ < 20 μ can be represented by the sum of two black bodies having temperatures T_{BB} ≈ 1200°K and T_{eff} ≈ 5500°K. The IR luminosity of the supernova is presently increasing linearly at a rate of ~1 $L_\odot$ per second! It is not yet clear whether the IR excess in the spectrum of SN 1987A is due to free-free emission or to a dust echo from material at ~1 × 10^{18} cm from the supernova. Radio observations (Manchester) show that SN 1987A is not embedded in a dense circumstellar shell. Presumably the material at R ~1 × 10^{18} cm will become a powerful source of radio radiation ~30 years from now when it is overrun by the shock wave from the supernova.

Van den Bergh used the frequency of supernovae discovered by Evans in Shapley-Ames galaxies to estimate a supernova frequency of approximately one per 500 years in the LMC. From N(novae)/N(SNIa) = (4 ± 2) × 10^3 and Graham's estimate of 2 to 3 novae per year in the LMC van den Bergh obtains an estimated SNIa rate of 0.6 per thousand years in the Large Cloud.

Speckle observations by Meikle and by Chalabaev indicate that a bright "mystery spot" is associated with SN 1987A. According to Peter Meikle this unresolved source is invisible in U and B, marginally visible (Δm ~4 mag) at 5876 Å and clearly seen (Δm ~3 mag) at 6585 Å. The separation between the mystery spot and the supernova may have increased from 58 to 74 m arcsec during the period of observation. Some form of energy storage would appear to be required to account for the high luminosity of the spot. Alternatively kinetic energy could have been fed to the spot directly via a "jet". Such a jet might be similar to the sulfur jet seen in Cassiopeia A (van den Bergh and Kamper). It would be interesting to know if the compact H II region that Djorgovski appears to have found 1″8 from the supernova is related to the mystery spot phenomenon or whether it represents an object related to the nitrogen-rich knots (Walborn) that are found to surround the supernova-like variable η Carinae. Pacini pointed out that a jet may develop when a plasma cavity surrounding a pulsar at the centre of a supernova develops a leak. Such a jet may break out some time before the pulsar itself becomes visible from Earth.

Perhaps the most exciting question discussed at the workshop was why SN 1987A was so different from any other supernova that has been observed to date. Part of the reason for such differences is, no doubt, that the progenitor of this object was a blue supergiant rather than a red supergiant. Maeder, Truran and Renzini all emphasized the fact that considerable "fine tuning" of models is required to produce core collapse in a blue supergiant. Parameters that can be adjusted are ṁ and/or Z, m(ZAMS), V(rotation) and the amount of convective overshoot.

Reports on observations of neutrinos produced during core collapse represented one of the highlights of the Workshop. The reality of the Mt. Blanc neutrino event was the subject of lively debate. A closely related question is whether the time delay between formation of a neutron star, and its subsequent collapse to a black hole, amounts to hours or microseconds!

Branch showed that rather crude synthetic supernova spectra are able to reproduce the main features of the observations quite well. In particular he finds that the λ 6050 feature in SN 1987A can be reproduced without having to appeal to a greatly enhanced Ba II abundance. From an application of the Baade-Wesselink method to SN 1987A Branch obtains a distance of 55 ± 5 kpc, which is quite similar to the canonical LMC distance of 50 kpc.

Because of its enormous luminosity SN 1987A represents an ideal probe of the interstellar medium allowing very high dispersion spectroscopy. (After 1987 February 28 the UV brightness of the supernova became too faint to use that part of the spectrum for interstellar line studies). Andreani, de Boer and Grewing reported observations of between 24 and 40 distinct velocity components in their interstellar line spectra. These lines appear to fall into 4 distinct groups: (1) Clouds with V ~0 km s^{-1} are clearly of Galactic origin. (2) Clouds with 50 < V < 150 km s^{-1} are located in the Galactic halo (or in a bridge between the Galaxy and the LMC). In these clouds the Na I/Ca II intensity ratios are low i.e. calcium is less depleted in them than it is in Galactic and LMC clouds. (3) Material with V > 150 km s^{-1} is clearly associated with the LMC. (4) A feature with V = 220 km s^{-1} is believed to represent a shell surrounding Sk −69°202.

An EUV pulse is expected to develop when the shock generated by core collapse reaches the surface of a SN progenitor. The total energy in such a pulse, which is expected to have 1 × 10^5 < T < 1 × 10^6 °K, will be ~10^{48} erg and the peak luminosity might reach ~10^{46} erg sec^{-1}. Such an EUV pulse will generate electrons in the upper atmosphere of the Earth. Ögelman made the interesting suggestion that such a pulse from SN 1987A might be revealed by an increase in the night-time conductivity of the E layer.

The Gaseous Environment of the Supernova 1987A in the Large Magellanic Cloud

A visual inspection of a deep photograph of the region centred on 30 Doradus obtained in the light of the gaseous emission of ionized hydrogen (e.g. the Hα pictures by Elliott et al. 1977, *Astron. Astrophys.* **55,** 187 and the multicolour photograph published in the *Messenger* No. 48) clearly suggests that the supernova occurred within the boundaries of that supergiant H II region. This is hardly surprising: the 30 Dor complex is the largest concentration of young, massive stars in the Local Group of galaxies and as massive stars are the progenitors of type II supernovae there was a high chance to observe the first close-by supernova in modern times in that region.

The supernova is located at about 21 arcminutes from the centre of 30 Doradus; the gaseous emission, although not as strong as in the centre of the nebula, is still quite prominent. There is no published study in the literature of the distribution of ionized gas in the direction of the SN. It will be difficult for some time yet to obtain a deep exposure of that area without saturating the detector with the light of the supernova. We circumvented this problem by using a reflecting spot inserted at the position of the supernova in the focal plane of EFOSC, the ESO Faint Object Spectrograph and Camera. A short description of this simple coronograph is given by Dekker and D'Odorico in this issue of the *Messenger*. Figure 1 shows an example of these masked images. Pictures were obtained in the light of Hα [N II], [S II], [O III] and the continuum. They provide an insight into the complex structure and into the ionization of the gas and will serve as a reference to study the modifications to the ionization to be induced in the coming years by the SN flash and the interaction with the ejecta.

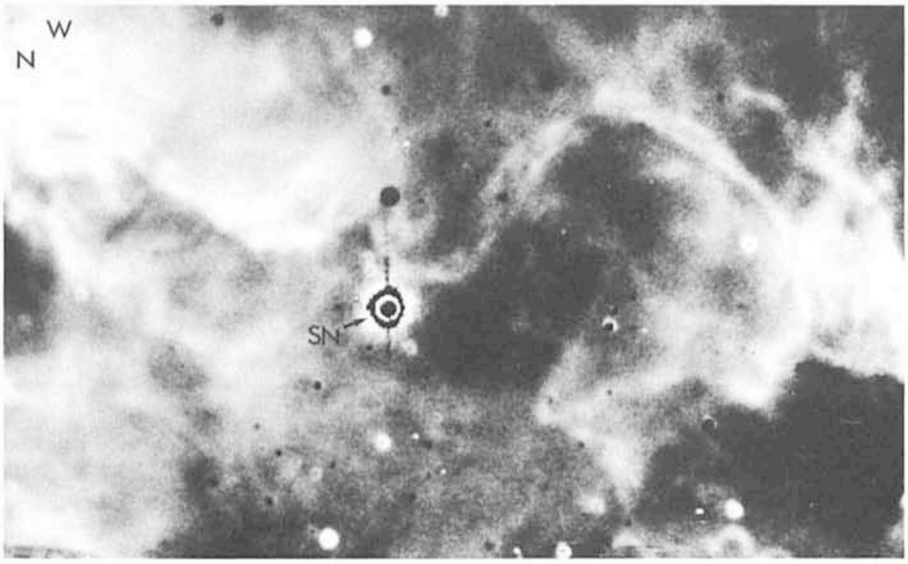

Figure 1: *The field of SN 1987A in the light of the O^{++} gaseous emission. The highly ionized gas appears white and diffuse and most of the stars appear as white dots in this picture which was obtained by subtracting from a CCD frame obtained through an interference filter centred at the 5007 Å emission line one other frame centred on the adjacent continuum. The observations are from the ESO focal reducer EFOSC at the 3.6-m telescope. About 99% of the light of the supernova (still brighter than V = 4.5 at that time) was blocked by a reflecting spot deposited on a glass plate mounted in one position of the aperture wheel of the instrument. Residual scattered light is still visible around the SN image. The exposure time of a single CCD frame was 5 minutes.*

The precursor star appears to have been located at the edges of a bright ridge of emission on one side and of a bubble on the other. The latter could be the result of a previous SN explosion or the effect of mass loss winds from massive young stars. It appears too extended to be attributed to the mass loss in the SN precursor alone. This type of structure is quite common in 30 Dor, where such energetic phenomena are relatively frequent. Their physical association with the supernova has to be proved by a detailed kinematical study, a chance projection being also a possibility.

S. D'Odorico

Updating and New Functions of EFOSC

This last August three new features have been tested in EFOSC and are now fully implemented in the instrument. This brief report is intended to make users promptly aware of the new possibilities.

A New Field Lens to Reduce the Scattered Light

The most serious shortcoming of EFOSC in the first two years of operation was possibly the so-called sky concentration, a diffuse spot of light 5–20 % above the background in the centre of the image which is caused by light – from the sky background and stars – reflected by the CCD back into the camera and returned by some optical surfaces, the main contribution coming from the field lens.

Careful flat-fielding could take care of this effect, which however remained the main limitation to the photometric accuracy of the instrument. Following a new design by Bernard Delabre, a new field lens has been manufactured and has been successfully integrated in the camera. The first tests show that the sky concentration is now reduced to 1–5 % depending on the CCD and the filter used. The scale of the instrument is now very slightly modified (0.674 arcsec/30 μm pixel). As of the end of August, the new lens is routinely used in the instrument.

A Coronographic Option in the Direct Imaging Mode

A simple coronograph provides now a new observing mode option in EFOSC. It consists of a coated glass plate on which 6 reflecting spots have been deposited. The current diameters are 1.5, 2, 3, 4, 6 and 8 arcseconds. The plate is mounted in the focal plane of the telescope in one of the positions of the aperture wheel and it is therefore compatible with the other observing modes. It is used in conjunction with a pupil mask mounted in the grism wheel which reduces the contribution of the scattered light acting as a Lyot stop (1, 2). Due to bad weather during the test period the performance of the system could not be explored in depth. We would welcome feedback comments from future users.

A Spectropolarimetry Option

Following the positive experience with field polarimetry with a Wollaston prism (3) a second Wollaston of larger size (to avoid vignetting when mounted on the grism wheel) has now been installed. It can be used in combination with any of the standard slits and grisms for spectropolarimetry of objects as faint as 19th magnitude. The separation between the two images (or spectra) of perpendicular linear polarization is 20 arcseconds. If sky subtraction in the spectra is essential, special care must be taken in the alignment of the Wollaston to obtain an image separation along the rows of the CCD.

H. Dekker and S. D'Odorico

References

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2. F. Paresce and C. Burrows, 1987, *The Messenger* **47,** 43.
3. H. Dekker and S. D'Odorico, 1986, *The Messenger* **46,** 21.

Remote Control from Garching

As an alternative to travelling to La Silla, remote control from ESO Garching has been offered to astronomers with observing time at the 2.2-m telescope since 1st July 1987. The instruments available are a Boller & Chivens spectrograph with a CCD detector and the CCD used directly with the 2.2-m adapter.

The same control consoles as those in the 2.2-m telescope control room are available to users in Garching. They can obtain field monitor, finder telescope frames and CCD images on-line, and are able to send commands to instruments and telescope (see picture). This is made possible by a leased line, which is also used for telephone communication.

Although most of the allocated July nights turned out to be almost unuseable due to bad weather, several astronomers had the opportunity to become familiar with the system.

Field identification of fairly faint objects (m_v = 19, seeing = 2″) was also attempted satisfactorily with a B & C in a test night in August.

By October 1987, the CES spectrograph (using the CAT telescope) with CCD will also be available by means of remote control from Garching.

G. Raffi

Remote control consoles at ESO Garching.

Figure 1: *The NTT Telescope at INNSE at Brescia (mid-August 1987). Photo: H. Zodet, ESO.*

Figure 2: *The NTT building on La Silla (Arch. U. Tolomeo).*

NTT Progress

Since the last issue of the *Messenger*, the mechanical pre-assembly of the NTT at INNSE Brescia (Italy) has been completed and the electronic hardware and software integration has started.

Figure 1 shows the telescope structure. The optical elements are being polished at Carl Zeiss and completion is expected by summer 1988. In the meantime, the primary, secondary and tertiary mirrors are substituted by steel concrete dummies while the telescope enters a phase of functional tests. It is expected to be shipped to Chile in March 1988.

Major advances have been made in the sphere of building activities and site preparation in the civil engineering work has begun on La Silla (construction of road, concrete base and service annex). The rotating building has been manufactured in Europe and is expected to be shipped to Chile in October 1987.

Figure 2 shows an artist's impression of the NTT building in its future location on La Silla. The innovative design of the building distinguishes it from the traditional dome structures.

Both building and telescope are manufactured in such a way as to facilitate mounting and dismounting. *M. Tarenghi*

Site Evaluation for the VLT: a Status Report

M. SARAZIN, ESO

The instrumentation for the VLT site seeing evaluation programme has been progressively installed at La Silla and tested there during the course of 1986. Part of it was calibrated during the Lassca campaign against various optical measurements made on the La Silla telescopes (*The Messenger* No. 44).

It includes a 35-cm diameter optical telescope equipped with the differential motion monitor, an acoustic sounder (sodar) to probe the atmospheric turbulence up to 800 m above the site, a scintillometer which delivers information about the turbulence in the high atmosphere and a local turbulence monitoring system using fast temperature and wind speed sensors.

Figure 1: *Trailed Sodar, Seeing monitor and control room shelter.*

During that time, the cloud cover and water vapour survey undertaken four years ago was continuously confirming the superior quality of the Atacama desert area and in particular of coastal summits between Taltal and Antofagasta. Cerro Paranal was picked up as the best candidate and after the construction of an access road and the erection of a 5 metre high tower, measurements could start in April 1987.

The instruments are gathered at the Northern edge of the summit (Fig. 1). Assuming that most short-scale variations of seeing quality would be mainly produced by boundary layer effects, the acoustic sounder was made easily movable to evaluate the suitability of the mountain slope for long-baseline interferometry. It is also aimed to probe several closeby summits and establish the total housing capacity of the site for other telescopes. It is also of prime interest to use the redundancy of the instruments to check from time to time that the total seeing measured at the telescope corresponds to the sum of the three other specialized instruments.

The type of optical measurements to use for site evaluation has been extensively discussed during the meetings of the Site Evaluation Working Group in 1984–1985 and the best choice for mobile instrumentation appeared to be the differential motion monitor. Such a system does not need a large telescope, neither a very stable mount and is not sensitive to optical quality. It performs a statistical measure of the wavefront quality by comparing the local slopes on two 5-cm diameter apertures, 20 cm apart. The variations of the slope of the wavefront are responsible for the motion of the star image. The image corresponding to each subaperture are physically separated on the intensified CCD detector, and their relative positions are measured in real time at a rate of five 10-ms exposures per second. The better the seeing is, the smaller will be the wavefront distortions and consequently the differential motion of the two images.

The telescope (Fig. 2) is placed a few metres above ground to escape from ground turbulence, dust and human hazards. It works in the open air to minimize self-induced seeing. Apart from the fine centring of the star in the finder, the experiment is remotely operated from the control room (Fig. 3) where the observer checks the telescope guiding and is informed every minute of the seeing variations, as well as of the local turbulence and the scintillation (measured on the same object).

Bright stars less then 30 degrees from

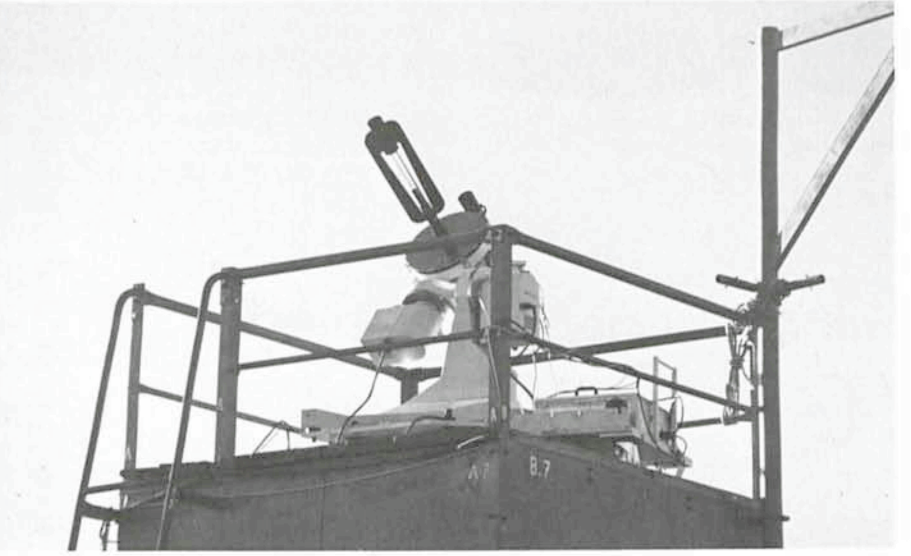

Figure 2: *The Seeing monitor telescope.*

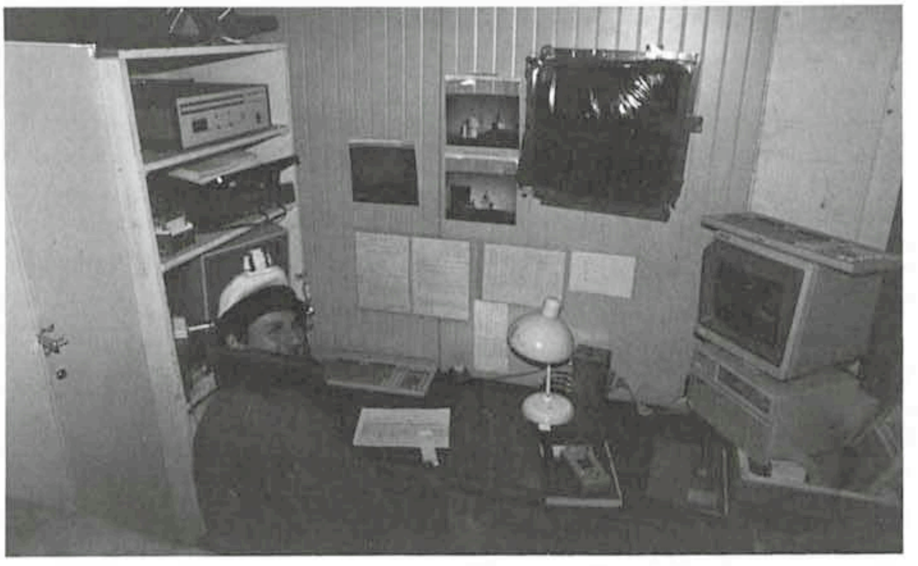

Figure 3: *Paranal control room.*

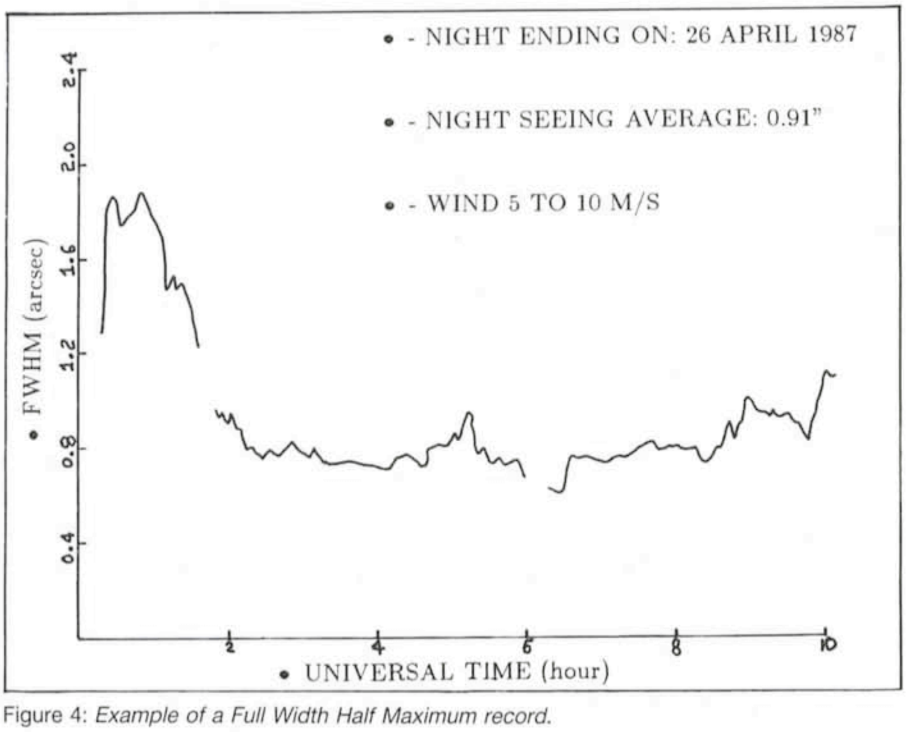

Figure 4: *Example of a Full Width Half Maximum record.*

the zenith are used, three objects are necessary to cover a full night. Results up to now confirm that, as at La Silla, the seeing may vary much during the night and from one night to the other. A typical example is presented in Figure 4 where the data have been averaged with a 5-mn moving window. Due to probable seasonal effects, a full year will be necessary to present a preliminary assessment of the quality of Paranal. At the end of July, thanks to the efforts of the Paranal team and to the technical support of La Silla, more than 70 % of the photometric nights had been monitored. The unique data base thus created will also permit a better parametric analysis and thus a first step towards the ultimate goal for flexible scheduling: the prediction of observing conditions . . .

MIDAS Memo

ESO Image Processing Group

1. Application Developments

An optimized digital filter to remove cosmic ray events from single CCD exposures is being developed in collaboration with M. Deleuil. The filter locates possible cosmic ray events and compares them with the point spread function to determine the probability of it being a cosmic ray. At a given probability level, pixels effected by such events can then be replaced either by a NULL or on interpolated value.

The FITS input/output commands can now also work directly on disk files. This makes it possible to transfer data files in FITS format over a Local Area Network to workstations which do not have their own tape unit.

The table file editor, one of the favourite commands, has been extended; now it is possible to create and delete columns during the editing session and to search for an entry in a given column. A new command allows the interpolation of data using splines; this command, working both on images and/or tables, complements the capabilities already provided by the rebin operator.

The plotting facilities have been further upgraded with some new features and commands. The ASSIGN/PLOT command has been redefined to make it more consistent with the other ASSIGN commands in the system; the old functionality of this command has been taken over by a new SEND/PLOT command. Also, some new OVERPLOT commands have been added. Among the new features the most important ones are: the possibility to specify scales, the support to different line types, and the separate manual specification of the x- and y axis.

2. Communication

The number of computers connected to the ESO Local Area Network is steadily increasing. In order to provide a homogeneous interface to external institutes a dedicated communication processor (Bull SPS 7/300) has been purchased. This processor is connected to the ESO network and will act both as a gateway to external electronic networks and provide general services to the ESO community such as bulletin boards. The special computer for communication makes internal changes to the ESO computer systems transparent to external users and should therefore utilize an easier communication between ESO and the user community. The implementation of this system has already been started and is expected to be terminated in the spring of 1988.

3. MIDAS Hot-Line Service

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

- EARN: MIDAS @ DGAESO51
- SPAN: ESOMC1::MIDAS
- Tlx.: 52828222 eso d, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

Also, users are invited to send us any suggestions or comments. Although a telephone service is provided, we prefer that requests are submitted in written form through either electronic networks or telex. This makes it easier for us to process the requests properly.

Five Nights on a Bare Mountain – an Outsider's Look at La Silla

G. SCHILLING, Utrecht, the Netherlands

The person in front of me is nearly unrecognizable. In the first place, it is very dark around us. Secondly, he is completely wrapped up in a fur jacket, with a cap around his head. The air temperature is just below zero, but that isn't the worst. It's the icy northern wind that blows literally through everything, and that's chilling you to the bone. The person's hands are uncovered, because he has to write, push buttons, turn dials, etc. His fingers must be frozen to death. He has already been working for about six hours, and after a short break for a sandwich and a cup of coffee, he has another six hours to go. This goes on for several nights, all of them cold and windy. No labour union would tolerate such severe working conditions. Nevertheless, this person doesn't complain. He loves his work. He is an astronomer. We are not at the South Pole, but at La Silla, the site of the European Southern Observatory.

Since I am a science journalist rather than a professional astronomer, I have little experience with the way of life at a big observatory. In my home country, the Netherlands, only some small historical observatories exist (apart from the Westerbork Radio Synthesis Telescope of course), and Dutch astronomers are used to do their observational work abroad. For instance at the European Southern Observatory in Chile. The Netherlands has been a member country of ESO since the establishment of the organization in 1962, and always played an important role, not only scien-

Figure 1: *A familiar view for visitors of La Silla: seen from the small airstrip in the neighbourhood, the white domes of the telescopes form a tight cluster on the saddle-shaped peak.*

tifically, but also organizationally: three of the four directors general of ESO (including Prof. Harry van der Laan, who will succeed Prof. Lodewijk Woltjer) came from Holland.

Dutch astronomers are well aware of the importance of ESO for Dutch astronomy, but the general public is very *un*aware of it. So I decided to write a number of articles on ESO in newspapers and magazines on the occasion of the 25th anniversary, which will be celebrated in October 1987. Because ESO's Public Information Office does a very good job in providing journalists with all kinds of information and pictures, I probably could have written these articles behind my word-processor, never leaving my writing desk in Utrecht. Nevertheless, I felt it was important to get a personal impression of life and work at the observatory, in order to make my articles appealing to a general public. ESO was so kind as to offer me free board and lodging during my stay in Chile, as well as transport me from Santiago to La Silla and back again. So at the end of April, 1987, I said goodbye to my wife and children, and took the cheapest plane to Santiago, at the other side of the planet.

Some of the readers of *The Messenger* (theoretical astronomers for instance) may never have been at La Silla. Perhaps my short impression will give them some idea of the conducts of their observational colleagues. Others, who have been there more or less often, probably have become used to the way things are at La Silla. For them, my 'outsider's look' may be of interest.

Everything at La Silla is just the other way around compared to the situation in Europe. First, the seasons are reversed. It takes some time before you get accustomed to the idea that winter is drawing near in May. Secondly, light and dark are reversed. Not only do people sleep during the daytime and work at night, which is to be expected, but also the influence of clouds is different. In most parts of Europe, it is dark on a clear night, while a cloudy night is much brighter, because of reflection of city-lights. ESO staff astronomer Michael Rosa, whom I met at ESO's guesthouse in Santiago, prepared me for a situation in which you can easily find your way at clear nights, helped by the light of the stars and the Milky Way, while clouds block this single available light source, making the night pitch-black. He was right; it was a strange experience. I even experienced an overcast sky (no stars visible), with thin clouds being illuminated from the backside by the light of the Milky Way!

In the third place, the stars themselves are of course 'reversed' – upside down. This can be very bewildering for someone who is familiar with the constellations (it took me quite some time to recognize Leo and Bootes for example), but for most astronomers it's no problem, since they are usually not so familiar with the sky. 'I wouldn't recognize the Southern Cross,' one astronomer said to me (I won't mention his name!), and he didn't seem to be an exception. Of course, most professional astronomers do not *have* to know the constellations. Just type the coordinates of your object on your computer terminal, and the telescope will take care of the searching and the tracking. Still, to me it was a strange idea that astronomers were observing certain objects from a telescope's control room, while they even hadn't the slightest idea in which direction their telescope was pointing at that time! For instance, S. Ortolani from the Asiago Astrophysical Observatory in Italy was looking for white dwarfs in the globular cluster Omega Centauri with the 3.6-m telescope. A marvellous sight: the television-monitor was completely filled with stars, most of which were dimmer than 20th magnitude. Wouldn't it be great to step outside after you've finished observing, to be able to find ω Cen high above your head with the naked eye, and to realize that all those thousands of stars belong to that tiny, hazy blob of light?

By the way, to *me* it was also an overwhelming experience to step *inside*, onto the observing floor of the 3.6-m, to

Figure 2: *The building of the 3.6-m telescope, with the adjacent CAT tower, is reflecting sunlight. Seen from a distance, the building looks smaller than it is because of the unusual clearness of the sky. But viewed from nearby, it doesn't fail to impress anyone.*

see this huge instrument towering high above my head, and to realize that all those thousands of kilogrammes of steel are necessary only to hold a few grammes of aluminium in the right place, as staff astronomer Hugo Schwartz put it. This telescope is really *big*! People walk around in the Cassegrain cage, and I lost my way in the immense building.

For me, looking at the southern sky with the naked eye (or with my 15 × 80 binoculars) was just as rewarding as looking at the faint stars in ω Cen 'through' the 3.6-m telescope. The Eta Carinae nebula, the clusters and nebulae in Scorpius and Sagittarius, the Magellanic Clouds, the ruddy supernova 1987A and the faint patch of light of Comet Wilson could hold my attention for hours. The serenity and the vastness of the universe, completely indifferent to our activities, put me at rest and made me feel small. Standing there, right at the middle of the world's largest observatory, I could easily imagine that I was the only one present. Sometimes, there was not a single sound to hear, apart from the occasional squeaking of a rotating dome. This, and the soft, red light that shone from some of the slits, reminded me of human presence in all those domes. Isn't it a lonely business, being an observational astronomer?

During a number of nights, I was not *a* visiting astronomer, but I was visiting astronomers, walking from one telescope building to the next. I came to the conclusion that being lonely is not the biggest problem. It's the *cold*, especially in the smaller domes, where the astronomer is working at the observing floor. ESO's André Muller provided me with an observing jacket, but even then, the wind was so penetrating that working for twelve hours under these severe circumstances looked like madness. At the bigger telescopes, the separate control rooms give some relief, but still, you keep your jacket on, because it's *cold*. In addition, depending on your observing programme, there's the problem of how to spend your time. Giuseppe Galletta of Padua University, who was taking spectra of faint S0-galaxies with the 2.2-m telescope, explained to me that even the sensitive spectrograph needed ninety minutes of photon-collecting in order to produce a decent spectrum. Since the telescope is equipped with an autoguider, there is not much to do in the meantime: Galletta had plenty of time to explain his observing programme to me, while his night assistant was reading a book! And staff astronomer Bo Reipurth, who was using the Danish 1.54-m telescope for a search of pre-main sequence binaries in star-forming regions, seemed to enjoy

Figure 3: *In the first weak of May, 1987, La Silla was experiencing an unexpected snowstorm. Though unwelcome for astronomers, the snow made for some impressive sights.*

my visit as an opportunity to talk about lots of things, from astronomy education to politics.

I really enjoyed my stay at La Silla. First of all, ESO's staff people take very good care of their visitors, and the food (including scores of cakes!) was delicious. But my visit also gave me a new look at observational astronomy. Until now, when I gave a popular lecture for a general audience about astronomy, I used to tell them that nowadays astronomy has lost some of its romance from the past; that computers, remote control, autoguiding and fast electronic detectors were making astronomical observing more or less luxurious, compared to the 'old' situation in which an astronomer's eye-brow could freeze to the telescope during a six hour exposure. But now I came to realize that things are not so easy. Of course, astronomy has changed a lot in the past few decades, but observing the universe is still a challenge. It can make you suffer, but it is rewarding. In this sense, astronomy is still romantic.

However, I can foresee a time in which the romance of observational astronomy really vanishes. When ESO's Very Large Telescope will be erected in the late nineties, perhaps at Paranal, nearly all observing programmes will be carried out by remote control from ESO's headquarters in Germany. This not only means that observers won't see the telescope they are using and that they are partly working during daytime, but they even will not have the possibility to look up and wonder at the beauty of the universe. Contact with the stars will be lost forever.

Like anybody who loves astronomy, I look forward to the construction and the completion of the VLT. But I hope to stand at the base of this monster instrument one night, watching the huge telescopes swing in unison to a position in which they are pointing at a black and empty part of the celestial void, and imagining how the gigantic mirrors are catching a handful of photons from an unknown galaxy at the edge of space and time.

I'm quite sure that I will revisit ESO one day, because in a sense a visit to ESO is a visit to the cosmos.

I would like to express my sincere thanks to Richard West, who arranged my visit to La Silla; to Hans-Emil Schuster for his hospitality; to Hugo Schwartz for showing me around, and to all staff and visiting astronomers for their patience in talking to me and answering my questions.

STAFF MOVEMENTS

Arrivals

Europe:

BRUNETTO, Enzo (I), Designer-Draughtsman
PLÖTZ, Franz (D), Electro-Mechanical Engineer

Departures

Chile:

BOOTH, Roy (GB), Associate
CRISTIANI, Stefano (I), Astronomer

Europe:

RODRIGUEZ ESPINOSA, José (E), Fellow
DEFERT, Philippe (B), Fellow

A Medieval Reference to the Andromeda Nebula

P. KUNITZSCH, Institute of Semitic Studies, University of Munich, F.R. Germany

Nebulous objects among the fixed stars, in the southern as well as in the northern hemisphere, have been observed and registered since antiquity. They are mentioned in both parts of the ancient knowledge of the sky, the theoretical (that is what we nowadays would call "astronomy"), and the applied, or practical (that is what we nowadays call "astrology").

The great master of astronomy in late antiquity, Claudius Ptolemaeus of Alexandria (2nd century A.D.), whose teachings remained authoritative through the Middle Ages and down to the times of Copernicus, has registered in his star catalogue (in books vii–viii of his *Mathematikê Syntaxis,* called the *Almagest* in Europe since the Middle Ages) five stars as "nebulous" *(nepheloeidés):* the 1st star of Perseus (χ h Per, M 34 = NGC 1039); the 1st star of Cancer (Praesepe, M 44 = NGC 2632, with ε Cnc at its centre); the 1st external star of Scorpius (most probably M 7 = NGC 6475); the 8th star of Sagittarius ($\nu^{1,2}$ Sgr, a pair of stars standing close together); and the 1st star of Orion (λ Ori, perhaps including the neighbouring star φ^1 Ori, or the two stars $\varphi^{1,2}$ Ori). In addition, he also calls the 17th star of Cygnus ($\omega^{1,2}$ Cyg, again a pair of stars) "nebulous", but without including it in the number of the five "nebulous" stars proper. Further, under the 6th external star of Leo, he mentions the "nebulous complex" between the hind parts of Ursa Maior and Leo which refers to the region of Coma Berenices, but without entering an object from this complex into the star catalogue. These data were repeated by all the astronomers down to Copernicus' time, both in the Islamic Orient (where the *Almagest* had been translated into Arabic, and revised, several times) and in medieval Europe (where the *Almagest* was generally used in a Latin translation made from the Arabic, in Spain, in the 12th century).[1]

It is remarkable that some of the most conspicuous nebulae were not registered, or called "nebulous", by Ptolemy, such as the Andromeda Nebula, or the globular cluster ω Cen (here, Ptolemy has registered the object as the 21st star of Centaurus, with magnitude 5, not mentioning its character as "nebulous").

Also in the astrological tradition a number of nebulous objects played a role. They were named for causing diseases of the eyes, or blindness. This tradition, again, originated with Ptolemy, in his astrological handbook *Tetrabiblos,* book iii, chapter 12 (the *Tetrabiblos* was also translated into Arabic, and later, in Spain, into Latin). Here, six objects among the zodiacal constellations are listed: the Pleiades in Taurus; M 44 in Cancer; the region of Coma Berenices, near Leo; M7 in Scorpius; the arrow point of Sagittarius (perhaps $\nu^{1,2}$ Sgr, mentioned above, but here placed on the arrow while in the *Almagest* it was located on the eye of Sagittarius); and the pitcher of Aquarius (not mentioned in the *Almagest*).[2] Apart from successive authors of late antiquity, this tradition was also set forth in the Islamic Orient, e.g. by Abu Ma'shar in his *Introductorium Maius,* book vi, chapter 20, and by al-Biruni in his *Kitab al-tafhim* (Elements of Astrology), § 460.[3]

The most famous author in the Islamic Orient on the fixed stars was Abu l-Husain al-Sufi (A.D. 903–986). He composed a *Book on the Constellations of the Fixed Stars* (ca. A.D. 964) in which

Figure 1: *Drawing of the constellation of Andromeda with the big Arabic Fish over the upper part of her body; from a manuscript of al-Sufi's* Book on the Constellations of the Fixed Stars. *On the mouth of the big Fish, several dots mark the "nebulous spot", i.e. the Andromeda Nebula.*

Figure 2: *The same drawing, from a manuscript of the Sufi Latinus tradition. The dots marking the "nebulous spot" are visible to the right of the big Fish's mouth.*

he described in detail the classical 48 constellations that had been established by Ptolemy in the *Almagest*.[4] For each constellation he gave a detailed discussion of the individual stars; a list of indigenous Arabic star names of objects falling under the Greek constellation, together with a precise identification of each object with the respective Ptolemaic stars; two drawings of the constellation, one as seen in the sky, and one as seen on the celestial globe (where the left and right sides, and East-West, are always reversed); and a catalogue of the stars belonging to that constellation. Here, under the constellation of Andromeda, in the description of the indigenous Arabic names, he occasionally mentions the Andromeda Nebula. In describing the figure of a big Arabic "Fish" lying across the figure of Ptolemy's Andromeda,[5] he says that this "Fish" is made up by two lines of stars beginning from the "nebulous spot" *(latkha sahabiya)* which is close to the 14th star of the constellation (ν And, on the right side of the figure, being one of the three stars βμν And on the girdle, or loin cloth, of Andromeda).[6]

This is an occasional reference, in al-Sufi's book, to the Andromeda Nebula. The author does not give more details about this object which did not form part of the material transmitted in Ptolemy's star catalogue; but it is evident that al-Sufi had observed the Nebula, and he used it, in context, as a point of reference in the description of the position of an old indigenous Arabic asterism.

The drawing of Andromeda with the big Fish, added to the description of the constellation, carefully indicates the "nebulous spot" mentioned in al-Sufi's descriptive text: it is marked by some dots on the mouth of the big Fish (see Fig. 1). In other manuscripts, in addition, the word *sahabi* ("nebulous") is written beside the dots on the Fish's mouth.

In the 13th century, there originated, perhaps in Sicily, a Western branch of the Sufi tradition, the so-called *Sufi Latinus corpus,* of which eight manuscripts have been found until now.[4] It consisted, basically, of Ptolemy's star catalogue in the Latin version made in Spain, in the 12th century, by Gerard of Cremona (from the Arabic); but in the star coordinates the longitudes were converted to al-Sufi's value (= Ptolemy + 12°42'); further, to each constellation a drawing was added (i.e., one of the two drawings in al-Sufi's original work); and in some of the manuscripts in the title the author's name was mentioned as *Ebennesophi* (from the corrupted Arabic Ibn al-Sufi, instead of the correct form al-Sufi). Most of the eight Latin manuscripts have meticulously repeated the dots designating the "nebulous spot" (i.e., the Andromeda Nebula), in front of the big Fish's mouth, in the drawing of Andromeda with the big Fish (for a specimen, see Fig. 2).

It is interesting to see how carefully the Western copyists and draughtsmen have reproduced those dots beside the figure of Andromeda although they could not understand what they meant because al-Sufi's descriptive text itself had not been translated into Latin.

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2. Ptolemy, *Tetrabiblos,* ed. and transl. F.E. Robbins (The Loeb Classical Library, repr. Cambridge, Mass./London, 1971), p. 320–321.
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4. P. Kunitzsch, article "al-Sufi", in: *Dictionary of Scientific Biography,* vol. xiii (New York, 1976); *idem,* "The astronomer Abu l-Husayn al-Sufi and his Book on the Constellations", *Zeitschr. f. Geschichte d. Arab.-Islam. Wissenschaften* 3 (1986), 56–81.
5. See P. Kunitzsch, *Untersuchungen zur Sternnomenklatur der Araber* (Wiesbaden, 1961), no. 126a.
6. H.C.F.C. Schjellerup, *Description des étoiles fixes . . . par Abd-al-Rahman al-Sûfi* (St.-Pétersbourg, 1874; repr. Frankfurt/M., 1986), p. 118–119.

ESO Pictorial Atlas Now Available

Just in time for ESO's 25th anniversary, the English, German and Danish versions of this beautiful atlas have now been published. French, Italian and Spanish versions are expected to follow in 1988. 90 colour plates and 147 black-and-white photographs of outstanding quality, accompanied by extensive captions, reference maps, complete plate data and indexes, introduce the reader to the southern sky. Many of the photographs are here published for the first time. Of special interest are photographs of Supernova 1987A and of Halley's Comet.

The English version, titled "Exploring the Southern Sky", is available at Springer-Verlag New York, P.O. Box 2485, Secaucus, New Jersey 07094, USA (US $ 39,–).

The German version, with the title "Entdeckungen am Südhimmel", may be obtained from Birkhäuser-Verlag, Postfach 113, CH-4010 Basel/Switzerland (DM 98,– until 31.12.1987, thereafter DM 128,–).

The publisher of the Danish version, "Sydhimlens Stjerner", is Rhodos, Strandgade 36, DK-1401 Copenhagen K, Denmark (DKr. 325,–).

The book can of course also be ordered from your local bookshop.

ALGUNOS RESUMENES

Bengt Strömgren (1908–1987)

Bengt Strömgren, ex presidente del Consejo de ESO (1975–1977) falleció el 4 de julio luego de una corta enfermedad. Su presidencia occurrió en un momento particularmente difícil en la historia de la ESO. Gracias a su sabiduría y la manera confiada y decisiva como manejó los asuntos de ESO, se pudieron evitar muchos riesgos y se pudo establecer un alto grado de armonía entre las delegaciones de los estados miembros, que aun perdura.

Bengt Strömgren fue un destacado científico. En el año 1922, a la edad de 14, publicó sus primeros resultados sobre el cometa Baade 1922c en "Astronomische Nachrichten" (217, p. 345). Uno de sus últimos preprints apareció tan solo pocos días antes de su deceso. Bengt, hijo de Elis Strömgren, Director del Observatorio de Copenhagen, obtuvo su doctorado en 1929, fue profesor de astronomía en 1938 y director en 1940. Entre los años 1951–57 fue director del Observatorio Yerkes de la Universidad de Chicago. Durante los siguientes diez años fue miembro de la Facultad del Instituto de Estudios Avanzados en Princeton. En 1967 regresó a Copenhagen para ocupar la "Casa de Honor", ser profesor de astrofísica y durante varios años director de NORDITA, el instituto de investigación común de los cinco países nórdicos. Entre los años 1970 hasta 1973 fue presidente de la Unión Astronómica Interna-

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where thirteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. A 3.5-m New Technology Telescope (NTT) is being constructed and a giant telescope (VLT=Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is being planned for the 1990's. Six hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.

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cional. Durante más de una década fue presidente del Comité Danés del Cáncer, lo que demuestra la vasta gama de sus intereses.

La mayoría de los astrónomos daneses en alguna forma son sus estudiantes, y muchos de nosotros en otros lados hemos sido influenciados por él como post-doctorados o asociados. Y muchos apreciaron la generosa hospitalidad de Bengt y Sigrid Strömgren.

Si para un científico la marca de una vida llena de éxito significa el haber tenido un gran impacto y haber contribuído a la ciencia en forma perdurable, entonces, en efecto, Bengt Strömgren ha sido una persona afortunada. Será extrañado por todos aquellos que lo conocieron.

L. Woltjer

Control remoto desde Garching

Desde el 1° de julio de 1987 ESO está ofreciendo el uso de control remoto desde Garching como alternativa a los viajes a La Silla, a los astrónomos que tienen tiempo de observación al telescopio de 2.2 m. Los instrumentos disponibles son el espectrógrafo Boller & Chivens con un detector CCD y el CCD usado en forma directa con el adaptador del 2.2 m.

Los utilizadores encuentran en Garching las mismas consolas de control como las que existen en el cuarto de control del telescopio de 2.2 m. Durante la sesión de observación pueden obtener monitor del campo, imágenes del buscador del telescopio e imágenes CCD, y pueden enviar órdenes a los instrumentos y telescopios (ver foto en la página 35). Todo ésto es posible a través de una línea arrendada que también se usa para comunicaciones telefónicas.

A pesar de que la mayoría de las noches adjudicadas en julio resultaron casi inutilizables debido al mal tiempo, varios astrónomos tuvieron la oportunidad de familiarizarse con el sistema.

Alrededor de octubre de 1987 también el espectrógrafo CES con CCD (usando el telescopio CAT) podrá ser utilizado a través de control remoto desde Garching.

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