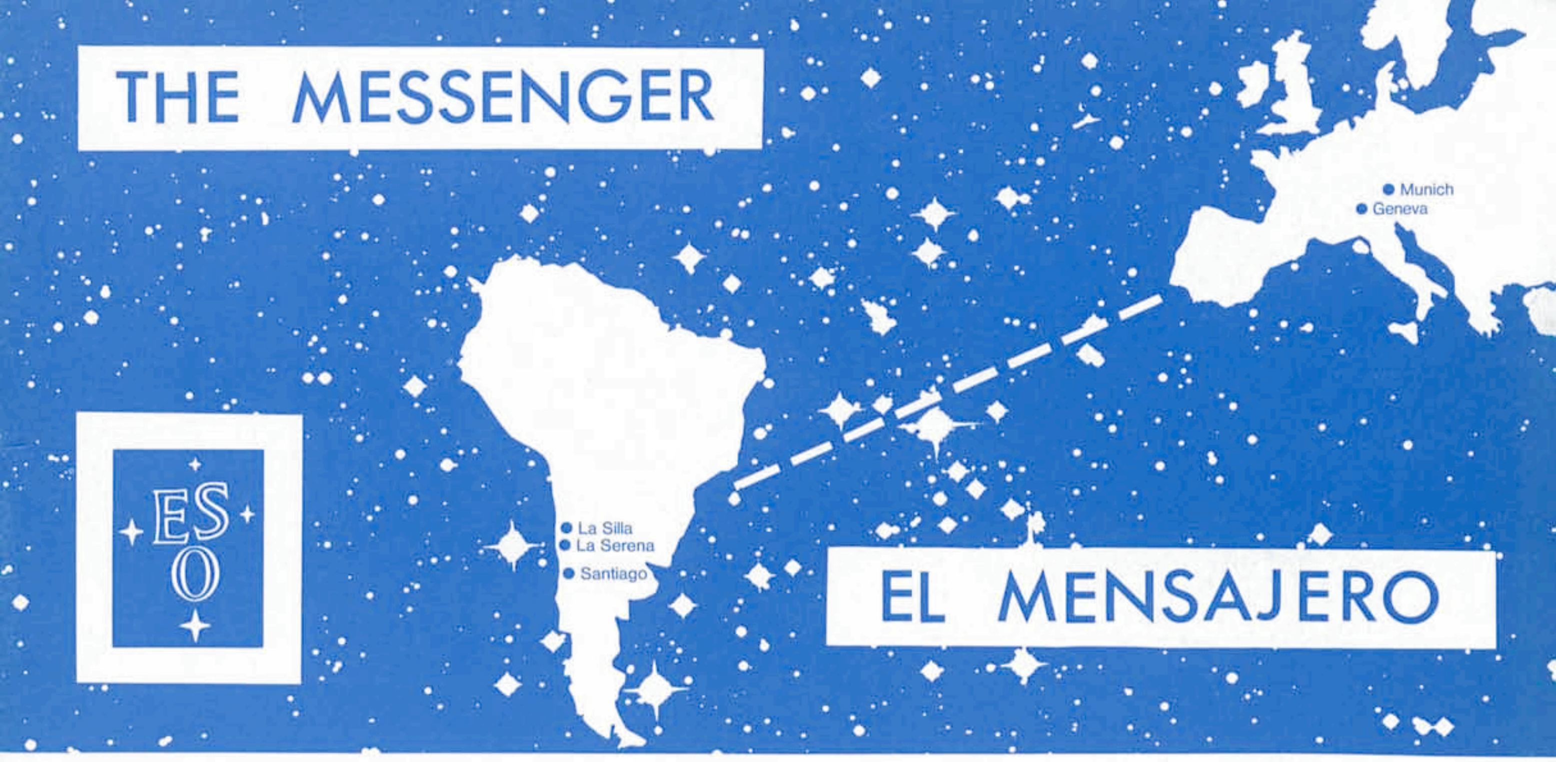

No. 17 – June 1979

Shells Around Southern Novae

H. W. Duerbeck and W. C. Seitter

Although less spectacular than their big brothers, the supernovae, the novae *are by no means less interesting. They are also much more frequent and several are known in the southern sky. After the initial explosion, a shell expands around the nova and may become visible after a while. Drs. Hilmar Duerbeck and Waltraut Seitter from the Hoher-List Observatory, near Bonn, FRG, recently observed three southern novae. The excellent resolution of the 3.6 m photos makes it possible to see details in the very faint nova shells that have never been perceived before.*

The southern sky comprises one of the most fanciful supernova remnants—the extended spider web of the Gum nebula. It harbours also some less spectacular, tiny, astronomically shortlived phenomena: the remnants of near nova explosions. They can be observed for only a few decades after outburst, before they thin out and merge into the interstellar medium. Due to their small size and low surface brightness, they require large telescopes, such as have recently become available in the southern hemisphere. Fortunately, some observing time was granted to us before the above-mentioned disappearances!

RR Pictoris

Two brilliant novae shone in the southern sky in this century. The first one, RR Pic, was discovered on May 25, 1925, and reached its peak magnitude of $1\overset{m}{.}2$ on June 9. It remained visible to the unaided eye for about a year. Spencer Jones published in 1931 a bulky volume of spectroscopic and visual observations made at the Cape Observatory. Another southern observer, J. Hartmann in Buenos Aires, observed the nova spectroscopically and wrote the most concise astronomical paper ever published, a telegram sent to the *Astronomische Nachrichten:* "Nova problem solved; star blows up, bursts." And indeed, when double-star observers examined the postnova two

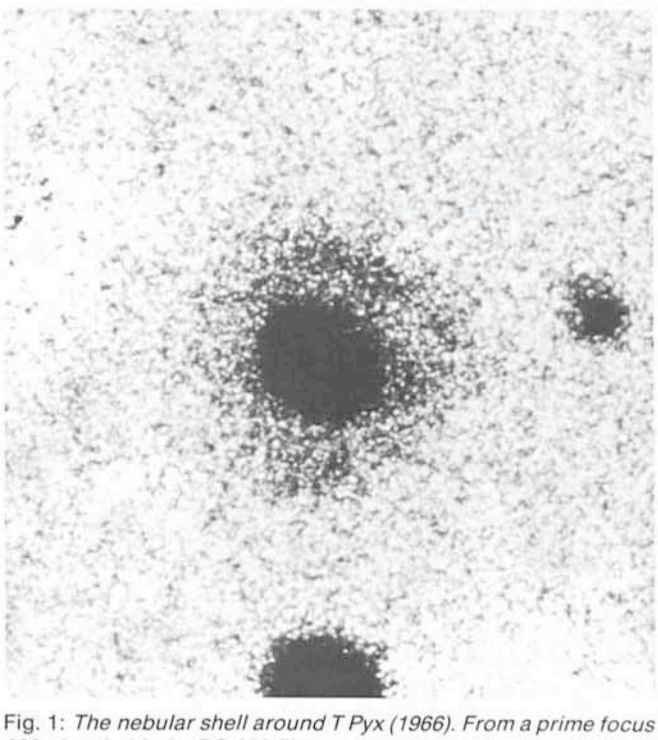

Fig. 1: *The nebular shell around T Pyx (1966). From a prime focus 098 plate behind a RG 630 filter, exposure 70 min.*

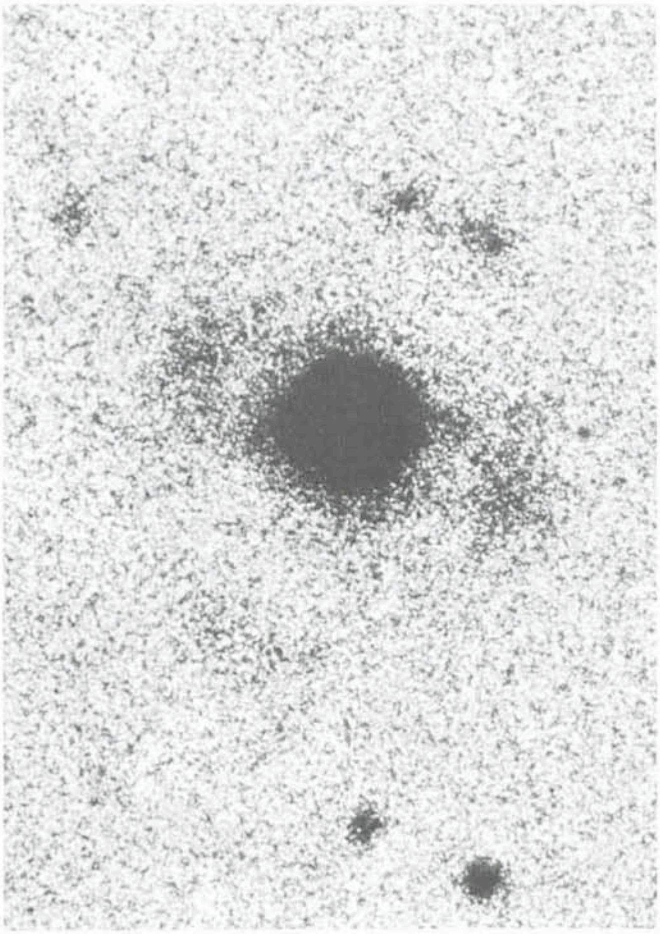

Fig. 2: *The nebular shell around RR Pic (1925). From a 3.6 m prime focus 098 plate behind a RG 630 filter, exposure 90 min.*

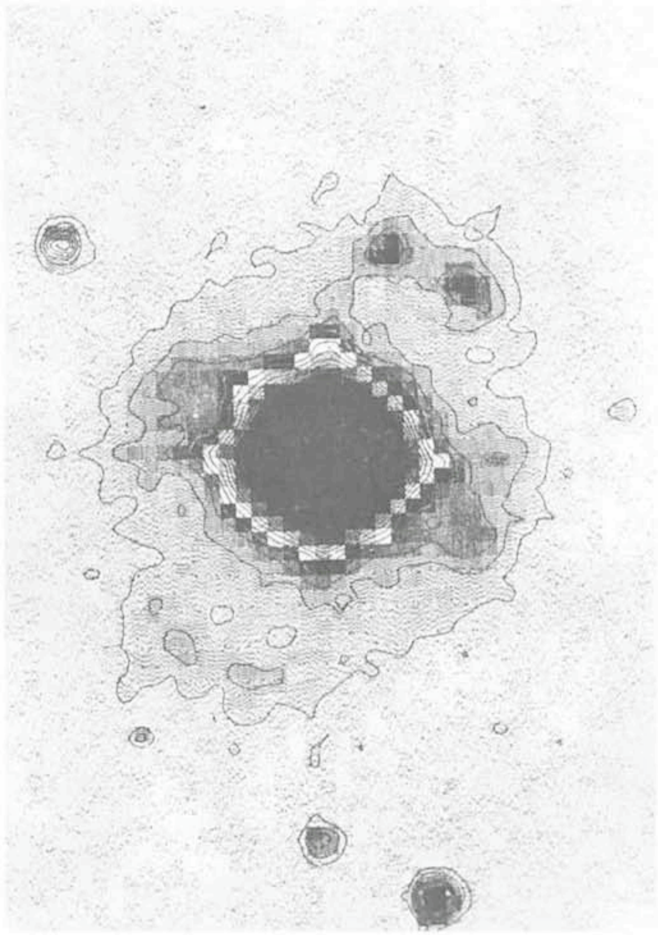

Fig. 3: *The nebular shell around RR Pic (1925). From a prime focus III a-J plate behind a BG 385 filter, exposure 60 min. Plot prepared from PDS density scans.*

years later, it was embedded in a nebula, with two distinct concentrations moving in opposite directions. We quote: "1928.284. Nebula slightly elongated in 250°±. Does not merely look double; looks granular and separated by patient watching. AC 253°±, AB 124°±, AD 353°±. × 810. In my opinion, A, B, C certain, D somewhat doubtful . . ." (Spencer Jones 1931).

Have a look at the appearance of RR Pic on a 90^m red exposure, taken at the prime focus of the ESO 3.6 m telescope (fig. 2). The postnova is surrounded by a structured nebulosity. A ring-like feature encompasses the central star, two pairs of condensations seem to have been ejected with higher (tangential) velocities, at right angles to the ring and opposite to each other. They can easily be identified as fragments B and C of the early double-star observers. A is, of course, the central star, and D part of the ring-like structure. The computer-enhanced, blue image is shown in figure 3.

RR Pic resembles the well-known remnant of Nova DQ Her, which also displays an "equatorial ring" and "polar blobs", but it has a more complicated structure: the polar blobs are double or even triple, and there are two equatorial rings, inclined to each other, and each nearly perpendicular to an axis joining prominent polar condensations. The similarities between DQ Her and RR Pic are striking: both are slow novae, both are short-period binaries (Walker 1954, Vogt 1975), both nebulae show the same basic geometry.

An important, and in principle straightforward, use of a nova remnant photograph is the determination of the nebular parallax: with the known expansion velocity of the shell in km s^{-1}, as observed during outburst, and the dimensions of the shell in arc seconds at some later time, the distance can be determined without any further assumptions. But alas! RR Pic showed many radial velocity systems in the course of its evolution, ranging from 40 to 1,600 km s^{-1}, and the shell has many diameters: that of the ring, that determined by the blobs, or merely, the projection of the blobs in the sphere, since the open ring structure indicates that the polar blobs are not ejected perpendicular to the line of sight. A preliminary analysis leads to a distance of 400 pc. This is a slight revision of the previously assumed value.

CP Puppis

The nova with the fastest development, except V 1500 Cyg 1975, is CP Pup of 1942. Observed expansion velocities were of the order of 1,200 km s^{-1}. High-resolution spectra obtained in the later nebular stage by Sanford (1945) showed Hβ and [O III] 4364 broken up into more than a dozen emission components.

Zwicky, in 1955, obtained a practically featureless photograph of the shell with the Palomar 5 m reflector. When he published the photograph in 1962, he wrote: ". . . it would merit greater attention than it has been accorded hitherto and it is to be recommended for more observations particularly to observers in the southern hemisphere . . ." Here it is (fig. 4): A fringed halo on the blue plate, a chain of black pearls on the red plate: a late confirmation of the early fragmented emission line profile? Again it must be said that a straightforward application of the nebular expansion parallax is not possible, but if it is assumed that the major portion of the material was ejected in a slightly inclined ring, data from the spectroscopic study and the direct photograph can be reconciled. The derived distance of 1,500 pc is in excellent agreement with an earlier determination, based on galactic rotation and interstellar lines, and leads to a very high peak brightness of M = $-11^{m}.5$. CP Pup was very likely the most luminous nova observed until now.

T Pyxidis

The third remnant, the nebulosity around the recurrent nova T Pyx, was in some respects a surprise. Recent photographs of the brightest recurrent nova, T CrB, had revealed only very weak nebular whisps (Williams 1977). The very strong nebulosity around T Pyx is thus unusual.

Again it is not trivial to derive the nebular parallax. Radial velocity observations are scarce for T Pyx and we find the added problem of having to decide which outburst caused the remnant. Was it produced in 1966, 1944, 1920, 1902, or even 1890?

Fortunately, Catchpole (1969) provides us with the knowledge of a radial velocity system observed in 1966 of $v = -900$ km s^{-1}, interpreted as being due to the principal spectrum. With this, a distance of 600 pc is deduced, corresponding to absolute magnitudes at maximum of $M_v = 2^{m}.9$ and at minimum of $M_v = +4^{m}.4$. Under the above assumptions, the recurrent nova does not fit into the t_3—absolute magnitude at maximum—relation.

It is possible to check on the 1966 origin of the shell. With the distance and the angular diameter known, the volume enclosed by a spherical nova shell and its content of interstellar matter can be deduced. Assuming that the detection of a shell requires its density to be 10–100 times

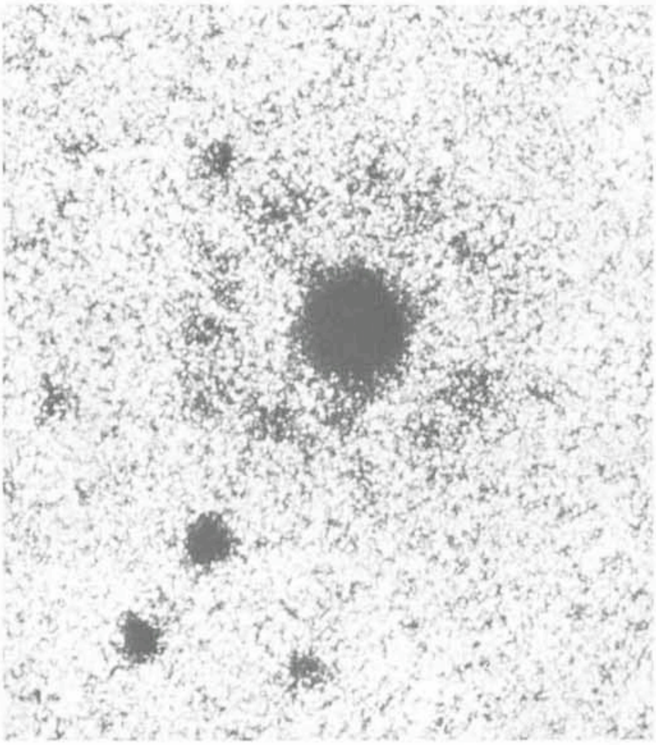

Fig. 4: *The nebular shell around CP Pup (1942). From a prime focus 098 plate behind a RG 630 filter, exposure 60 min.*

New ESO Slide Sets

Two new ESO slide sets will become available during the next months.

The first of these consists of 20 5 × 5 cm colour slides showing the ESO installations on La Silla. Buildings, telescopes and views of the site are included. A full description in several languages explains the slides.

The second set contains some of the best photographs that have been obtained with the 3.6 m prime focus camera (Gascoigne corrector). 20 black-and-white slides have been selected from more than 1,000 photographs. Nebulae, galaxies, etc. Full details in accompanying text.

The price for one slide set is German Marks 18,– (or the equivalent) for Europe, and US$ 10.– by surface mail to all other countries, or US$ 12.50 by airmail (to be paid in advance).

Send your cheque or bank draft to:

European Southern Observatory
Schleissheimer Strasse 17
D-8046 Garching bei München

(Commerzbank, München, Account No. 2 102 002).

Some copies of the first ESO slide set with 20 photos from the 1 m Schmidt telescope are still available (same price as above).

the interstellar density, we find that a 1944 shell must contain at least 10^{28}–10^{29} g of matter and, with a suspected higher expansion velocity of 1,700 km s^{-1}, even 10^{29}–10^{30} g, while a shell ejected in 1966 has a lower mass limit of 10^{27}–10^{28} g. The former values seem rather too large, especially in view of earlier determinations for other recurrent novae which yield 10^{28} g or less. It must be kept in mind, however, that the above argument requires spherical volumes. Thin shells or remnants with strong condensations combine smaller ejected masses with longer lifetimes.

Perhaps the strongest argument in favour of a 1966 shell is the absence of strong remnants of earlier outbursts, possible proof of a short lifetime, as well as a more spherical nature of recurrent nova shells.

While all arguments are weak, they provide us with a comfortably complete set of data for a 1966 outburst. With the implied fast development of the remnant it is easily possible to verify or to reject our conclusion by systematically following the future development of the remnant of T Pyx.

The photographic investigations reported here are clearly only the beginning of a closer study of nova remnants and must be supplemented by spectroscopic investigations which will permit a closer look at the physics of the nova shell and hopefully shed more light on the nature of the nova process.

We are pleased to thank the night assistant of the ESO 3.6 m telescope, Sr. Yagnam, for most efficient handling of the telescope and the coffee machine, and Dipl. phys. H. J. Becker (Bonn) for his readiness to produce beautiful plots from PDS scans.

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Mapping of Galaxies at High Radio Frequencies

R. Wielebinski

Professional astronomers are sometimes asked the question of whether observations with radio telescopes are better than the "old-fashioned" optical observations? The answer is of course that they are equally valid: to understand the objects in the Universe, we must observe them over the widest possible spectral range. For this purpose, short-wavelength observations are now carried out from spacecraft, and in the other end of the spectrum we rely upon the ingenuity of the radio astronomers with their giant antennas. In this review, Dr. Richard Wielebinski of the Max Planck Institute for Radioastronomy in Bonn, FRG, gives examples of the important interaction between optical and radio observations for the study of nearby galaxies.

The detailed study of the distribution of the radio continuum emission of "normal" galaxies began only ten years ago, when G. G. Pooley published a map of the Andromeda nebula (M 31) made at 408 MHz. This map showed for the first time details of the spiral structure at radio frequencies. Until that time no single-dish radio telescope had sufficient angular resolution and no synthesis array the necessary brightness sensitivity to be able to map nearby normal galaxies. A typical angular resolution required for the largest objects is a few minutes of arc, while tens of seconds of arc resolution allow us to study numerous smaller galaxies. A number of presently operating synthesis arrays have this resolution, and have been used to map galaxies, particularly at lower radio frequencies. The surface brightness of the radio continuum emission of normal galaxies is low, typically a few degrees K at 408 MHz, but dropping rapidly to a few mK at 4800 MHz. (The temperature spectral index β is typically $\sim$ 3.0 for galaxies in this frequency range — $T \propto \nu^{-\beta}$.) For such sensitive measurements the large collecting area of a single dish, like the 100 m Effelsberg radio telescope, is ideal. To map galaxies at frequencies above 5 GHz, where weather effects seriously hamper observations, the development of new techniques was necessary to allow studies to be made in this important frequency range.

Thermal and Nonthermal Emission

To understand the importance of mapping of galaxies at high frequencies, a short summary of the emission processes which produce the radio continuum in our galaxy should be made. Along the galactic plane we have a narrow band of discrete H II regions with thermal (flat) spectrum. The brightest of these H II regions placed at the distance of 1 Mpc would be barely detectable as individual sources, but the integrated effect should certainly be the dominant emission at the highest radio frequencies. A somewhat broader distribution of nonthermal supernova remnants (with steep spectrum) is found along the galactic plane in the Galaxy. The strongest of these SNR's should be easily detected at a distance of even 4 Mpc as individual radio sources. The supernova events are known to produce pulsars, and they as well release energy in the form of relativistic particles. These electrons in turn produce diffuse nonthermal emission which is linearly polarized. The measurement of the linear polarization should enable us furthermore to study the magnetic fields in the galaxies.

Sensitive measurements of the emission above the plane, particularly in edge-on galaxies, allow us to study the diffusion (or convection) of relativistic particles from the sites of their formation into the magnetic fields of a possible "halo". The study of the diffuse thermal emission, known to exist in our galaxy from the absorption of low frequency continuum emission, could be tackled once a careful separation of the thermal/nonthermal emission is made. To separate all these effects radio maps at many frequencies are required. These radio results, combined with various other observations, should enable us to understand the energy balance of galaxies.

Mapping the Spectral Indices and Magnetic Fields

The 100 m radio telescope of the Max-Planck-Institut für Radioastronomie has been used to map nearby galaxies at a number of frequencies from 840 MHz to 23 GHz. At first a λ 11 cm (2.7 GHz) map of M 31 was made with r.m.s. noise of 3 mK. Measurements with such sensitivity were never made before and were only possible due to the combination of the excellent telescope and the highly stable, low-noise receiver. The data obtained for M 31 were studied in detail by E. Berkhuijsen, particularly for correlations between radio continuum and the various constituents like H II regions, OB associations, supernova remnants, H I gas, blue light, etc. Similar investigations have been made on the basis of λ 11 cm and λ 6 cm maps of M 33. In M 33 the emergence of the thermal emission as the dominant constituent, even below 4.8 GHz, is evident.

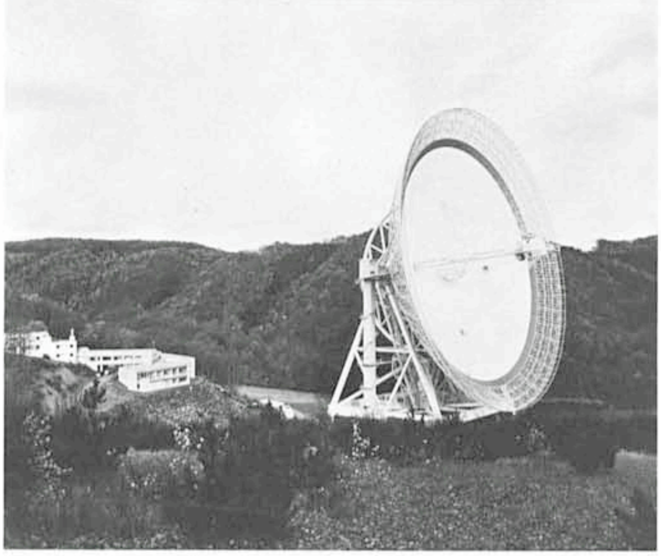

Fig. 1: *The 100 m radio telescope at Effelsberg. It has been used to map galaxies at frequencies as high as 23 GHz.*

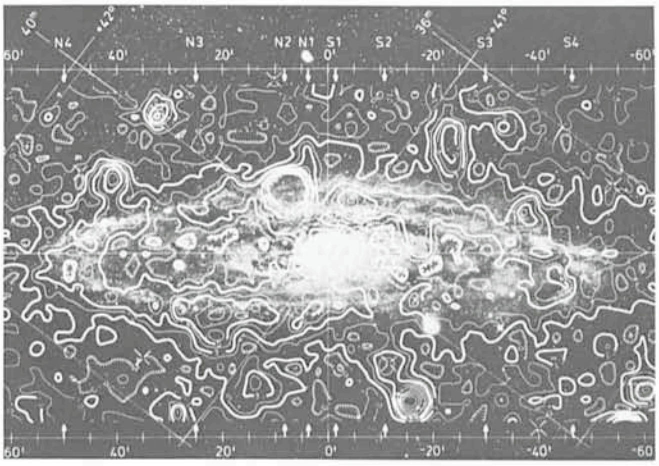

Fig. 2: *M31—An overlay of radio contours onto a Lick Observatory photograph. 2695 MHz (λ 11.1 cm), 4.'7 beam (Berkhuijsen and Wielebinski).*

Studies of IC 342, M81, M51 and, more recently, M82 at frequencies as high as 23 GHz have aimed at an accurate thermal/nonthermal separation. To map galaxies at these high frequencies, without being subject to base-level variations due to perturbations from atmospheric thermal emission, the technique of beam switching was extended from point sources to extended objects by D. T. Emerson, U. Klein and G. Haslam. It now appears possible to map galaxies with 1 mK r.m.s. noise and a resolution of 1.2 arc min at 10.6 GHz (λ 2.8 cm). In the near future maps with ~ 30 arc sec resolution at 32 GHz (λ9.6 mm) should be possible. Such maps, when combined with similar resolution maps made, for example, with the Westerbork Synthesis Radio Telescope in the Netherlands at 610 or 1420 MHz, or with the Cambridge 150 MHz telescope in England, can give us excellent spectral index distribution maps and hence thermal/nonthermal ratios in a number of nearby galaxies.

Maps of linear polarization of M31 and M33 have been made by R. Beck at 2.7 GHz with 4.4 arc min angular resolution. These observations have shown that the nonthermal emission is generated in magnetic fields which are ordered on scales of kpc. The degree of polarization is high, up to 40% in some areas. As yet no maps at other frequencies have been made, but in the south-preceding arm of M31 there seems to be very little Faraday rotation. The well-aligned "E" vectors imply that there is a large-scale magnetic field of some 5 μG along this spiral arm. Observations now planned at other frequencies should give details of the magnetic fields and of the electron densities in the spiral arms.

Galaxy Halos

Nonthermal emission from the Galaxy was the first radio-astronomical observation made some 40 years ago. Studies of nonthermal emission in our galaxy has led to

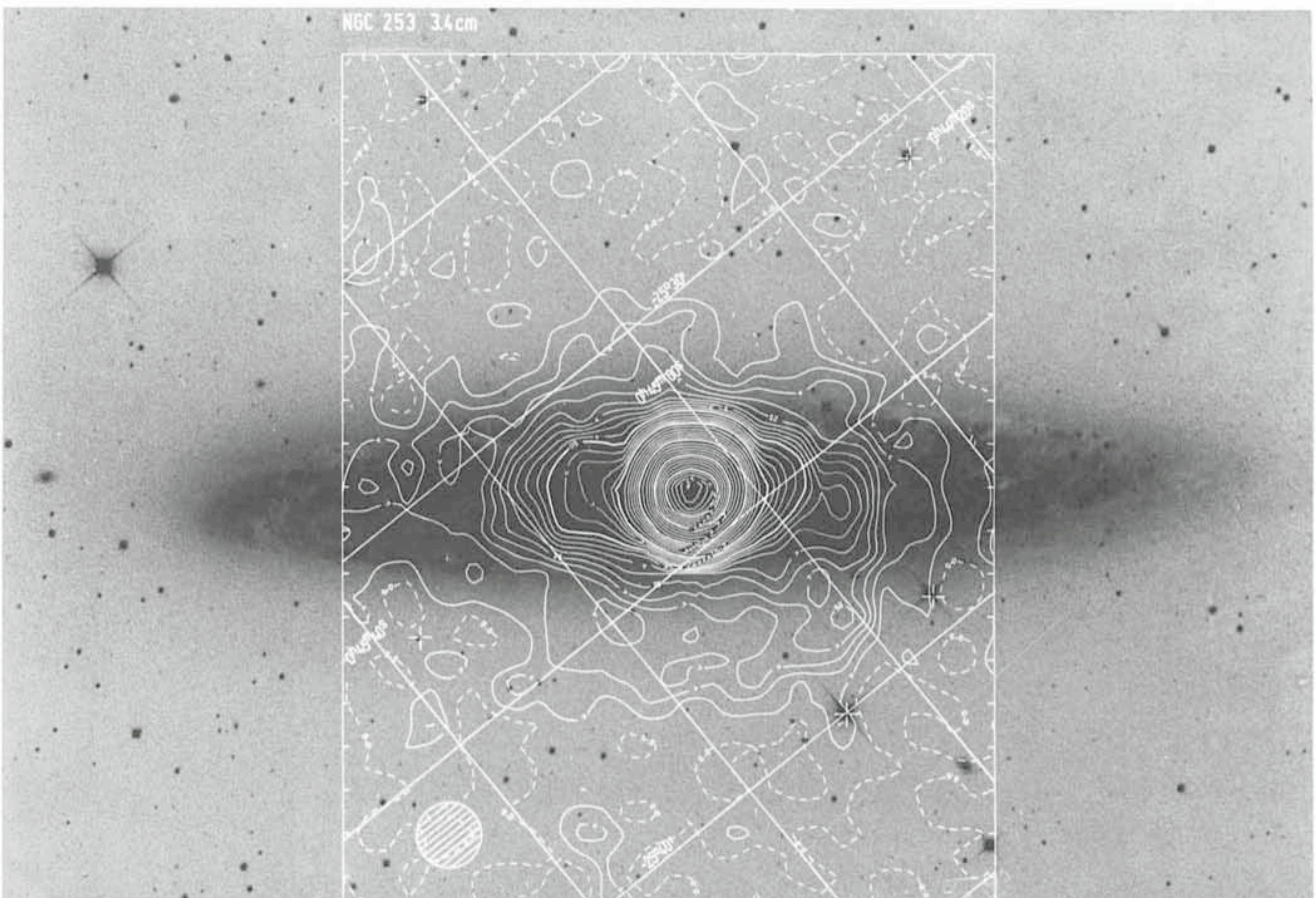

Fig. 3: *NGC 253—An overlay of radio contours onto an ESO Schmidt plate. 8.7 GHz (λ 3.4 cm). The radio emission shows an extended halo surrounding the galaxy (Beck, Biermann, Emerson and Wielebinski).*

a long-standing controversy about the existence of an electron halo. If cosmic rays are to be contained in the Galaxy, a rather strong electron halo is expected. The refinement of measuring techniques over the last 20 years has led radio astronomers to conclude that any such large scale component surrounding the galaxy must be weak. Also the experimental evidence indicates that the spectral index of the radio continuum emission at high distances above the galactic plane is steeper than the spectral index near the plane.

Observations of edge-on or nearly edge-on galaxies offer the best opportunity to study the halo phenomenon. An analysis of 408 MHz observations led R. Wielebinski to conclude that any halo around M31 is weaker than that surrounding the Galaxy. Further studies of the halo of M31 using the 100 m telescope were made recently at the "low" frequency of 842 MHz by R. Gräve et al. Other edge-on galaxies mapped were NGC 891 and NGC 4631. The only high frequency halo so far found was at 8.6 GHz in NGC 253 (R. Beck et al.). This observation implies a young population of relativistic electrons and this may be due to the high nuclear activity seen in NGC 253. The relation between nuclear source and radio emission in the disk is unclear at present. Studies of the nuclei of galaxies, particularly with the highest angular resolution of the VLBI technique, should tell us something about these relations and hence about the energy production in galaxies.

What Comes Next?

Future instrumental developments necessary in this field of research are now becoming apparent. Single-dish maps at the highest frequencies will be able to provide information on the thermal emission distribution in nearby galaxies. At present, to map a larger galaxy at 10.6 GHz down to the confusion level of the telescope would take ~ 1,000 hours. Developments which would speed up the observing, such as use of multi-beam receiver systems, are highly desirable. Aperture synthesis telescope maps at lower frequencies require the filling of the missing spacings. If this is not done, the extended structure is lost and the resulting map unusable for detailed studies. Combination of synthesis arrays and single-dish maps would give data which could be used in detailed spectral studies. The improvement in VLBI sensitivity by the use of a broader bandwidth should enable detailed studies of a larger number of nuclei of galaxies.

Studies of the radio continuum distribution in galaxies require parallel information from all other astronomical observation modes. For the investigation of the thermal content Hα-data are required. To study the relation of radio continuum to the density wave theory, high resolution H I studies of the same galaxies are needed. The halo of our galaxy can be investigated either in radio continuum or in γ-ray observations. Molecular line studies of normal galaxies have so far been limited either to nuclei or to extremely large H II regions. The advent of new techniques in all fields of astronomy and their application to studies of nearby galaxies will certainly bring us nearer to understanding the workings of these beautiful beings.

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δ Crucis is Variable!

E. W. Elst

During a recent visit to La Silla, Dr. Eric W. Elst of the Royal Observatory at Uccle, Belgium, discovered that one of the stars in the Southern Cross is variable. So are many other stars, but the present case is particularly interesting because the maximum amplitude in the lightcurve is only 0ᵐ006! The discovery is a powerful demonstration of the quality of the La Silla site and a tribute to the Bochum 61 cm telescope and its photometer.

Although the bright, southern star δ Crucis (V = 2ᵐ8) has been observed many times during the past, its variability has remained undiscovered until now. Due to the high precision of the Bochum 61 cm photometric system and extremely good weather conditions, it was possible, during my last stay at ESO in February 1979, to detect a short-periodic light variation of δ Crucis, with an amplitude of only 0ᵐ006!

Fig. 1: *The Southern Cross above La Silla. δ Crucis is indicated. Photographed by ESO photographer B. Dumoulin in 1977. The two bright stars below are α and β Centauri.*

Earlier Observations

In 1956 the radial velocities of seven bright southern B-type stars (from the D.H. McNamara list) were systematically examined at the Radcliffe Observatory, in an effort to detect the presence of short periods (Pagel, 1956, *MNRAS,* **116,** 10). Positive results were obtained for β Cru, τ^1 Lup and α Lup, whereas no conclusion could be drawn for δ Cru because the lines in the spectrum were too diffuse to be measured accurately.

It is interesting to note, that photoelectric observations of α Lup at that time by A.B. Muller (Leiden Observatory Southern Station) did not reveal any variation in excess of 0^m01. α Lup was therefore considered as apparently constant, which was confirmed by earlier observations of this star, carried out at the Cape Observatory in 1948 and 1950.

In connection with an investigation of the multiperiodicity of β Cru (Van Hoof, 1959, *Z. f. Astrophys.,* **47,** 198), Haffner observed this star during several nights at the Boyden Observatory. He used δ Cru as the comparison star during the first two nights, but its brightness was not checked for constancy.

From the third night on, δ Cru was replaced by the closer star 39 Cru. This change, Van Hoof states, was not a favourable one, since night-to-night variations were found in the average Δm (β-39).

In 1972, Shobbrook (*MNRAS,* **156,** 5P) again observed δ Cru, together with β Lup, η Lup, δ Lup and ε Cen. After a few nights it became apparent that δ Lup varied by up to 0^m005 and ε Cen by up to 0^m015. The other three stars appeared constant to 0^m003, and were not observed further.

In 1973, δ Cru appears once more in a list, this time compiled by Percy *(A&A,* **30,** 465) with the aim of doing some statistics of undiscovered β Cephei stars. However, since Percy relied on the Shobbrook investigation, δ Cru was considered as "not variable".

Finally Jerzykiewicz and Sterken (1977, *Acta Astronomica,* **27,** 365) put δ Cru on their list, during a search for β Cephei stars. But for some reason, they indexed this star with "NO". This symbol indicates stars which the authors do not plan to observe in their present programme, either because they are already well-known variables, or because no suitabel comparison stars could be found for them.

Photometric Observations with the Bochum 61 cm Telescope

In order to establish more firmly the TPA (timeshift-period-amplitude) relation (Elst, 1978, *Astrophys. J.,* **223,** 959), I planned to observe in February 1979 several δ Cephei stars and some well-known β Cephei stars. The observations were done with the automated photometer which is attached to the Bochum 61 cm telescope. Due to the extremely favourable weather conditions, I soon ran out of stars! Therefore, without previous planning, I selected six early B-stars from the sky in an arbitrary way, and observed them for several nights. During the day time, a preliminary photometric reduction of the observations was made by means of a pocket calculator.

It immediately became clear that all of the six stars had to be considered as variable (Elst, 1979, *Inf. Bull. Var. Stars,* 1562), but since at that time I did not know of the previous history of δ Cru, I did not observe this star very extensively. However, from the observations of four minima and one maximum, it is still possible to estimate the period and the amplitude of the light variation of δ Cru. Table 1 gives some information about the observed minima. The deduced period is $P = 3^d62491$ and the amplitude is $\Delta V = 0^m006$.

Table 1: *Minima of δ Cru*

Date (UT)	UT
31–1–79	7^h 43^m
12–2–79	6^h 16^m
13–2–79	7^h 22^m
15–2–79	6^h 34^m

Figure 2 shows the lightcurve as deduced from observations on two nights. Overlapping points are not shown.

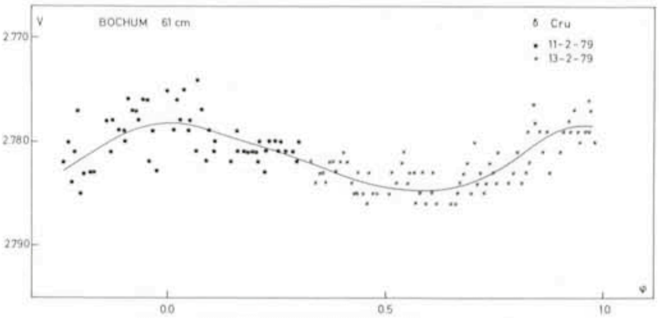

Fig. 2: *The lightcurve of δ Crucis, as measured in February 1979.*

So, by pure coincidence, δ Cru was now observed once more, and due to the fine photometer at the Bochum 61 cm telescope, and the excellent weather conditions, it could no longer hide its variability!

* * *

This article is dedicated to Mrs. Hilde Fritsch, formerly in charge of the ESO Guesthouse in Santiago and now retired. I also thank Mr. De Kersgieter for drawing the figure.

List of Preprints Published at ESO Scientific Group

March–May 1979

51. G. TENORIO-TAGLE, H. W. YORKE and P. BODENHEIMER: The Gas Dynamics of H II Regions. III. Submitted to *Astronomy and Astrophysics.*
52. D. PELAT and D. ALLOIN: High-Resolution Profile of the [O III] Lines in NGC 1068. Submitted to *Astronomy and Astrophysics.*
53. G. CONTOPOULOS: How far do Bars extend? Submitted to *Astronomy and Astrophysics.*
54. M. AZZOPARDI and J. BREYSACHER: More Wolf-Rayet Stars in the Large Magellanic Cloud. Submitted to *Astronomy and Astrophysics, Suppl. Series.*
55. M. P. VERON and P. VERON: A Study of the 4C Catalogue of Radio Sources between 20° and 40°. II The sample. Submitted to *Astronomy and Astrophysics Suppl.*

Cluster Hunt in the Southern Milky Way

L. O. Lodén

Most of the known stellar clusters in the Milky Way have been found because they contain conspicuous groupings of relatively bright stars. Nobody doubts, however, that there are many other clusters, in particular very loose ones, which are not known at present. But how to discover them and to prove that they are real physical entities? In this article, Dr. Lars Olof Lodén from the Stockholm Observatory, Sweden, summarizes one aspect of a large investigation that has been underway for nearly two decades: finding new clusters in areas that are densely packed with stars.

In 1962 we began to work seriously with the material from the large spectral survey of the Southern Milky Way that was outlined by the late Bertil Lindblad a few years earlier. This material was secured at the Boyden Observatory in South Africa between 1958 and 1962. It consisted of objective-prism plates obtained with the ADH Baker-Schmidt telescope (widened spectra), direct-photographic plates in blue and yellow taken with the 25 cm Metcalf astrograph, and photoelectric UBV photometry of a large number of standard sequences distributed over the whole investigated part of the sky (obtained with the reflecting telescope). The region covered included a galactic belt between $l = 235°$ and $l = 10°$ with an approximate width of 7°5.

The intention was to select "interesting" stars from the objective-prism plates by means of visual inspection. These stars should then be subject to subsequent, detailed investigation, maybe also statistical studies with respect to spatial distribution, etc. A problem was that from the beginning of the project it was not clear how to define the concept "interesting stars"! Rather soon, however, it turned out that the quality of the objective-prism exposures was relatively uneven, ranging from excellent to miserable with statistical concentration somewhere between acceptable and good, and it became evident that the objects in question must have the exclusive property of being easily detectable independently of the quality of the plates. In practice this implied that our "targets" should be (a) very early-type stars, (b) very late-type stars, (c) stars with particularly conspicuous spectra (for instance emission-line stars). At that time there was still a lot to be done as far as the mapping and listing of these types of stars were concerned and, in fact, we made a decent contribution to the first-approximation exploration of the Southern Milky Way, particularly its very southernmost parts. My most diligent co-workers at that time were Anita Sundman and Birgitta Nordström.

Close Pairs of Similar Stars

During the inspection of the objective-prism plates, we were immediately surprised by the extremely frequent occurrence of two (sometimes more) spectra of (practically) identical type and magnitude, situated so close together that they formed a very conspicuous configuration for the inspector's eye. Already in the beginning we were convinced that the phenomenon itself was not necessarily a unique astrophysical one, but merely had to do with human perception. In other words: one reacts when two almost equal spectra appear close together on the plate. This concept could also be supported by means of a comparison between the observed frequency of these coincidence phenomena and the one calculated under the assumption that they were produced just by chance. The result of this comparison showed a (not unexpected) clear correlation between the relation between observed and calculated number, as well as the magnitude and angular separation of the components. For stars brighter than about $m = 11$ and with an angular separation less than ten minutes of arc, there was an overwhelming excess of observed coincidences, but the gradients were steep and beyond $m = 13$ and separation $= 12'$ the excess had turned into a corresponding deficit. Thus: when the stars (i.e. their spectra) are bright enough and appear sufficiently close to each other, one discovers the coincidence immediately; otherwise one tends to ignore them. The ultimate separation limit, of course, is set by the diameter of the field of view in the inspection microscope.

Now the question was: how should we explain the excess of coincidences that was actually observed? The phenomenon itself was still an observational one and it would be dangerous to state that there was only one unique physical explanation behind it.

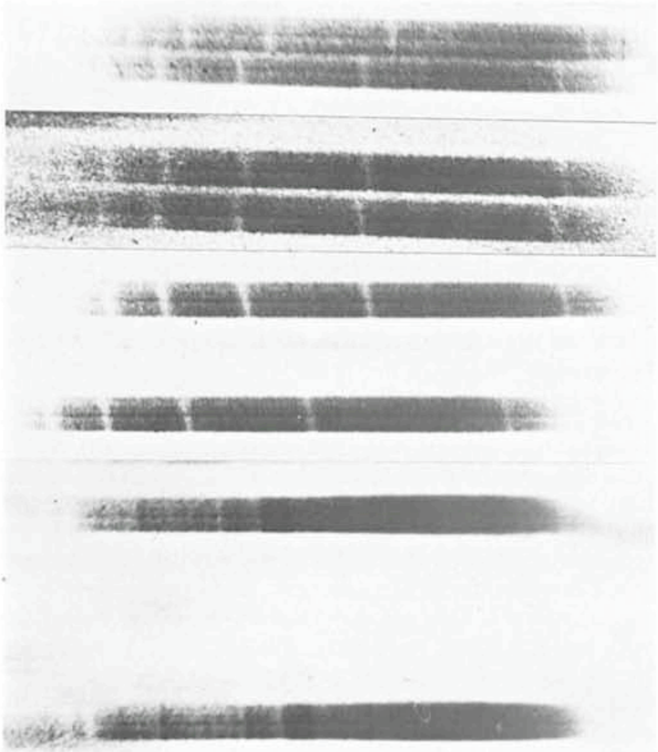

Fig. 1: *Some examples of close pairs of objective-prism spectra of nearly the same spectral class and magnitude. The three upper pairs are all early type; the strong lines are the hydrogen (Balmer) lines. The lower pair is of late (K) type and shows the prominent G band at the centre.*

Our working hypothesis was that within a cluster (or better: clustering) of stars there is an enhanced probability for accidental appearance of two equal stars close to the same line of sight and that therefore a certain fraction of the coincidences would probably belong to open clusters or associations, many of which are too loose or poor to be discovered directly by "conventional" methods. One might call these objects "cluster traitors". The coincidence phenomenon is thus accidental but it facilitates the detection of the cluster. One may think of a pair of identical twins in a gang wanted for crime. If they appear far apart in the mob, their risk of being captured is appreciably smaller than if they show themselves close together.

Observations at ESO

Our first step was to check the relationship between the components of the candidate objects. For that purpose we used UBV photometry and slit spectra. The observations were carried out at La Silla during 1969, 1973, 1974, and 1975 and the results showed that a considerable majority of the coincidences were definitely situated so close to each other in space that there was very little doubt about their mutual relationship. Next step was to study a selection of stars in their immediate neighbourhood in order to discover other presumptive cluster members. This was appreciably more difficult. The only "standard methods" available were analysis of radial velocity or proper motion data—under ideal conditions both. Unfortunately, none of them could be used with any chance of success in this case. Therefore we started desperate attempts to find a physical criterion for cluster membership, preferably a photometrically measurable one. Perhaps a certain metallic peculiarity would be characteristic for a particular cluster or association? We investigated the use of the metal index m_1 in the Strömgren four-colour system for discrimination of mutually associated members from stars in the general field, and uvby observations were made at La Silla between 1976 and 1979, together with UBV photometry, of a large number of stars in the immediate surrounding of some representative candidate objects.

Unfortunately it turned out that the metal index in question was considerably more sensitive to temperature and interstellar reddening than to subtle spectral details, particularly for spectral types A and earlier which predominated in our material. For this reason we are now trying to find a new criterion as a most urgent part of our present research project.

Although we did not find any convenient, elegant, and reliable discrimination method, we could, by means of clumsy classical procedures, get a satisfactory answer to our principal question concerning the suspected objects: more than 80 % of the investigated objects are physically real. A certain number turned out to be situated in or in close connection with more or less ordinary clusters (some of them already known or even well known). A majority of the other ones are very loose open clusters or clusterings, well in accordance with the working hypothesis. There is also a significant number of very small and very poor clusters which we prefer to call "microclusters" or "mini-clusters", possibly some sort of cluster remnants. In a few cases our candidate objects have more the appearance of a binary or multiple system with extreme separation between the components. It may be reasonable to assume that such a configuration represents the ultimate state of a cluster in dynamic decomposition. The last stars leaving the cluster should be the most massive ones. The most

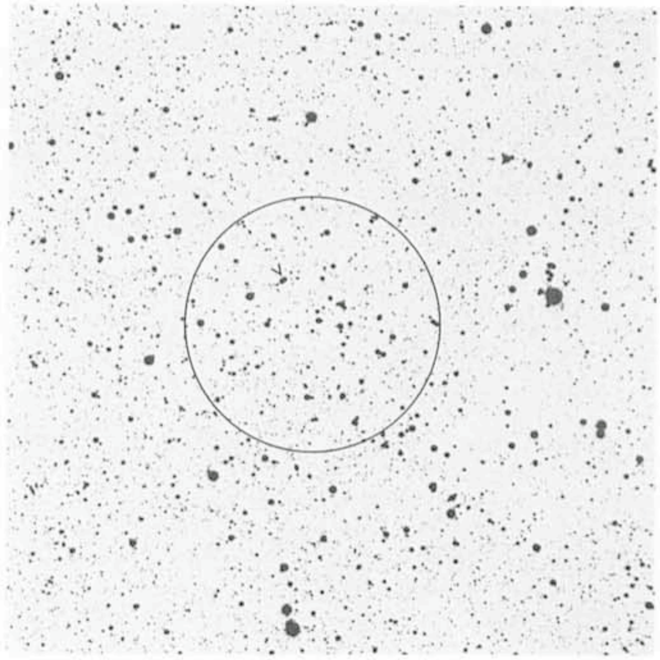

Fig. 2: *A small part of the Milky Way in the constellation Carina. Many groupings of stars are seen. The circle encloses a possible, very loose cluster. A very close pair of stars (indicated with an arrow) first drew attention to this area because of equal spectral type and magnitude.*

massive star and the second most massive one are expected to have nearly the same magnitude and spectral type.

How Many Clusters are there?

Next we come to the astrophysical implication of the observed phenomenon. If we consider the spectral type coincidence to be more or less accidental, we are forced to believe that there are many loose stellar clusterings which are less conspicuous and consequently remain undetected. It is even possible that we detect only a very small minority of the clusterings and that the true number is several orders of magnitude larger than the number of ordinary clusters and associations catalogued thus far. There still would be a majority of free stars without dynamical connection to any particular cluster, but no more an overwhelming one. The concept "general stellar field" or "general stellar background" should in that case be used with a certain caution. What we see when we carelessly talk about this background field might as well be a puzzle created by a successive superposition of a manifold of various clusterings and associations. Some of them are visible; others disappear in the crowd. The denser and richer a cluster is, the higher is its chance of being detected.

If, on the other hand, stars of various magnitudes are randomly distributed in space there is also a high degree of probability that a few of them accidentally will form apparent groupings that are erroneously considered as clusters. In other words: You don't see all real clusters in your Milky Way region and all clusters you see are not real. And there is no reason to believe that the two processes cancel out.

With respect to the general structure of the Milky Way, we can make two different models, each one representing an extreme case. To begin with we forget the time parameter. In the first one the stars are completely homogeneously distributed—except for some random groupings. In the second one there are no "free" stars at all, only clusters and associations of clusters in some sort of hierarchic organization. Observations tell us that none of the models is correct but that the real situation is somewhere in between these extreme cases. The natural question then is: *Where* in between? Here we must introduce the time parameter; the relation between "free" and "bound" stars is definitely correlated to the stage of evolution of the Galaxy—unless we believe that the processes of creation and disintegration of clusterings are in perfect equilibrium.

Personally I do not think that it would be realistic to use the number of cluster(ing)s as a criterion of the age of a galaxy but, more probably, it could be used in an empirical check of the theories for the dynamical stability of these clusters and that is interesting enough.

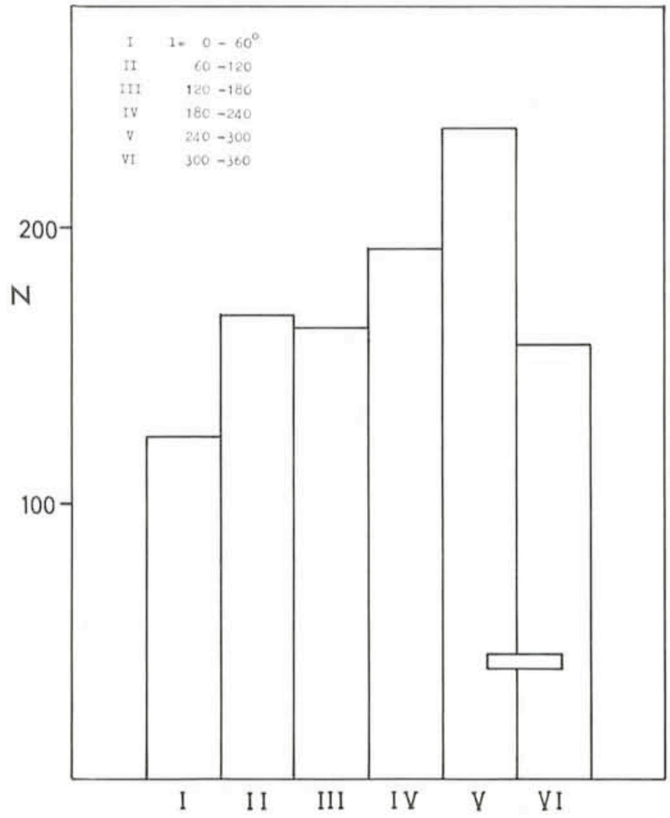

Fig. 3: *The distribution of known open clusters in 60° intervals of galactic longitude. The small rectangle indicates the area investigated by the author and his collaborators at the Stockholm Observatory.* ▶

Discovery of New Wolf-Rayet Stars in the Magellanic Clouds

J. Breysacher and M. Azzopardi

As a result of a thorough search with the ESO GPO astrograph, the number of known Wolf-Rayet stars in the Small Magellanic Cloud has just been doubled (from 4 to 8). Drs. Jacques Breysacher (ESO) and Marc Azzopardi (Observatoire de Toulouse, France) also discovered 17 new WR stars in the Large Magellanic Cloud. Slit spectra of these stars have been obtained with the 3.6 m telescope and there is an indication of a significant difference between the WR stars in the Clouds and those in our own galaxy.

The Magellanic Clouds offer the possibility to study objects of various classes which are at the same distance from us. It is known that some notable differences exist between the stellar populations of the two Clouds, and the Wolf-Rayet (WR) stars do not seem to be an exception to the rule. However, before any comparative study can be undertaken, it is first necessary to make sure that the detection of WR stars in both Clouds is as complete as possible.

The Objective-Prism Search

A systematic search for this kind of star was carried out in October 1977, in March, and in November 1978 with the ESO 40 cm Objective-Prism Astrograph using an interference filter centred at λ 4650 which has a passband of 120 Å wide. WR stars show up strongly in this spectral region due to the emission, mainly from either λ 4650 C III (WC) or λ 4686 He II (WN). This detection technique enabled us to study very crowded regions by reducing the background fog and the length of the spectra, i.e. the number of overlapping images.

Figure 1 reproduces an LMC survey plate. The field has 85′ in diameter. The limiting magnitude of the survey is $m_{pg} = 16.5$ for the Small Cloud and $m_{pg} = 17.5$ for the greater part of the Large Cloud. But due to the poor sensitivity of some of the IIa-O plates used, for a few LMC fields only the continuum of 16.0 m_{pg} stars was reached. The B magnitudes of the WR stars were determined from astrographic plates taken after removing the prisms of the Objective-Prism Astrograph, in combination with a Schott GG385 filter. In order to get an accurate classification of the newly discovered WR stars, slit spectra were obtained for all of them with the Boller and Chivens Cassegrain spectrograph equipped with either the Carnegie image-tube or the Image Dissector Scanner at the ESO 3.6 m telescope.

SMC

In the Small Magellanic Cloud, 4 new WR stars of the WN type ($12.9 \leq m_{pg} \leq 15.3$) were identified (Azzopardi and Breysacher, 1979a) increasing to 8 the number of known WR stars in this system. Considering the distribution among the different WR subclasses, it is remarkable that in the SMC only subclasses W3 to WN 4, 5 are present with, in the WC sequence, one doubtfully (Breysacher and Westerlund, 1978) extreme Wolf-Rayet of type WC4. This has possibly something to do with the general metal deficiency of the SMC and one of us (J. B.) is now studying this point. Adopting the absorption-free distance modulus of 19.2 for the SMC, we come to the result that the 3 faintest SMC WR stars, also binaries, have absolute magnitudes which are hardly compatible with the existing absolute magnitude calibrations for WR and OB stars. These 3 WR binaries located in the same south-west region of the SMC tend to confirm that the extension in depth of the Small Cloud is rather large, as previously suggested by Hindman (1967) from 21-cm radio observations.

LMC

In the Large Magellanic Cloud the present survey led to the detection of 17 new WR stars of the WN type ($11.9 \leq m_{pg} \leq 16.4$), 13 of which are in the region of and to the west of the 30 Doradus nebula (Azzopardi and Breysacher, 1979b, 1979c). 101 WR stars are now known in the LMC; the corresponding figure for the Galaxy is 154.

With an LMC distance modulus of 18.5 the absolute magnitudes obtained for 8 WR stars ($m_{pg} > 15$) are significantly fainter than the values given by Smith (1973) for the corresponding subclasses. Since the Large Cloud is generally considered as a system which is seen almost "face on", local stronger absorption is possible but it may

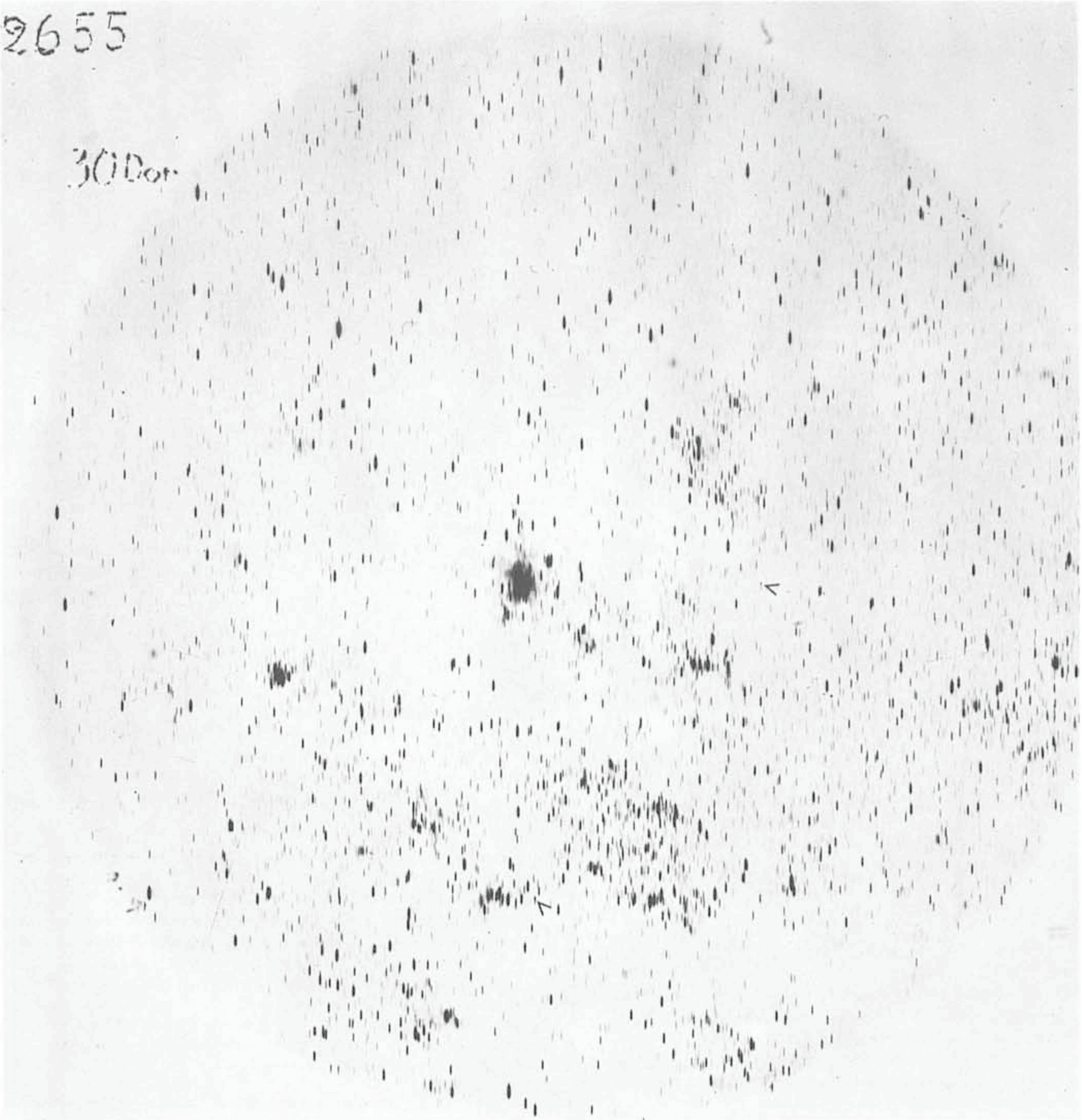

Fig. 1: *A 6-hour exposure on IIa-O nitrogen baked plate in the 30 Doradus region obtained in October 1977 by M. Azzopardi with the Objective-Prism Astrograph and the λ 4650 filter. Wolf-Rayet stars with their emission feature are easily recognizable. Two of them are indicated by arrows.*

well be that these WR stars really have lower intrinsic luminosities than those stars of similar types previously observed in the LMC. This is now being investigated.

The census of the WR population in the Magellanic Clouds can now probably be considered as quite complete, except, maybe for subclass WC 5 which has possibly escaped our detection due to the technique employed: the width of the λ 4650 emission feature is comparable to the filter passband in this case.

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Breysacher, J. and Westerlund, B.E.: 1978, *Astron. Astrophys.* **67**, 261.

Hindman, J.V., 1967, *Australian J. Phys.* **20**, 147.

Smith, L.F. 1973, IAU Symposium, N°49, 15.

Instrumentation Schedule

This is the up-dated time schedule for the major instruments which are being developed at ESO in Geneva for use on the 3.6 m telescope. See also *Messenger* No. 15, p. 10.

Triplet Adaptor (M. Tarenghi, M. Ziebell). Target date: Sept. 1979. The components are:
- two 3-lens correctors for prime focus
- an adaptor with tv for acquisition and guiding
- a remote-controlled shutter and changer for 4 filters
- a remote-controlled changer for 8 plates (3 magazines); plate size is 240 × 240 mm.

For more details see *Messenger* No. 16.

4 cm McMullan Camera (W. Richter). Target date: October 1979.
- Electronographic camera as developed by McMullan. Can be used behind triplet adaptor in prime focus.

Coudé Echelle Scanner (CES) (D. Enard, J. Andersen [Copenhagen], A. Danks). Target date: mid 1980.
- instrument to record very high resolution digital spectra (up to 100,000) on a 1876-channel-DIGICON detector. Double-pass scanning mode permitting calibrations on bright objects with very clean instrumental profile.

For more details see *Messenger* Nr. 11.

Coudé Auxiliary Telescope (CAT) (T. Andersen, M. Dennefeld). Target date: mid 1980.
- 1.5 m spectroscopic telescope feeding CES of the 3.6 m telescope. Three-mirror alt-alt telescope with f/120 (f/32 after focal reducer). Dall-Kirkham optics with spherical secondary. Direct drive servos without gear.

For more details see *Messenger* No. 10.

Infrared Top-End (R. Grip, P. Salinari). Target date: mid 1980.
- Wobbling secondary mirror with f/35 in Cassegrain focus, new telescope top-ring which puts radiating material away from light beam.

For more details see *Messenger* Nr. 13.

Cassegrain Echelle Spectrograph (CASPEC) (M. le Luyer, J. Melnick). Target date: end 1980.
- Instrument with resolution of 15,000, 30,000 and 60,000 with an SEC-Vidicon detector. Data-reduction process not yet defined in detail.
  More details are published on page 27 in this *Messenger*.

Compared to the schedule which was published three months ago, the target date for the Triplet Adaptor has changed from before to after the holiday period.

NEWS and NOTES

The 100th Anniversary of the Birth of Bernhard Schmidt

Fig. 1: *Bernhard Schmidt (1879–1935).*

The inventor of the so-called "coma-free telescope" was born a hundred years ago, on March 30, 1879, as the son of a poor fisherman on the island of Nargen in the Baltic Sea near Reval in Estonia. Already as a child he experimented scientifically, and he lost his right arm, due to an explosion in his primitive laboratory.

In 1901 he registered as a student of engineering sciences at the Technical High School at Mittweida in Germany. Very soon, however, he gave up his regular studies and became independent as designer and constructor of small optical elements for amateurs. He, himself an outstanding amateur astronomer, is known as one of the first explorers of Nova Persei 1901.

Due to the high quality of his products and the deeply founded knowledge in practical optics, he soon (1904–1913) became an independent collaborator to the Astrophysical Observatory at Potsdam under K. Schwarzschild and later at the Hamburg Observatory at Bergedorf under R. Schorr.

During a long travel to the solar eclipse at Manila he accompanied W. Baade. Maybe inspired by him, he conceived the famous telescope, which in 1930 got its final shape in the "Original Hamburg Schmidt Telescope". This first Schmidt with a free aperture of 36 cm was a real optical sensation. With a hitherto unbelievable F ratio of 1 : 1.75 it covered a field of 15 degrees of diameter, completely free of all optical aberrations, except field curvature. Shortly after Bernhard Schmidt's sudden death in 1935 the Schmidt telescope started its triumphal procession throughout the astronomical world. There is a straight line from the Original Schmidt to the big Hamburg Schmidt and finally to the ESO-Schmidt telescope on La Silla.

On the occasion of his centenary the Hamburg Observatory, in cooperation with the Astronomische Gesellschaft, organized an international meeting of observers with modern Schmidt telescopes, showing the ever-growing importance of the Schmidt telescope as an instrument especially suitable for all kinds of sky surveys.

On March 30, 1979 a small Bernhard Schmidt Museum on the site of the Hamburg Observatory was inaugurated where a number of optical elements and tools made by his own hands have been collected. Most important of all, the original handwritten manuscripts, hitherto unknown, could be shown for the first time to the public, due to a generous gift of the heirs of R. Schorr. They show that Bernhard Schmidt very carefully studied the theoretical conditions of his problem before he set out to realize the first Schmidt telescope. *A. Behr*

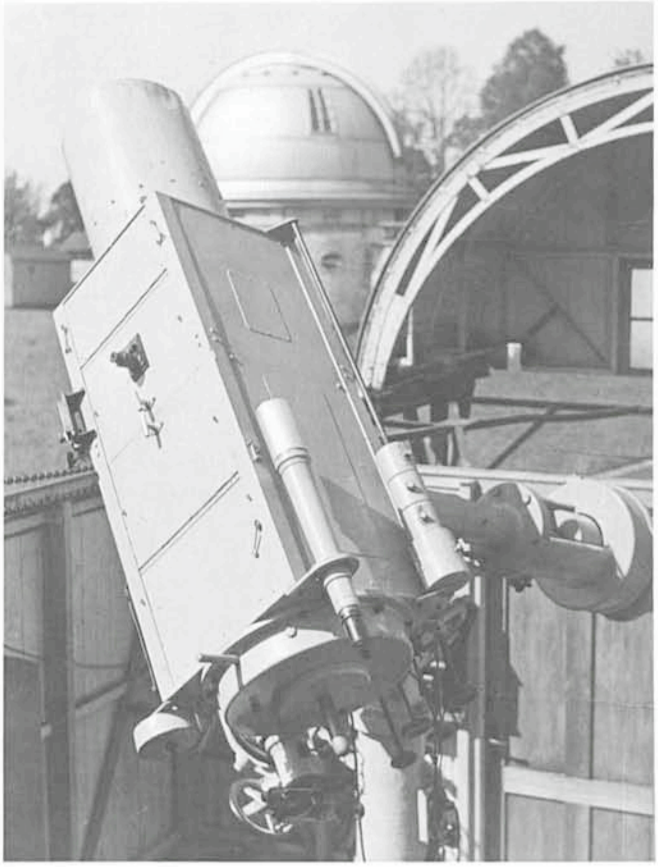

Fig. 2: *The Original Schmidt Telescope at the Hamburg Observatory; f/1.75, 15° field.*

Astronomy in Europe

Professional astronomers sometimes receive letters that begin like this: "Dear Mr. . . ., I am 16 years old and very interested in astronomy. I should like to know how I can become an astronomer . . ."

All astronomers are happy to see examples of deep devotion to the science they like themselves. So most of them answer such letters with kind words of encouragement and an explanation about the study of astronomy at the national universities. But there is one point—and probably the most important of all—the prospects for a successful career in astronomy, that is very difficult to answer. Few sciences have avoided the effects of the present tightening of financial resources, and the number of positions that are available at universities and other research institutions is small. So the letter to the young astronomer-in-spe will have to tell him that he has little hope of ever getting a job in astronomy—unless, of course, he is very brilliant.

But how bad is really the situation? A partial answer is given by a report "A study of manpower in astronomy in the countries represented in the European Science Foundation", that was published by ESF last year. This report, for the first time, assigns quantitative figures to the shortage of posts. It also includes a number of interesting findings concerning the European astronomical community.

The total number of astronomers in the countries that were studied (16 in all, including the 6 ESO countries) is about 2,400. In this connection, an "astronomer" is defined as somebody with a PhD or equivalent competence, working actively as a scientist in a field of astronomy. The corresponding figure in the USA is about 1,400. The European age distribution is peaked near 37 years and about 50 % are in the age group 30–40 years. The number of posts in astronomy (in Europe) that will become vacant due to normal retirement during the forthcoming 15 years is about 350. When taking into account the number of new posts that are likely to be created, an optimistic figure is about 50 new posts per year. This should be compared with the 220 new astronomy PhD's that are produced every year. It is therefore clear that only about 20 % of those who obtain a degree in astronomy will also obtain a permanent position within astronomy.

There is one positive aspect, though: very few people with an astronomy degree are actually without work. It appears that astronomy as such includes so many valuable assets that a candidate will have little difficulty in finding jobs in related fields. Many astronomers teach physics and mathematics in schools and others are employed in industry. The knowledge of practical work in astronomical instrumentation and in particular experience with computers is of value.

Funding of astronomical research has increased by about 40 % (in real terms) between 1970 and 1976, proving the importance of astronomy as a fundamental research discipline in the eyes of budgetary commissions in the various countries. And astronomy is obviously able to attract the best people everywhere. Therefore the present situation is clearly very promising for the science as such, but less so for its many admirers. Fortunately, astronomy can be enjoyed equally well by the scientist in the prime focus cage of the largest telescope in the world and the amateur in his backyard with his home-made reflector. This is a great advantage in comparison with most other sciences, also if we consider that the amateurs still play an important role, first by finding novae and comets and in general by monitoring the skies from all over the world. Perhaps the Olympic motto is also valid in astronomy: "The most important is not to win (i.e. to become a full-time professional), but to participate!"

Echelle Spectrograms

An informal ESO workshop to discuss data-reduction techniques for echelle spectrograms was held in Geneva on March 1–2, 1979.

Astronomers and engineers from all ESO countries already having considerable experience in the treatment of echellograms gathered at ESO-TP to share their experience and to discuss the various difficulties inherent in the reduction of echelle data.

The techniques being used at present to reduce data from the La Silla and Haute-Provence spectrographs, and from IUE and the Utrecht Ultraviolet balloon experiment were discussed in great detail with the aim of familiarizing the ESO astronomers, engineers and computer programmers responsible for the design and construction of the ESO 3.6 m Cassegrain echelle spectrograph (cf. p. 27) with the results of other European groups which operate similar instruments.

The main conclusion from this workshop may be summarized by saying that the extraction of astrophysically useful information from echellograms may be difficult but is by no means impossible!

The workshop was a good starting point for the ESO team responsible for the operation and data reduction of CASPEC. The software is being written in parallel with the hardware construction and should be completed and tested well ahead of the time when CASPEC is put in operation. *J. Melnick*

Proceedings of the ESA/ESO Workshop on Astronomical Uses of the Space Telescope

The Proceedings of this workshop have now been edited and will be available in print by end of May 1979.

The price for the 450-page volume is SFr. 40.– (in Europe) and US$ 20.– (elsewhere), including postage. Please send your order to:

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0.5 Arcsecond Images with the Danish 1.5 m Telescope on La Silla!

J. Andersen and B. Niss

The 2.4 m Space Telescope will achieve 0.″1 resolution in 1984. But what is the best possible angular resolution from a ground-based observatory? Recently, fantastic long-exposure plates were obtained with the Danish 1.5 m telescope at La Silla, proving at the same time the excellent performance of this new telescope and the quality of the ESO site. Drs. Johannes Andersen and Birger Niss from the Copenhagen Observatory, Denmark, tell the exciting story.

In the last issue of the *Messenger*, the general features as well as the optical alignment, commissioning, and initial performance of the Danish 1.5 m telescope on La Silla were described. The conclusion, based mainly on laboratory tests and the accuracy achieved in the alignment, was that the image quality until then had been entirely limited by seeing, but confidence was expressed that the telescope would be "able to take advantage of even the nights of very best seeing".

Such prophecies are not uncommon in articles describing new telescopes. They are usually met with a benevolent scepticism of seasoned observers, who know by experience all the good excuses why the theoretically predicted image quality is (almost) never experienced in practice: Seeing, whether external or internal in the dome or telescope tube, and imperfect optical alignment, mechanical stability, and/or guiding, all combine to make images of one arcsecond or slightly less the best one hopes for in longer exposures, even if theoretical resolution is half that figure or better.

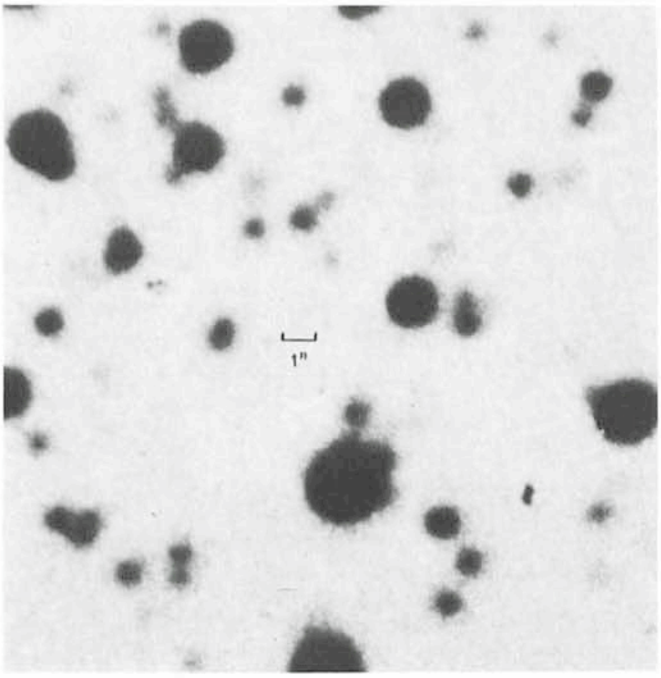


Fig. 1: *Enlargement from a 1-hour exposure on IIIa-J emulsion behind a GG385 filter, showing stars in the globular cluster NGC 3201. The images are perfectly round and measure about 0.5 arcsecond in diameter. Danish 1.5 m telescope; observer Dr. B. Niss, March 7, 1979. Average zenith distance 18°.*

The sanguine predictions for the Danish 1.5 m telescope were, however, confirmed before the ink on them was dry—with one startling reservation as will be discussed at the end of this note. In early March this year, one of us (B. N.) was continuing the observing programme in globular clusters described in *Messenger* No. 10, p. 14. Although the telescope was (and still is) in the testing phase, good cooperation from the equipment combined with a spell of excellent atmospheric conditions to produce a superb collection of plates. The image sizes range from 1″ through several plates of 0.″7–0.″6 to the best one, a *one-hour* exposure on IIIa-J emulsion of NGC 3201, which shows images nicely circular—and of diameter 0.″5 (30 microns) as measured on a projection micrometer! The figures show a reproduction of this plate and a PDS scan through one of the images.

This was an almost unbelievable result (J. A. was in fact only convinced by his own eyes looking through the micrometer eyepiece!). As mentioned in the previous article, the mirror acceptance tests indicated a geometrical energy concentration of 80 % in 0.″45, to which must be added the diffraction disk of 0.″2—and you already have the observed diameters! In fact, had these images been taken in a laboratory vacuum test tank, they would have been considered a most gratifying confirmation of the more indirect test methods. Obtaining such images in a long exposure with a real, moving telescope in a real dome and equally real atmosphere is an entirely different matter; however, not the least if one keeps in mind that asymmetries of 0.″1–0.″2 would have been plainly visible! This leads us to several pleasant conclusions:

- The optical test results supplied by Grubb Parsons were probably even on the conservative side;
- The optical alignment was in fact done to better than 0.″1 of coma, as previously described, *and* it remained intact after four months of operation;
- The telescope tube and drives are of excellent mechanical quality;
- The autoguider and control system achieved a guiding accuracy of about 0.″1 as specified, and, last but not least,
- Seeing, external *plus* internal, was significantly better than 0.″5.

We leave the many possibilities offered by such images to the reader's imagination, but a quick comparison with previous electronographic work indicates that had one of our McMullan cameras been on the telescope that night, we would have been able to detect and measure stars of magnitude between 26 and 27! We do not suggest that such nights are the rule, even on La Silla, but nor do they belong entirely in the realm of dreams.

If one insists in being ungrateful, than it should be said that our mirrors, which we always considered excellent, did *not* in the end live up to those "nights of very best seeing". Rather unexpectedly, the resolution seems ultimately to be limited by residual optical (mostly zonal) aberrations, even at this very low level. It will be interesting to see whether the CAT optics, made by the same manufacturer under even tighter specifications, will produce still better images under optimum conditions.

Being far from ungrateful, however, we wish to conclude by paying tribute once again to those responsible for this achievement: to the firm of Grubb Parsons for their outstanding optical and mechanical craftsmanship, to the ESO Optics Group for their invaluable help in testing and aligning the optics, and to the ESO Controls Group and the workshops of Copenhagen University Observatory for the successful combination of control system and autoguider.

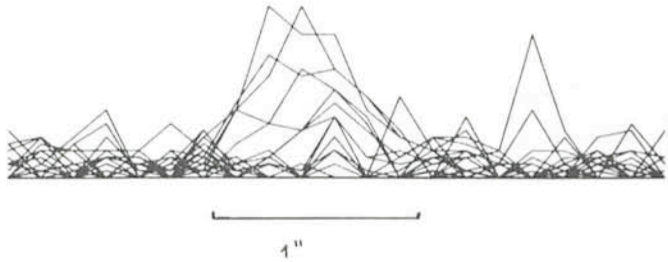


Fig. 2: *A scan through one of the images in figure 1, made with the PDS microdensitometer at the Lund Observatory through a 10 × 10 micron square aperture.*

The Problem of Star Formation—and what Ten Nights of Sub-millimetre Observations with the VLT Could Contribute to its Solution

P. G. Mezger

Astronomical observations are regularly carried out over the whole electromagnetic spectrum, from γ-rays to low-frequency radio waves. There are few unexplored "holes", but one of these—in the neighbourhood of 1 mm—is exactly where we expect most of the radiation from stars during their early stages of formation. The VLT would be ideally suited for ground-based observations in the sub-millimetre range, because of its large surface and good angular resolution. Dr. Peter Mezger of the Max Planck Institute for Radioastronomy in Bonn explains how the VLT can make a very important contribution to the study of stellar formation.

Sub-millimetre Observations, Star Formation and the VLT

The transformation of gas into condensed objects, either ordinary main-sequence stars with masses ~0.1–100 $M_\odot$ or perhaps also much heavier supermassive stars, is one of the most fundamental processes in the Universe. Star formation plays a leading role in the formation of galaxies, in the chemical evolution of the interstellar matter (i.e. its enrichment with elements heavier than ^{4}He) and may well be related to some of the phenomena associated with radio galaxies and quasars.

In spite of a wealth of radio and IR observations related to both dense molecular clouds (out of which protostars form) and pre-main-sequence evolutionary stages of massive stars, the basic process of the formation of protostars out of the interstellar matter is far from being understood, even in a qualitative way. The reason is that the formation of protostars occurs at very low temperatures of the interstellar gas (typically ~10 K) and that the outer shell of the contracting protostar remains at such low temperatures until nuclear burning starts at its centre. Thus the Planck curve for 10 K (shown as dash-dotted curve in Figure 1) is an upper limit for the intensity of both continuum and line TE radiation emitted by dense molecular clouds and protostars in their early evolutionary stages. This curve peaks at ~500 μm (= 0.5 mm). In Figure 1 is also shown the transparency (heavy curve) of the atmosphere for an amount of 1.3 mm of precipitable water, conditions as they prevail at an altitude of ~3,000 m for about 30 % of the clear nights. One recognizes a number of atmospheric windows whose transparency decreases with decreasing wavelength. Below ~300 μm the atmosphere is practically opaque. The wavelength range between 1.8 mm and 300 μm, although accessible for ground-based observations with a telescope placed at a very high and dry site, is largely unexplored. This is due to both a lack of sensitive radiometers and of radio telescopes with a sufficient surface accuracy of its reflector.

Promising developments of both coherent radiometers (for spectroscopy) and incoherent radiometers (bolometers for broadband continuum observations) for the submillimetre wavelength range are in progress in various laboratories in Europe and the US. But even the second generation of mm-telescopes, now being planned or under construction, are only marginally usable for sub-millimetre observations. The reason is that the quality of a telescope for coherent detection is determined by the rms deviation of its reflector surface from a best-fit paraboloid, and this in turn is determined by the surface accuracy of the reflector panels, the accuracy with which these panels can be adjusted, and by the design of the reflector back-up structure. Most mm-telescopes in operation today have rms deviations $\sigma \gtrsim 100$ μm. For the new large mm-telescopes one anticipates rms deviations in the range $90 \gtrsim \sigma/\mu m \gtrsim 50$, which degrade the telescope characteristics (such as gain, aperture, and beam efficiency) according to exp

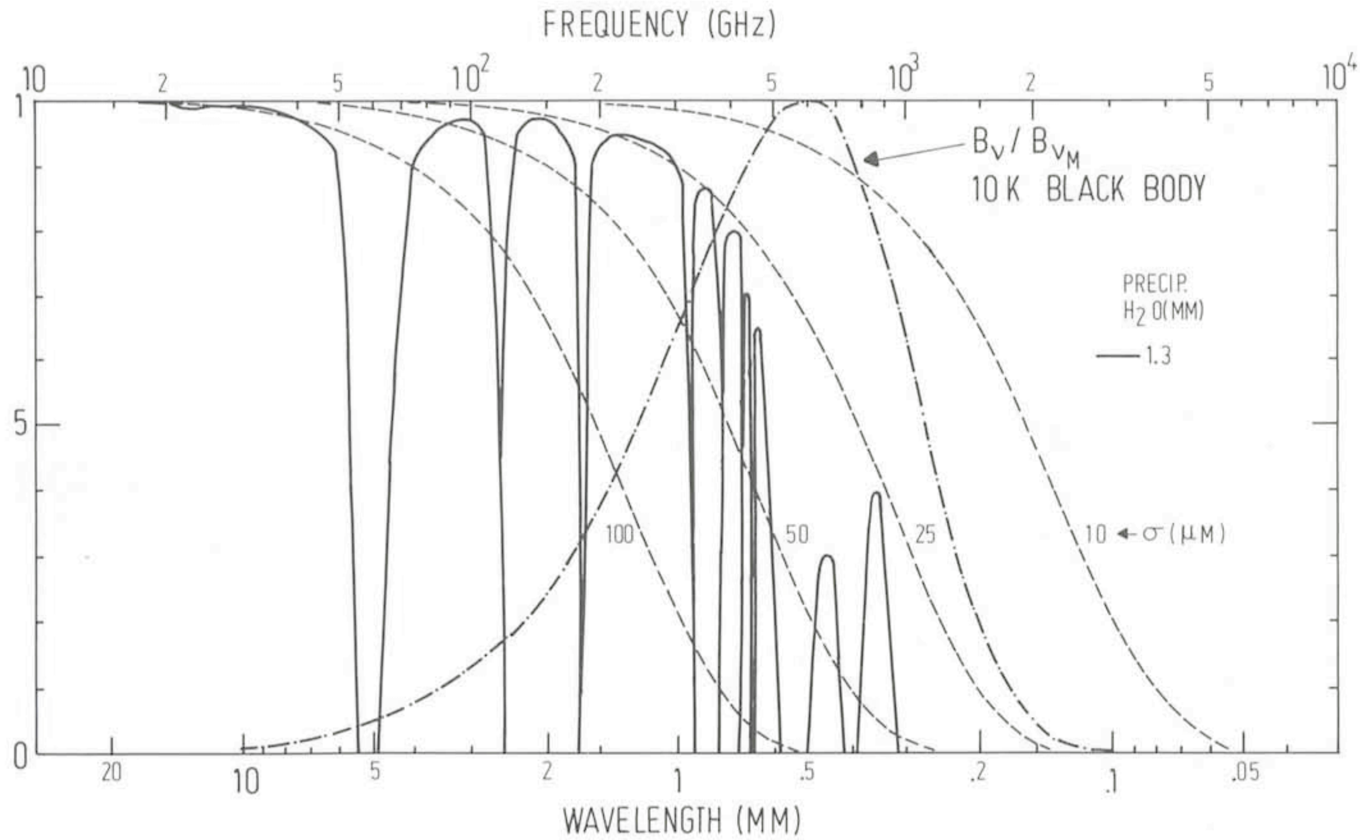


Fig. 1: *Transparency of the atmosphere (heavy curve) for an amount of 1.3 mm of precipitable water. Relative change of gain and efficiency of a telescope used for coherent detection (dashed curves). Curve parameter is the rms reflector deviation σ from a best-fit paraboloid. And (dash-dotted curve) normalized Planck radiation curve for 10 K. (Adapted from Leighton, 1978, Final Technical Report NSF Grant AST 73–04908).*

$\{-(4\pi\ \sigma/\lambda)^2\}$. This function is shown in Figure 1 for different values of σ as dashed curves. Telescopes to be used in the sub-millimetre range $\lambda \gtrsim 300\ \mu m$ should have rms deviations $\sigma \lesssim 10 \sim 20\ \mu m$. Today, such accuracies are only attained by optical reflectors and this explains why at present observations in the sub-millimetre range are exclusively done with large optical telescopes, mostly at twilight and during moonlight nights. Considering these facts und the observing interests of me and some of my associates at the MPIfR it is obvious that we would use VLT observing time for an investigation of the early phases of protostars. Within ten "nights" at the VLT, sub-millimetre observers with improved coherent and incoherent radiometers should be able to gain insight into some of the basic processes of star formation. I have deliberately put "nights" in quotation marks, since sub-millimetre observers would probably always request only such observing time on a VLT which could not—or only marginally—be used by optical observers.

What Do We Know about Star Formation?

From recent radio and infrared observations we have learned quite a lot about the pre-main-sequence evolution of massive OB stars. We know that these stars form out of dense clouds of interstellar gas where practically all hydrogen is in molecular form. H_2 has no observable radio transitions, but since it is the most abundant collision partner its density can be crudely estimated from the intensities of collisionally excited transitions of molecules such as CO, CS, CN or HCN. From such observations we know that giant molecular clouds have masses 10^5–$10^6\ M_\odot$, mean densities of 10^3–$10^4\ cm^{-3}$ and kinetic gas temperatures $\gtrsim 10$ K. And it appears that at densities $\gtrsim 10^4\ cm^{-3}$ gas and dust are in thermodynamical equilibrium. But what initiates (or inhibits) star formation in these clouds we do not know. We have learned from recent model calculations that (at least the more massive) stars form by accretion. At the centre of a contracting protostar, density and temperature become high enough for hydrogen burning. An embryo star forms, which grows by infall from the outer layers of the protostar und therefore evolves up the main sequence. After the embryo star stops accreting, a shell of gas and dust is left behind, which is visible first as a FIR source and subsequently as a compact H II region. The sequence of observable stages of the protostellar shell, after hydrogen burning has started at the centre of the embryo star, is shown in Figure 2. But practically nothing is known about the earliest evolutionary stages of protostars, when these objects should appear as dense but isothermal condensations in cool molecular clouds.

The situation becomes even worse if we turn to the formation of lower-mass stars (i.e. stars with masses less than a few solar masses) which account for the bulk of the mass of stars. While both high-mass stars and lower-mass stars form out of massive and dense clouds of interstellar matter, the former appear to form predominantly in the main spiral arms, the latter appear to form predominantly in the interarm region (observable in some cases as T-Tauri associations). What determines the stellar birthrate function, why is it easier for nature to form low-mass stars than massive stars (in contradiction to what the Jeans criterium tries to tell us), and which fraction of mass ends up in substellar objects with masses $\lesssim 0.07\ M_\odot$? Answers to these questions will probably only come from sub-millimetre and FIR observations.

Emission from Dust, from Molecules and from Atoms at Sub-millimetre Wavelengths

Let us first consider the quasi-thermal emission from cool dust. At sub-millimetre wavelengths $\gtrsim 300\ \mu m$ even for the giant molecular clouds the average dust optical depth is small, so that protostars which form deep in these clouds, due to their higher densities and hence optical depths, should be observable as emission centres or "hot spots". Hildeband and his colleagues of the University of Chicago, using optical telescopes at Cerro Tololo and Mauna Kea, have actually observed thermal dust emission from cool molecular clouds and from the globule Barnard 335. For the latter the colour temperature of the dust was found to be ~ 8 K. This type of observations with telescopes of high angular resolution (a 25 m VLT at λ 500 μm will have a HPBW of ~5 arc sec) should be a very powerful tool for the investigation of the earliest protostellar stages. At present, one uses composite Ge-bolometers which are cooled to temperatures of ~ 1.5 K, attainable with pumped liquid ^{4}He. However, temperatures as low as ~ 0.3 K can be attained by using ^{3}He as a coolant, and this should increase the sensitivity of future bolometers by at least an order of magnitude.

The optical depth of dust is independent of temperature and varies only slowly with frequency. The spectral shape of optically thin dust radiation thus is still very similar to that of a Planck curve. On the other hand the optical depth of the rotational transition of a molecule increases with T_{ex}^{-2}, but decreases rapidly with increasing rotational quantum number J or decreasing wavelength once E(J) > kT. Figure 3 shows the intensity distribution of rotational lines of the CO molecule, computed for $T_{ex} = 10$ K; curve parameter is τ_{co} (J = 1→0), the optical depth of the lowest transition. Even for τ_{co} (1→0) = 10–100 (which may be typical for dense molecular clouds) the lines with J $\gtrsim$ 4-5 become optically thin and thus allow observations of condensations in the cloud. Again, the high angular resolution of the VLT should allow to observe dense condensations inside the optically thin clouds, which I would expect to be the first evolutionary stages of protostars. Equally important is the fact that the analysis of several (optically thin) rotational transitions of one molecule leads to a much more accurate determination of the physical state of a molecular cloud than does the currently applied method of observing one handy transition at mm wavelengths $\lambda \gtrsim 2$ mm of different molecules with different dipole moments. Plambeck and Williams, for example, compared density determinations from the J = 1→0 and 2→1 transition of the isotopic ^{13}CO, with corresponding densities derived from one transition of CS, CN and CHN, respectively. They found that the latter method overestimates densities by typically a factor of 10! This is one reason why the sub-millimetre range with its possibility to observe several rotational transitions of one molecule, is so important for the astrophysical application of molecular spectroscopy. Other reasons are that several molecules, such as the possibly very important species of hydrides, have such low moments of inertia that their rotational spectra only start at wavelengths < 1 mm. Observations of

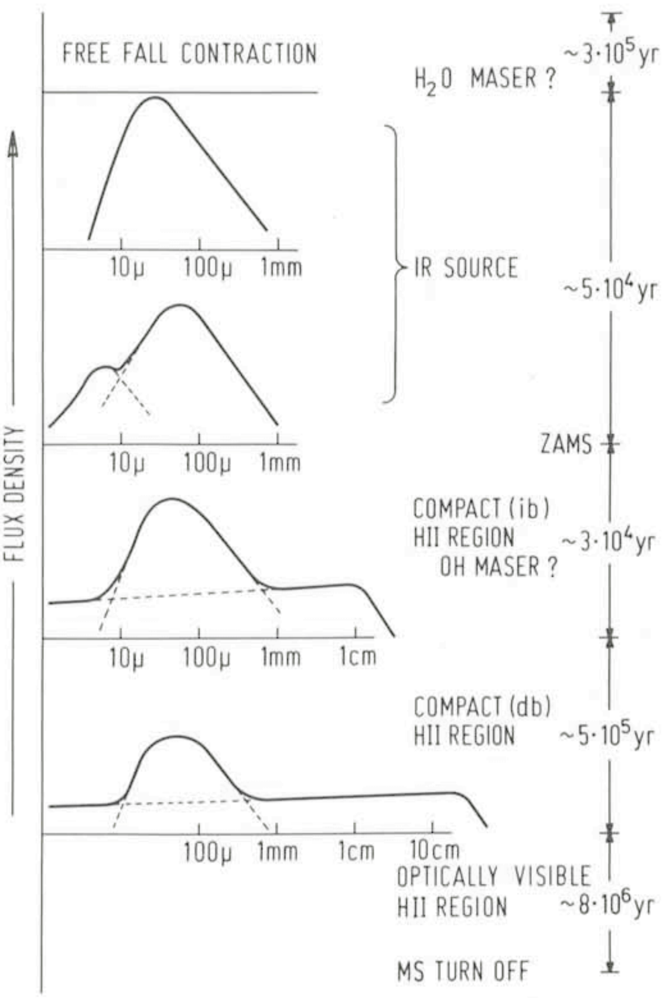


Fig. 2: *Observable spectra of an evolving massive protostar. Time scales on the right side correspond to a main-sequence star of 17 $M_\odot$. During the free-fall contraction the protostar should be observable as a 10 K black body (see Fig. 1). A compact radio H II region forms after the accretion has stopped and the star has attained the ZAMS. The maser, IR and Radio stage of an O star together last for ~5–10 % of its MS life time (Mezger, 1978, Infrared Astronomy [G. Setti and G. G. Fazio, eds.] D. Reidel Publ. Co. p. 1.).*

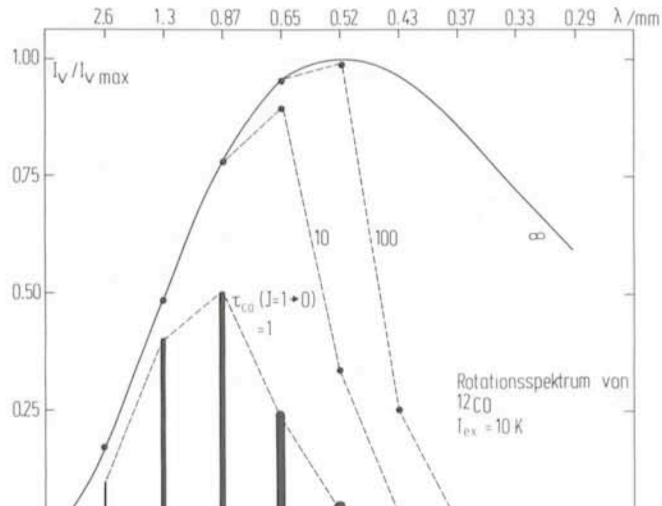


Fig. 3: *Intensities of rotational lines J→ (J-1) of the ^{12}CO molecule computed by Schmid-Burgk for a plane-parallel gas layer in TE at 10 K. Curve parameter τ_{co} (J = 1→0) is the optical depth for the lowest rotational transition. The curve $\tau_{co} \rightarrow \infty$ corresponds to the Planck curve. Note that the width of rotational lines increases approximately proportional with J.*

hydrides may in fact play a key role for our understanding of interstellar chemistry. Of special interest for astrophysics are transitions of atoms and atomic ions since they allow abundance determinations. Furthermore, fine structure lines of atoms and ions as C° and C^{+} provide part of the cooling for interstellar clouds. The λ 610 μm line of C° should be of special interest for the physics of dense interstellar clouds and may be observable with a ground-based telescope. However, only heterodyne radiometers will provide sufficient sensitivity for sub-millimetre spectroscopy. As mentioned before, intensive development work on this type of radiometer is in progress in several laboratories in Europe and USA:

There are other, more speculative, objects to be observed in the sub-millimetre range, such as the redshifted dust radiation from giant elliptical galaxies in their formation stage. The cosmological implications of such observations are obvious. We may also envisage a galactic survey for both the quasithermal emission from cool dust and for some higher rotational (and therefore optically thin) transitions of the CO molecule. (But of course such a survey would be carried out not with the VLT but with small telescopes.) This should lead to a much more realistic picture of the distribution of interstellar gas than the present one which is based on the observation of the opaque $J = 1 \rightarrow 0$ transition of ^{12}CO.

European Astronomers Discuss the Use of the Space Telescope (continued)

With the publication of the Proceedings of the ESA/ESO Workshop on "Astronomical Uses of the Space Telescope", held in Geneva on February 12–14, 1979, it is now possible to better judge the interest of the European astronomical community in the Space Telescope. The Proceedings of course only represent the "official" part of the meeting. There were also lively discussions among the 186 participants and it is impossible to write them all down!

The Space Telescope

The workshop was opened by three speakers—Longair, O'Dell and Macchetto—presenting a general introduction of the technical as well as the political aspects of the ST.

In his contribution "The Space Telescope and its capabilites", Longair compared ST with ground-based telescopes, stressing the improvements in angular resolu-

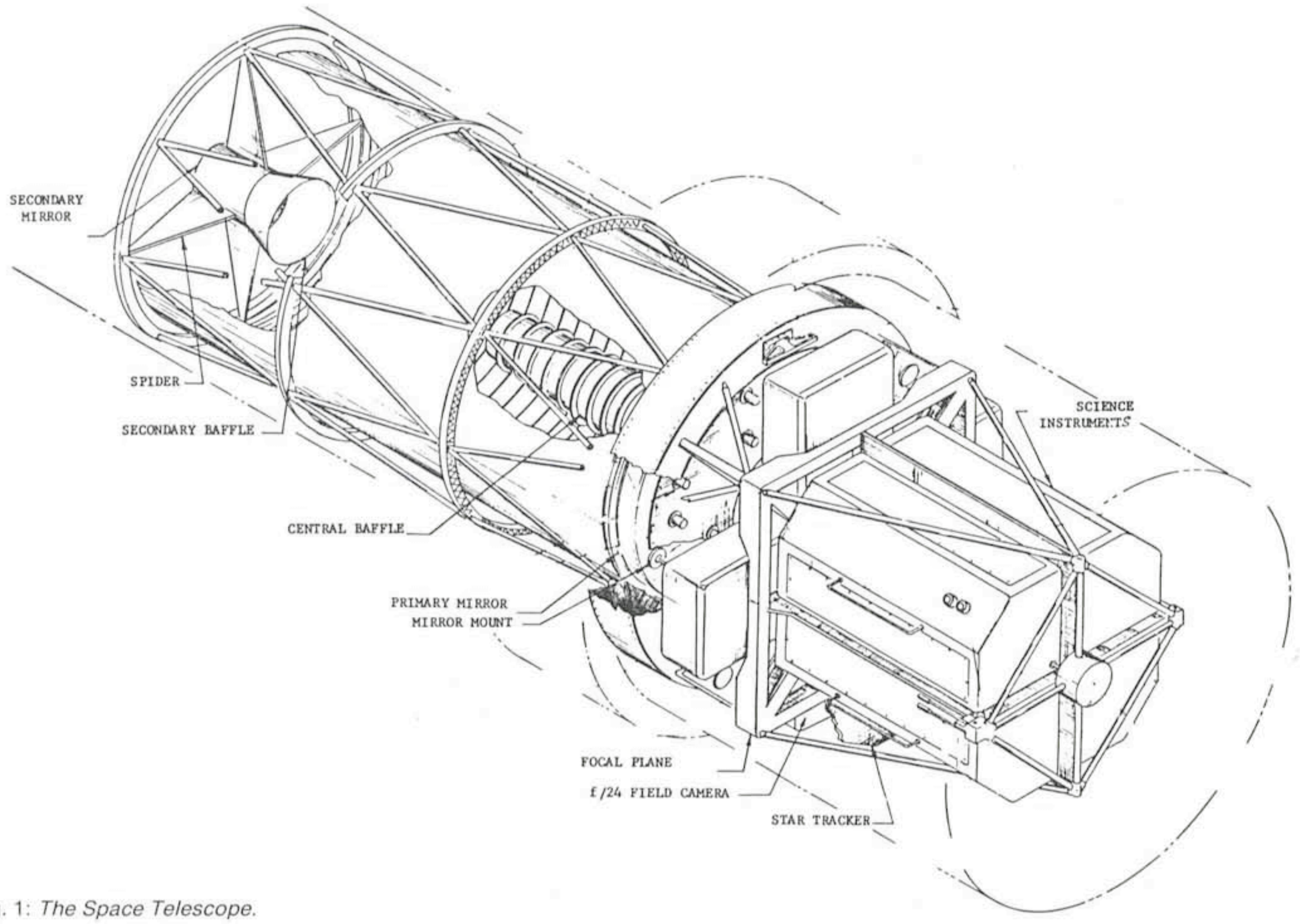


Fig. 1: *The Space Telescope.*

Space Telescope Parameters

Specification and performance goals of the NASA Space Telescope

Telescope aperture	2.4 m
System focal ratio	f/24
Optical design	Ritchey-Chretien Cassegrain
Central obscuration	14 % aperture area
Field of view for science	18 arcmin diameter
Spectral range	120 nm – 1 mm
Optical performance: system wavefront error	$\lambda/13.5$ r.m.s. at 632.8 nm
Radius of 70 % encircled energy from a point source at 633 nm	0.1 arcsec
Faint object sensitivity subject to viewing in directions greater than i) 50° from Sun ii) 70° from Earth's limb iii) 15° from Moon	Point objects having m_v = 27 or brighter; extended sources to a limit of 23 magnitudes (arsec)$^{-2}$ in visual wave-band. Both in 10 hours of integration.
Pointing stability	0.007 arcsec on a target having m_v = 13 in the range 400–800 nm
Minimum reflectivity	85 % at 632.8 nm 70 % at 120 nm

Satellite orbit

Circular Earth orbit serviceable by the Space Shuttle

Altitude	about 500 km
Inclination	28.8°

The Wide-Field/Planetary Camera

The Camera can operate with two different focal ratios, f/12.9 or f/30. The former gives a field of view 2.67 × 2.67 (arcmin)^2 and is referred to as the Wide-Field Camera; the latter gives a field of view of 68.7 × 68.7 (arcsec)^2 and is called the Planetary Camera.

	Wide-Field Camera	*Planetary Camera*
Picture format	1600 × 1600 pixels	1600 × 1600 pixels
Angular field of view	2.67 × 2.67 (arcmin)^2	68.7 × 68.7 (arcsec)^2
Pixel size	0.1 arcsec	0.043 arcsec
Dynamic range (per pixel, single exposure)	> 15,000	> 15,000
Maximum S/N (per pixel, single exposure)	450	450
Photometric precision	Better than 1 %	Better than 1 %
Photometric accuracy	Better than 2 %	Better than 2 %
Overall dynamic range for stars (m_v)	+ 3 to + 29	+ 1 to + 29

Faint-Object Camera

This table shows the proposed instrumental parameters which will be achieved by the Faint-Object Camera operating in the f/96 mode.

Field of view	11 × 11 (arcsec)^2
Angular resolution	Essentially limited by the performance of the Optical-Telescope Assembly at wavelengths longer than 300 nm
Wavelength range	120 to 800 nm
Dynamic range (single observation)	m_v = 21 to 28 on point sources; 15 to 22 visual magnitudes (arcsec)$^{-2}$ for extended sources
Photometric accuracy	~ 1 % when not photon-noise limited
Focal ratio	f/96 assuming 25 μm pixels. Additional focal ratios are desirable (see text)
Number of pixels	500 × 500
Exposure time	Up to 10 hours
Calibration	Internal sources and standard stars, necessary to provide required photometric accuracy

Faint-Object Spectrograph

Spectral range	114 to 1010 nm
Spectral resolving power $R = \lambda/\Delta\lambda$	R = 10^3 first priority R = 10^2 second priority
System Absolute Efficiency	> 1 %
Radiometric precision	< 1 % of maximum scene signal
Slot sizes: fixed apertures	1.00 arcsec diameter 0.50 arcsec diameter 0.25 arcsec diameter (fail-safe position) 0.10 arcsec diameter Special purpose occulting mask Closed
Centering stability	± 0.03 arcsec
Angular resolution	0.1 arcsec
Dynamic range	10^7
Relative wavelength calibration	20 % of resolving power
Detectors	512 diode linear array Digicons
Exposure times	Minimum gate time 50 μs Minimum periodicity 10 ms No limit on maximum length of target integration

High-Resolution Spectrograph

Spectral resolving power $R = \lambda/\Delta\lambda$	2 × 10^4	1.2 × 10^5
Detector channel width:		
at 150 nm	0.0075 nm	0.0013 nm
at 230 nm	0.0115 nm	0.0019 nm
Detector step or sub-step size	variable 0.001 – 2.3 nm	variable 0.002 – 0.38 nm
Overall spectral range	105–170 nm 110–320 nm	110–170 nm 170–320 nm
Spectral range per integration		
at 150 nm	3.5 nm	0.56 nm
at 230 nm	5.9 nm	1.02 nm
Minimum and maximum integration times (seconds)	0.05 to ∞	0.05 to ∞
Field view	1.0 × 1.0 (arcsec)^2 0.30 arcsec	1.0 × 1.0 (arcsec)^2 0.30 arcsec
Dynamic range per resolution element per exposure	10^7	10^7
Photometric resolution	count-limited	count-limited

High-Speed Photometer/Polarimeter

Spectral range	115–850 nm (photometry) 210–700 nm (polarimetry)
Spectral resolution	~ 2 nm (200–300 nm) ~ 25 nm (115–350, u, b, v, y, Hβ) ~ 80 nm (UBVR) ~ 200 nm (110–350 nm) ~ 500 nm (300–800 nm)
Fields of view	0.7, 1.4, 2.8 arcsec
Temporal resolution	As fast as 16 μs
Photometric characteristics	Pulse counting over dynamic range of 10^6 with no dead-time correction over first five decades; analogue mode extends range to 10^7 and overlaps counting mode over four decades with 2 % A/D conversion accuracy.

tion, the "24-hours per day" observing time, and the wide observable waveband. He described in some detail the five scientific instruments: the Wide-Field/Planetary Camera, the Faint-Object Spectrograph, the Faint-Object Camera, the High-Resolution Spectrograph and the High-Speed Photometer/Polarimeter. Longair concluded: "It is essential to plan your Space Telescope observing programme *now* because there will not be time available for making mistakes. Everything possible should be done from ground-based observatories so that when the Space Telescope observations are made, we are all in a postition to make the optimum use of them."

O'Dell (NASA) and Macchetto (ESA) presented the status of the project and showed that ST is not a telescope under study but an instrument under construction. If everything goes well, we shall have a 2.4 m telescope in orbit in 1984. So the rest of the conference was concerned with how to make the best possible scientific use of it. For the benefit of all interested parties we have reproduced on page 19 the main parameters of the Space Telescope and its auxiliary instrumentation.

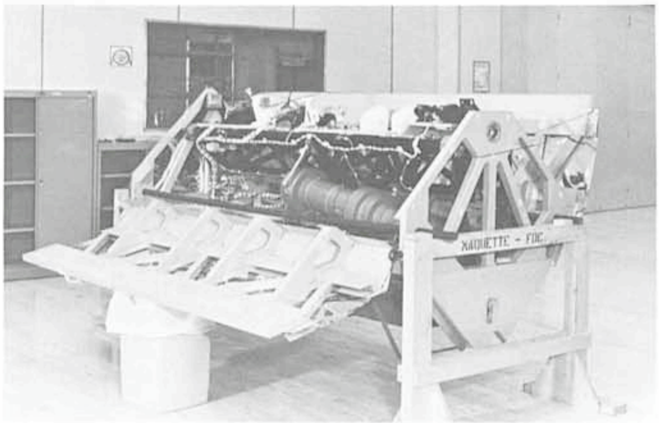


Fig. 2: *One of the main instruments onboard the Space Telescope is the Faint-Object Camera (FOC). It constitutes one of the major European contributions to the ST project and is here shown (as a full-size mock-up) at the European Space Agency (ESA).*

Galactic Research

Different aspects of star formation and stellar evolution were the subject of interesting contributions by Appenzeller, Gahm, Staller, Hack, Buser, Rakos and Jaschek. New spectroscopic data obtained with IUE, a 45 cm space telescope—rather primitive when compared with the ST—were used to demonstrate the great potential of ST. The unique possibility offered by ST to obtain extremely deep pictures of star fields in different colours from the UV to the IR will be used to investigate the space distribution, luminosity function and chemical gradients of stars inside and around our galaxy.

The H II regions, interesting because of their relation with the star formation problem, opened the topics of interstellar matter. Galactic as well as extragalactic H II regions, planetary nebulae and supernova remnants were discussed by Courtès, N. Vidal, Elsässer, Perinotto, D'Odorico and Danziger. Making use of the advantage of the monochromatic character of the emission of these objects there was general consent that high-resolution pictures, obtained with narrow interference filters, centred on lines and on the continuum, will show new structures that could revolutionize our ideas concerning the interstellar matter. The main limitations will be in the angular sizes of the ST fields of view, which are indeed very small when compared with the extension of H II regions or supernova remnants.

Globular clusters are traditionally objects of transition between galactic and extragalactic astronomy, and during the ST Workshop they continued to play this role. The great advantage of the use of ST in globular cluster research was strongly expressed by Castellani. He concluded: "It looks clear to me that ST could be devoted to such a problematic for a very long time without exhausting this subject. I, of course, cannot ask for a GCST (Globular Cluster Space Telescope) though I am personally convinced that such an instrument would be among the most busy and useful instruments to be launched in space!". This idea was immediately accepted by Aurière, Renzini and Wyller who presented observing programmes for the ST for globular clusters. Following these speakers, Weiss discussed the use of globular clusters as distance indicator for galaxies.

Extragalactic Research

Westerlund pointed out that "many of the research programmes that one may foresee for the Magellanic Clouds with the aid of the ST are of a similar nature to those that may be planned for objects in the Galaxy". Studies of field stars, star associations, interstellar matter will make significant contributions to the solution of the riddles of the Magellanic Clouds. With ST it will be feasible to extend similar programmes to other galaxies in the Local Group and to the Virgo Cluster. Pagel presented a review paper on the chemical evolution of galaxies and van der Kruit described the advantage of ST in the study of dynamics of galaxies. In this field of astronomy one of the problems is the velocity dispersion in elliptical galaxies. Crane described the potential of the Faint-Object Camera in the spectrographic mode with respect to dynamics of the nuclear regions in elliptical galaxies.

If normal galaxies will be primary targets of ST, then the so-called "active" galaxies, including quasi-stellar and BL Lacertae objects, are the extragalactic objects from which we hope to obtain the most surprising results. Since long one of the dreams of extragalactic astronomers is to observe NGC 4157, 3C273 or OJ 287 with high spatial resolution over a wide spectral range. ST will for the first time allow us to look into the inner part of active nuclei of galaxies close to "the source".

These subjects for ST research were discussed extensively by Ulrich, Penston, Disney and Heidmann.

Tarenghi, N. Vidal and Fong dealt with distant galaxies and clusters of galaxies and the puzzling problem of galaxy evolution. The workshop ended with a review by Tammann on "Cosmology with the Space Telescope". In the beginning, ST was considered "the tool" to solve all cosmological problems. However, after a lucid analysis of the limits of ST, Tammann concluded: "ST will be helpful for the determination of H_o, it will be very important for the mapping of the expansion field, and it offers a unique chance to determine q_o from supernovae and to verify the Doppler nature of cosmological redshifts."

The general impression after this workshop is that ST will be a heavily oversubscribed telescope and that the European astronomical community will try hard to obtain more time than the 15 % share they are guaranteed in the ESA-NASA agreement.

M. Tarenghi

HD 101947—the First Very-Long-Period Classical Cepheid in Our Galaxy?

W. Eichendorf and B. Reipurth

The ESO observatory on La Silla is not just a place where you go to observe—it is also an important meeting place for European astronomers. Many papers with co-authors from different institutes have resulted from encounters over a cup of tea and a "completo". This was also the beginning of the long collaboration between Drs. Walter Eichendorf from the Astronomical Institute in Bochum, FRG, and Bo Reipurth from the Copenhagen Observatory, Denmark. Over a period of several months, they continued to observe a star that later turned out to be unique among the Cepheids in our galaxy.

The Danish, German and Swiss telescopes on La Silla are often used by "national" observers spending several months on the mountain—in contrast to most other ESO observers. This means that a huge observational material can be secured for a programme, and also that such an observer at times can be recognized on the black circles around his eyes at the end of an observing run. But it also means that different types of programmes can be initiated, for example the study of very long-periodic phenomenae.

Meeting on La Silla and recognizing this fact, we incorporated each night, in our respective photometric and spectroscopic programmes, observations of the bright, 5^m yellow supergiant HD 101947, which Fernie (*IBVS* No. 1305) from observations on a few nights suspected to be a Cepheid with the long period of one month. Our observations have shown this to be a conservative estimate: We now believe HD 101947 is an extremely long-period low-amplitude classical Cepheid with a period of 125 days, thus making it by far the longest-period Cepheid hitherto known in our galaxy. In addition, this star may be especially important for Cepheid research, because of its membership in the small young open cluster Stock 14, which has been observed by two Bochum observers, A. F. J. Moffat and N. Vogt, in their study of southern open star clusters.

All classical Cepheids known today in our galaxy have periods ranging from 2 to 40 days, most of them falling in the period range between 4 and 8 days. In the Magellanic Clouds, however, Cepheids have been found with periods up to hundreds of days. A few searches for such Cepheids have been carried out in our galaxy—with no success so far. Of course, heavy selection effects work against the discovery of these stars in our galaxy, in particular, if their amplitudes are small. Recently several investigations based on Cepheids have been published on possible systematic differences between galaxies. Such differences, which might be due to chemical differences, could even influence the calibration of the extragalactic distance scale.

Observations on La Silla

Between February and July 1978, HD 101947 was observed with the Danish 50 cm and the Bochum 61 cm telescopes on La Silla, photometrically and spectroscopically with the Strömgren photometer and the Bochum spectrum scanner. Part of the observations were kindly performed by our successors after we left La Silla. As one result, we present

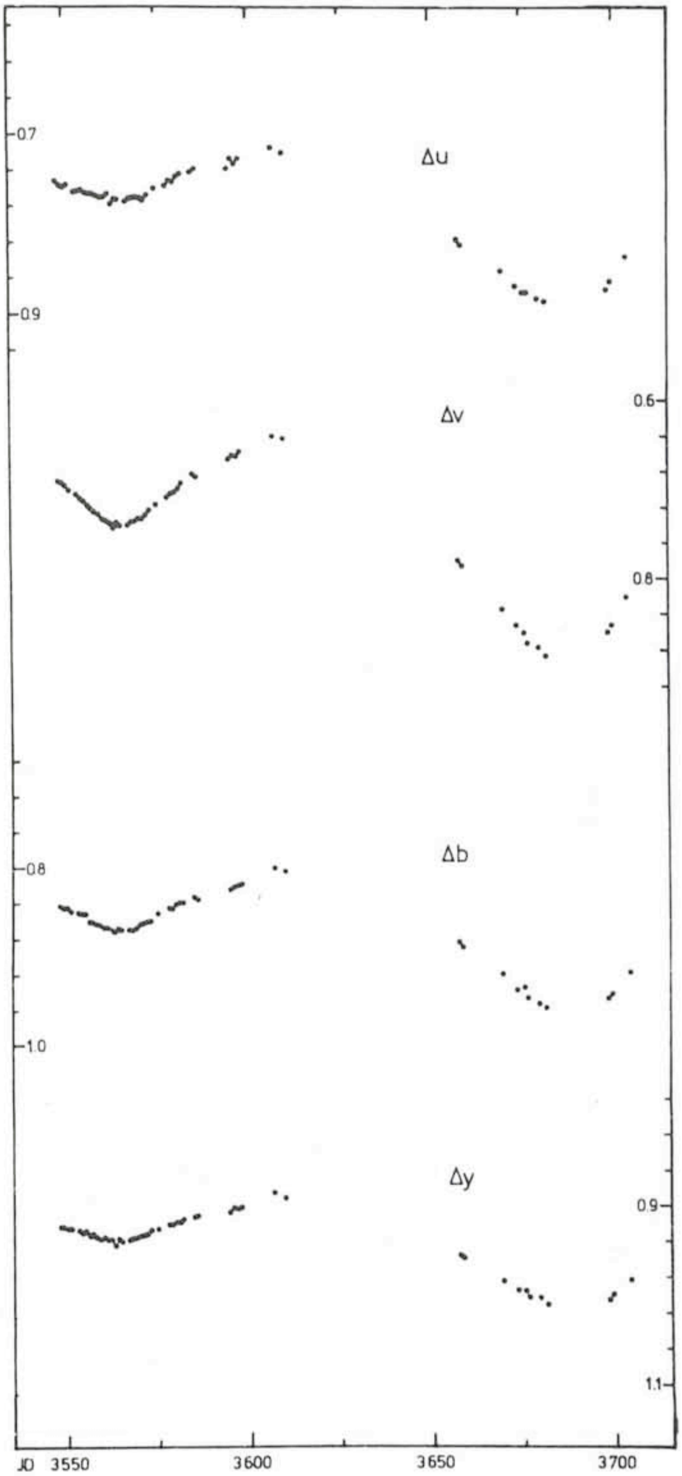


Fig. 1: *The uvby lightcurve of HD 101947, which after the work described here has been named V 810 Centauri. The diagram covers half a year from January to July 1978.*

here the differential uvby lightcurves (HD 101947 – HD 102350 in the instrumental system). Figure 1 covers half a year. The internal accuracy of all measurements is better than $0\overset{m}{.}005$.

We have observed two minima, and because of the very smooth behaviour of the light variations we can fairly safely exclude that another minimum happened during the gap in the observations. Therefore the period of the light variations of HD 101947 appears to be about 125 days, with maximum amplitudes ranging from $0\overset{m}{.}13$ in y to $0\overset{m}{.}24$ in v.

During the first descending branch and minimum of the lightcurve we obtained blue and red scanner spectra as well as H α line profiles. On all spectra a clear H α emission in the absorption core is seen, shifted redwards about 1.5 Å. A careful check did not reveal any variations in the spectra.

The Nature of HD 101947

It will obviously take some time to find out whether the lightcurve is really periodic, and we shall here assume that it repeats, a suggestion that may find some support in the very smooth light changes. Without going into details here, we found it very improbable that HD 101947 is a binary with ellipsoidal variations, a SRd star or a RV Tauri star. The spectral type, the luminosity class, an increasing blueness with increasing brightness and the H α emission at least at certain phases are all characteristics of long-period Cepheids. Also the low galactic latitude of $b = -0^\circ 38'$ is typical for these stars. A period of 125 days gives an absolute magnitude of $-8\overset{m}{.}3$ in Sandage and Tammann's period-luminosity relation, in good agreement with the value of $-7\overset{m}{.}9$ we get from the distance of Stock 14.

Using a theoretical HR diagram from Cox and Hodson (IAU Symposium No. 80) we find HD 101947 situated on the blue edge of the Cepheid instability strip with nearly perfect agreement between the theoretically expected and the observed period.

Two features of the lightcurve cannot be readily explained: the small amplitudes, and the changing amplitudes. Concerning the first point we have already noted that perhaps different chemical compositions would give Magellanic Cloud long-period Cepheids large amplitudes, and galactic ones small amplitudes. Or, being situated on the blue edge of the instability strip, HD 101947 may be a first overtone pulsator, for which smaller amplitudes are theoretically expected, and it may even be switching to the fundamental mode. Also, it has recently been found that resonance phenomena may be effective for long-period Cepheids. For example, the small amplitudes might result from a coupling of a damped first overtone pulsation with an excited fundamental mode. The problem of changing amplitudes could perhaps also be understood as double-mode pulsations, which are known from short-period Cepheids.

The discovery of more stars in our galaxy behaving like HD 101947 may help to solve this question. For other galaxies, finding stars with amplitudes of only $0\overset{m}{.}2$ over months may be rather difficult at the moment.

Stock 14 and IC 2944

The young, loose, open cluster Stock 14 is situated at a distance of approximately 2.5 kpc on the inner side of the Carina spiral feature. Only 1 degree away is the cluster and large H II region IC 2944. At the IV. European IAU meeting in Uppsala A. Ardeberg and E. Maurice reported that IC 2944 actually consists of at least seven aggregates

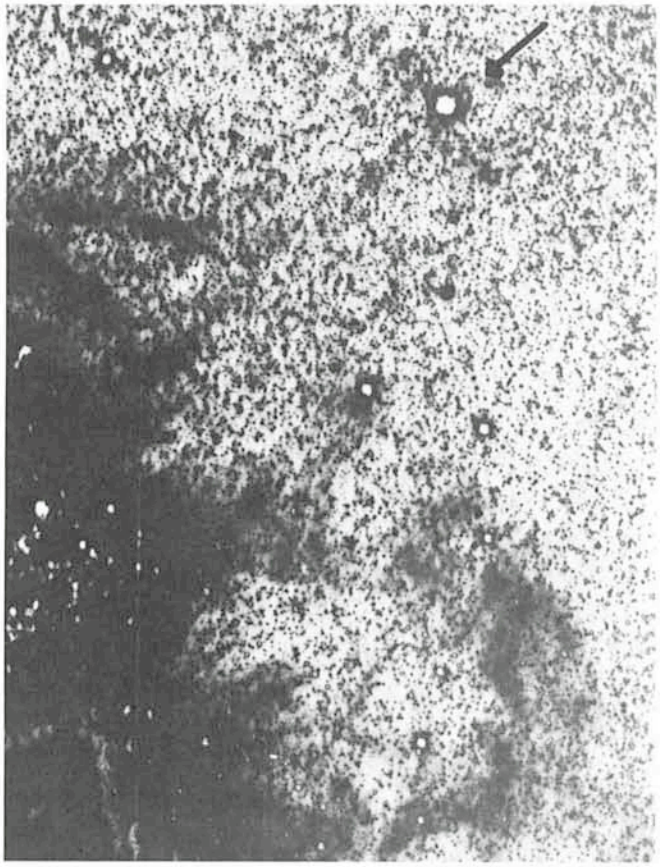


Fig. 2: *An equidensity-picture of the region around IC 2944 and Stock 14 in red light. North is on top. In the lower left the large H II region IC 2944 is seen; the bright star indicated by an arrow is HD 101947. It is evident that IC 2944 extends at least to a very small angular separation from Stock 14.*

This picture is an overlay of two equidensity-pictures (one of first and one of second order) of a red plate taken by G. Lyngå (Lund). In this way the H II region is very dark, but the fine extensions towards Stock 14 are easier to see than in a usual photograph. For the picture we are grateful to the staff photographer in Bochum, Mr. W. Hünecke.

stretching out along the line of sight. The one closest in angular distance to Stock 14 also seems to be at comparable distance, suggesting that they may be physically connected. We have made a preliminary search for faint bridges of matter between Stock 14 and the aggregates in IC 2944 using the technique of equidensitometry on deep red plates, taken by G. Lyngå. Figure 2 shows an example of the pictures obtained that way, and it is seen that part of the H II region in IC 2944 is stretching out at least to small angular distances from Stock 14. A more detailed study with a microdensitometer on more plate material is in preparation. Also radial-velocity studies in the region will be important to solve this question.

To confirm the Cepheid nature of HD 101947, more observations over long-time intervals will be necessary, both photometrical and spectroscopical. For a precise understanding of the pulsations, observations over more than a decade may perhaps be needed. We shall certainly try to continue observing HD 101947, but we here want to take the opportunity to urge observers in the southern hemisphere to include this exciting star in their photometric and spectroscopic observing programmes.

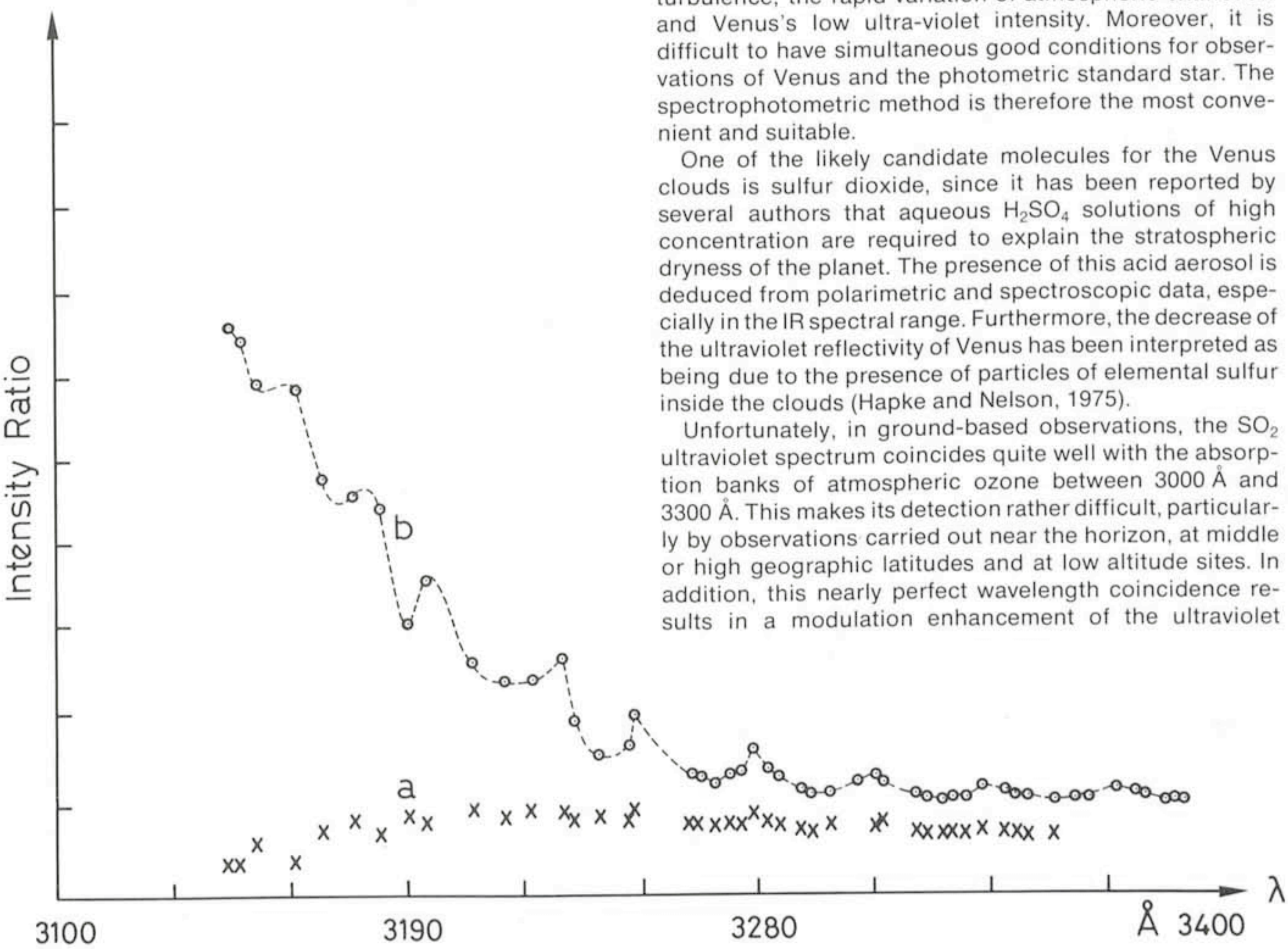
Financial support by the German (DFG, Da 75/3 and Schm 160/13) and Danish research council is gratefully acknowledged.

Sulfur Dioxide and Carbon Disulfide in the Venus Clouds

C. T. Hua, G. Courtès and N. H. Doan

Exciting results were obtained from the Pioneer Venus spacecraft as it reached our mysterious neighbour planet in late 1978. In contrast to our own life-supporting, oxygen-rich atmosphere, that on Venus is dense, hot and poisonous. Spectroscopic observations near the atmospheric cut-off at 3000 Å were recently made at La Silla by Drs. C. T. Hua and G. Courtès (Laboratoire d'Astronomie Spatiale, Marseille), together with Dr. N. H. Doan (Observatoire de Lyon), showing for the first time that there may be carbon disulfide in the Venus clouds, adding a compelling malodorous reason for not going there!

We have recently obtained very interesting spectroscopic data concerning the clouds on Venus, in the range of 3100–3300 Å and with a resolution better than 2.5 Å/mm. The observations were carried out by means of a scanner attached at the Cassegrain focus of the ESO 1.52 m telescope, on January 27, 1979.



The ultraviolet spectrum of Venus, as observed with the ESO 1.52 m telescope. Tracing (b) shows the intensity ratio (Venus/sky background) and the absorption bands in the Venus atmosphere. The crosses (a) indicate the ratio between two separate sky measurements (see text) and that the effects of the ozone absorption bands in the terrestrial atmosphere have been cancelled.

A detailed examination of the spectra seems to indicate the presence of carbon disulfide (CS_2), rather than sulfur dioxide (SO_2) as previously thought; this conclusion is based on an extensive investigation of the UV absorption of SO_2 and CS_2.

A preliminary study concerning the optimization of the optical arrangement for the VENERA experiment of the Service d'Aéronomie and CNES proposed by Prof. J. E. Blamont facilitated our choice of the best observational parameters for our present investigation of the Venus clouds. In particular, it was found that the contrast in the UV spectral range near 3300 Å appears to pass through a maximum; this was deduced by examining various filtered photographs obtained at the Pic-du-Midi Observatory. However, until recently few ground-based or space experiments have been carried out with the aim of explaining the reason for this increase in contrast, i. e. why the clouds are better visible in this spectral range, i. e. near the atmospheric cut-off at 3000 Å.

In order to identify the nature of the absorbing molecular bands which are the probable cause of this contrast phenomenon, the best method is evidently to analyse high-resolution spectra. This is because direct photographs from the ground are limited by the atmospheric turbulence, the rapid variation of atmospheric extinction and Venus's low ultra-violet intensity. Moreover, it is difficult to have simultaneous good conditions for observations of Venus and the photometric standard star. The spectrophotometric method is therefore the most convenient and suitable.

One of the likely candidate molecules for the Venus clouds is sulfur dioxide, since it has been reported by several authors that aqueous H_2SO_4 solutions of high concentration are required to explain the stratospheric dryness of the planet. The presence of this acid aerosol is deduced from polarimetric and spectroscopic data, especially in the IR spectral range. Furthermore, the decrease of the ultraviolet reflectivity of Venus has been interpreted as being due to the presence of particles of elemental sulfur inside the clouds (Hapke and Nelson, 1975).

Unfortunately, in ground-based observations, the SO_2 ultraviolet spectrum coincides quite well with the absorption banks of atmospheric ozone between 3000 Å and 3300 Å. This makes its detection rather difficult, particularly by observations carried out near the horizon, at middle or high geographic latitudes and at low altitude sites. In addition, this nearly perfect wavelength coincidence results in a modulation enhancement of the ultraviolet spectrum of the Venus clouds, the intensity of which is already very weak at the limit of transparency of the terrestrial atmosphere.

However, a previous study by Barker et al. (1975) reported the presence of a broad absorption feature between 3200 Å and 3100 Å, from relatively low resolution spectra (10 Å). But no identification of the clouds was made. Recently, Young (1979), discussing these above data, suggested that the 3150 Å band could be attributed to carbon disulfide (CS_2).

The Observations

We observed the ultraviolet spectrum of the Venus clouds by means of a scanner with a rather higher resolution (2.5 Å). Our recent report (Hua et al., 1979) also described a method allowing us to derive the intrinsic spectrum of the planet despite the strong terrestrial ozone absorption and thus to measure the absorption bands, presumed attributable to SO_2. At the same time, Stewart et al. (1979), in an article concerning preliminary results from the NASA Pioneer Venus Orbiter, found two broad absorption features near 2100 and 2800 Å, fitting well the known SO_2 absorption bands. The main advantage of our study, however, is the use of a scanner with a higher resolution that is capable of resolving the individual molecular bands (spaced at about 20 Å interval), as compared to the 13 Å resolution of the Pioneer UV spectroscopy.

Tracing (b) in figure 1 shows the ratio I_λ (Venus)/I_λ (sky background) plotted against wavelength, as obtained on January 27, 1979, with a photoelectric scanner attached at the Cassegrain focus of the ESO 1.52 m telescope. Since the atmospheric ozone absorption (the origin of the atmospheric cut-off at 3000 Å) influences the sky background spectrum as well as that of Venus, the intensity ratio of two sky background spectra, one recorded near Venus and the other near the western horizon at the same zenith distance, should be the same for all wavelengths, cf. tracing (a). The small residuals we observe can be ascribed to local differences in the thickness of the ozone layer. Hence, the absorption features that are seen in the Venus/sky ratio (b), are only attributable to the Venus clouds. Two of the absorption bands are centred at 3150 and 3170 Å and coincide with known SO_2 bands. But the strongest SO_2 bands are observed at somewhat shorter wavelengths and it therefore appears that it is more reasonable to connect the observed features at 3150, 3190, 3204, 3235 and 3275 Å to CS_2, involving the vibrational structure. The electronic absorption spectrum of CS_2 has been extensively investigated in the past, cf. the V-system in the 2900–3300 Å range.

We presently need more observations to confirm the above preliminary conclusion. It would be worth while to extend this kind of analysis to longer wavelengths. We are now examining several 3 Å/mm coudé spectra from the 1.52 m telescope of good quality (taken by P. Bouchet and N. Bahamondes) and we hope soon to be able to present further details.

References

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NEWS and NOTES

Spectra from the ESO Schmidt Telescope

One of the most efficient means for astronomical spectroscopy is the objective-prism method, cf. the work at the GPO astrograph described in this issue of the *Messenger*, pages 10 and 29.

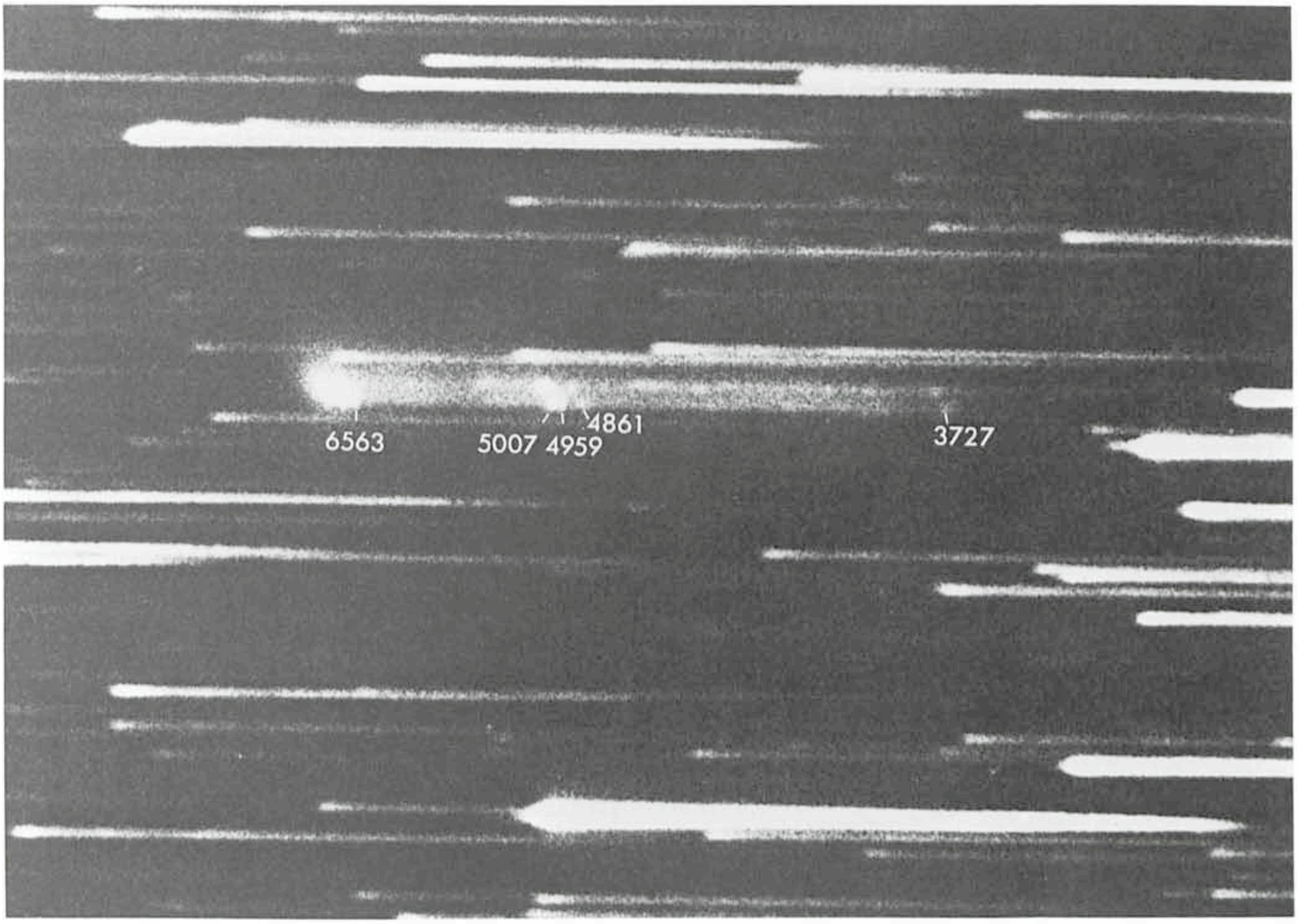
One of the largest objective-prisms in the world is the 1 m ultraviolet-transparent prism at the ESO Schmidt telescope. This prism gives a dispersion of about 450 Å/mm near Hγ at 4340 Å. It was provided for stellar spectroscopy and has already proved its great value in connection with extensive classification programmes.

With a moderately high dispersion in the blue and violet, the ESO prism still has a reasonable dispersion in the red, about 1500 Å/mm between 5000 and 7000 Å. It is therefore an extremely useful device for search programmes that aim at finding objects with f. inst. Hα-emission at 6563 Å and it has already yielded many new planetary nebulae and other emission objects in the Milky Way.

Now, however, it appears that there is an even more important field for the ESO Schmidt telescope. For several years now, quasars have been found with the smaller Curtis Schmidt telescope at Cerro Tololo, just south of La Silla, and in Australia with the SRC 48" Schmidt telescope at Siding Spring. These quasar searches were carried out by means of IIIa-J plates, which are sensitive to blue light and with prisms of relatively low dispersion (1800 to 2400 Å/mm near Hγ). For this reason, all of the quasars that have been found have redshifts less than about 3.5, corresponding to the Lyman α line at 1216 Å redshifted to about the red limit of the III a-J emulsion, near 5500 Å.

Searches for quasars with higher redshifts have not been possible with these telescopes, because of the very low dispersion of their prisms in the red. But, of course, the results in the blue have already had a profound impact on our knowledge about quasars, and more than half of the known quasars have been found with them, including some of the most intriguing ones with absorption lines, etc. However, the 1 m Schmidt telescope at La Silla has a sufficient dispersion (or rather resolution) in the red to make a high-redshift quasar search possible. In addition to the dispersion, the large field (5.5 × 5.5 degrees) and the faint limiting magnitude are important parameters because nobody expects to find many high-z quasars (if any at all). Remembering that the redshift, according to the majority of astronomers, is a measure of distance, it therefore seems as if the ESO Schmidt has a unique potential for looking further out into the vast expanses of the Universe than most other telescopes.

The first very deep plates have now been obtained. 180-minute exposures on red-sensitive IIIa-F emulsion show a wealth of objects of different spectral classes and are now being searched by a number of astronomers, in ESO and outside. No high-z quasars have been found so far, but the search has just begun. It is probable that any Lyman α-emission lines near 6000 Å or further to the red will be very broad and maybe also rather shallow. Unfortunately, the IIIa-F emulsion is not equally sensitive to all wavelengths, there are spectral regions where it is particularly sensitive and which therefore appear as "humps" on the otherwise "flat" spectra. These features can easily be confounded with emission features, and careful measurements are necessary to confirm whether they are intrinsic, i.e. belong to the astronomical



A double emission-line galaxy recorded on a 180-min exposure with the ESO 1 m telescope, on IIIa-F emulsion behind a GG385 filter. The spectral region is roughly 3800–7000 Å. Several emission lines are seen, i. e. Hα (6563 Å), the [O III] doublet at 5007 and 4959 Å, the Hβ line at 4861 Å and, at the ultraviolet edge, [O II] (3727 Å). These spectra are unwidened in order to reach the faintest possible limiting magnitude. Observer: H.-E. Schuster.

object, or whether they are just artifacts of the III a-F emulsion. In any case, a candidate object must first be studied with a slit spectrograph at much higher dispersion before it can be said to be a quasar.

Let us hope that it shall soon be possible to report some further news about this important research. Meanwhile, as an illustration of the possibilities offered by this technique, we show a small part of one of the IIIa-F prism plates with a double galaxy that clearly has a very strong emission-line spectrum. Many more are seen on these plates.

PERSONNEL MOVEMENTS

(A) Staff

ARRIVALS

Geneva

Sölve ANDERSSON (Swedish), Electronics Technician, 24. 4. 1979.

La Silla

Bernard BUZZONI (French), Optical Technician, 1. 4. 1979.

Ray WILSON (British), Head of Instrument Development Group; transferred from Geneva, 15. 6. 1979.

Egon HESSENMÜLLER (German), Optical Technician, 1. 7. 1979.

DEPARTURES

Garching

Ursula LIESE (German), Shorthand-typist (telephone and telex operations), 31. 3. 1979.

Heino WIRING (German), Internal Auditor, 30. 6. 1979.

Roman MARCINOWSKI (Belgian), Accountant, 31. 8. 1979.

Geneva

Bernard GUTTIN-LOMBARD (French), Laboratory Technician (Electronics), 31. 7. 1979.

La Silla

Max Jean LIZOT (French), Optical Engineer, 31. 7. 1979.

Fred SUTER (Swiss), Systems Analyst/Programmer, 31. 7. 1979.

Sten RÖNNBOM (Swedish), Electronics Technician, 31. 8. 1979.

(B) Temporary

La Silla

Christopher SMITH (Canadian), Resident Astronomer, from 16. 5. – 31. 8. 1979.

First Photographs of Andromeda and Galactic Clusters at 1950 Å

M. Golay, D. Huguenin, Geneva Observatory; M. Deharveng, LAS, Marseille

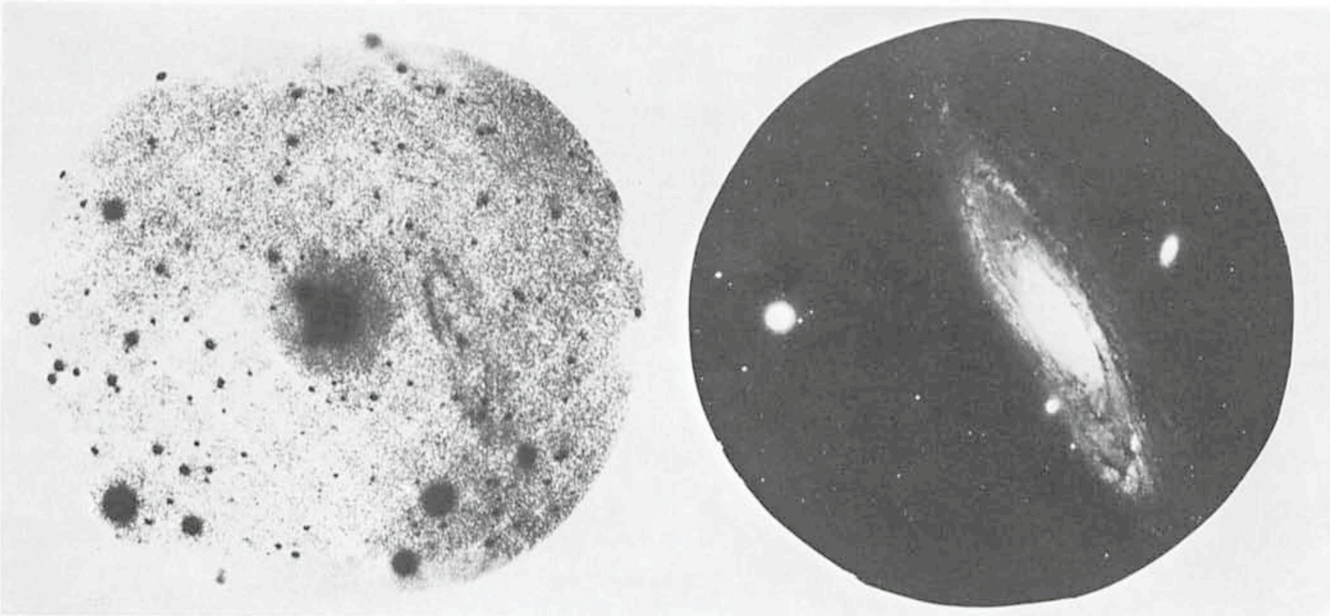


Fig. 1: *10-minute exposure of Andromeda (M 31) at 1950 Å (left). To the right a visual photo (5500 Å) for comparison.*

The photographs shown in this note were taken on October 30, 1978, with a camera built by the Space Astronomy Laboratory of Marseille (LAS) and launched in the stratospheric gondola of Geneva Observatory.

This was the second flight of a long series of launchings the main purpose of which is photography at 1950 Å of the entire galactic plane and certain regions near the northern and southern galactic poles. More than 30 photographs are presently being analysed. B stars down to 13th magnitude are observable, and some galaxies have already been detected in the ultraviolet, as well as a number of blue, galactic halo stars.

The three pictures presented here are of particular interest because they are the first photographs in the ultraviolet of a spiral galaxy, of a pair of young galactic clusters and of a supernova remnant which exploded 50,000 years ago. A part of this nebulosity is also an X-ray source. For the first time a fine structure of a spiral galaxy can be analysed in the ultraviolet. The nucleus of Andromeda (M 31) in the ultraviolet is much smaller than on the plate taken in the visible. The intensity of the nucleus can be estimated to be about 5×10^{-13} erg cm^{-2} sec^{-1} Å^{-1} at 1950 Å.

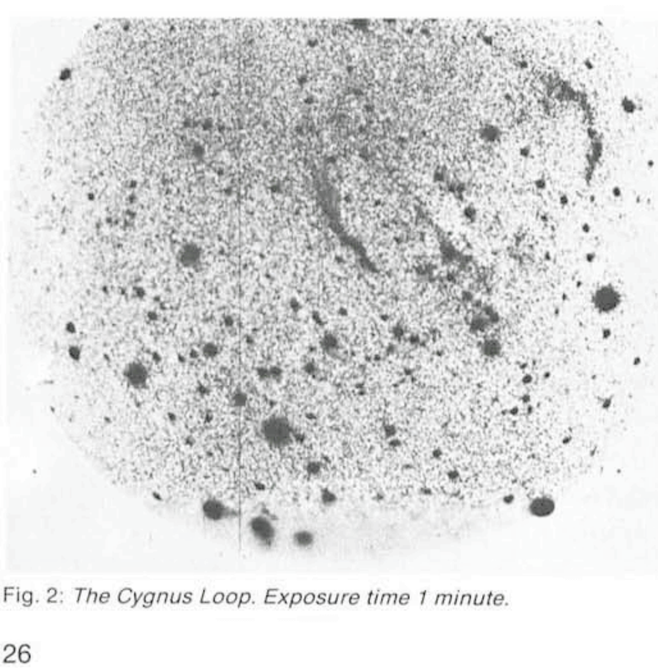


Fig. 2: *The Cygnus Loop. Exposure time 1 minute.*

The camera is composed of a Schmidt-Cassegrain objective, an ultraviolet image intensifier and a 35 mm film holder. Here are several other characteristics of the camera and the gondola:

Camera:

Diameter of the aperture:	130 mm
Focal length:	230 mm
Equivalent photometric aperture:	F : 2.10
Field:	6° diameter
Passband:	1900 Å–2075 Å obtained by selective coating of 2 mirrors. Blocking in the visible by the Cs-Te cathod of the image converter

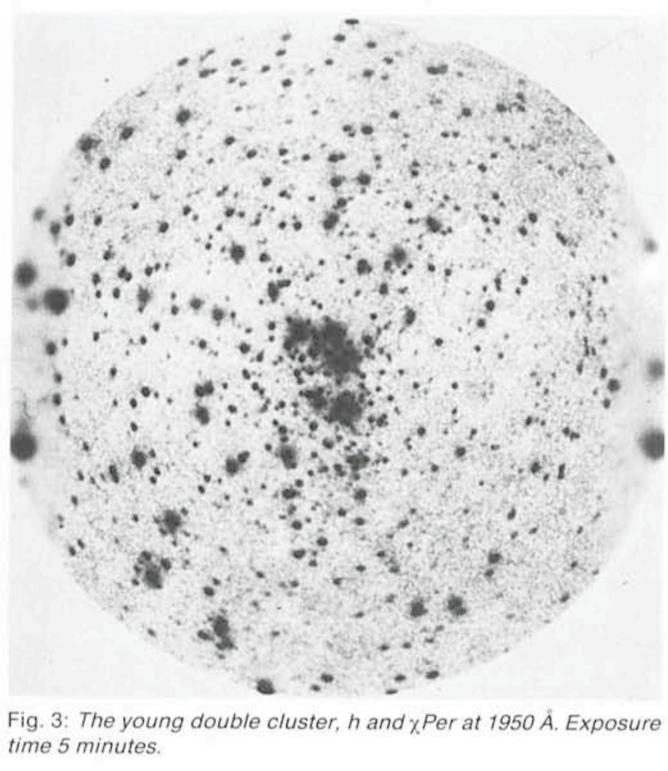


Fig. 3: *The young double cluster, h and χ Per at 1950 Å. Exposure time 5 minutes.*

Film:	Kodak
Weight:	17 kg

Gondola:

The Observatory of Geneva system constructed in cooperation with the Space Astronomy Laboratory of Marseille.

Guiding:	single axis by servo-guided siderostat of 300 × 300 mm RMS precision of 20 arc seconds magnitude range $m_B = -2$ to $+6.4$
Total weight:	337 kg
Flight altitude:	40 km, balloon of 350,000 m^3

Construction of the ESO Headquarters Building

The Max-Planck Society informed ESO that the construction company in charge of the ESO project has unexpectedly run into financial difficulties and that a new construction firm has now taken over the project.

There will be some delay but the termination of the building is still expected for summer next year. The exact date is 31 July 1980.

Cassegrain Echelle Spectrograph (CASPEC)

M. le Luyer, J. Melnick, W. Richter

The CASPEC figures prominently among the future, highly advanced auxiliary instruments for the ESO 3.6 m telescope. It will allow high-dispersion, spectroscopic observations of comparatively faint objects to be made in a reasonable amount of observing time. When it enters into operation in late 1980, it will become possible to analyse distant stars and nebulae in great detail. The CASPEC project is directed by Maurice le Luyer, Jorge Melnick and Wolfgang Richter from ESO Geneva.

CASPEC is the first major instrument for observation at the Cassegrain focus of the 3.6 m telescope which has been designed by ESO and which is now going into manufacture. This seems to be the appropriate moment to describe the main features of the instrument and to hope for eventual comments from the future users, comments which are useful for the finalization of the instrument.

1. Astronomical Purpose

Placed at the Cassegrain focus of the 3.6 m telescope, the CASPEC will provide astronomers with spectrograms of resolutions previously obtained only with large coudé instruments, where a significant fraction of the light is lost in additional reflections required to bring the beam to the remote coudé focus. The considerably higher dispersion of echelle gratings as compared to conventional grating spectrographs makes high-resolution work possible at the Cassegrain focus. The CASPEC will allow observers to obtain high-resolution spectra of objects much fainter than what would normally be possible with a coudé spectrograph.

The possibility of obtaining high-resolution spectroscopic observations of stars as faint as 15 magnitude will open a vast field of research to European astronomers, in particular since very high resolution studies of the properties of galactic and nearby extragalactic stellar and interstellar systems only observable from the southern hemisphere will become possible for the first time.

2. Optical Concept

The concept is based on a 15 cm echelle grating and a plane cross-dispersion grating which provide two-dimensional spectra.

The instrument has been designed to be used in three different modes (resolving powers 17500, 30300 and 60600) as shown in table 1. Shown also is the required combination of echelle grating, cross-disperser grating and camera for each of these modes.

The principal detector will be a SEC vidicon tube, which is described on page 34. This tube has a target area of 25 × 25 mm and a pixel size of 25 μm. The last lines of table 1 give slit width and length (and the corresponding angular resolution on the sky) per pixel. The optical scheme uses the minimum number of elements to get a very efficient white instrument. It comprises 3 mirrors, 2 lenses and

Table 1. Optical Parameters

Resolving power	17 500	30 300	60 600
Dispersion at = 5000 Å	9.5 Å/mm	5.5 Å/mm	2.8 Å/mm
Echelle grating	Jobin Yvon	Bausch and Lomb	
blaze angle	46°30′	63°26′	
line pairs	95 mm^{-1}	79 mm^{-1}	31.6 mm^{-1}
Cross disperser			
blaze angle		4°18′	
line pairs		300 mm^{-1}	
White camera			
focus	F = 279 mm		560 mm
aperture	f/1.66		f/3.3
Resolution/pixel			
slit width	144 μ	173 μ	86 μ
sky angle	1″	1″2	0″6–
slit length	192 μ	277 μ	138 μ
sky angle	1″3	1″9	1″

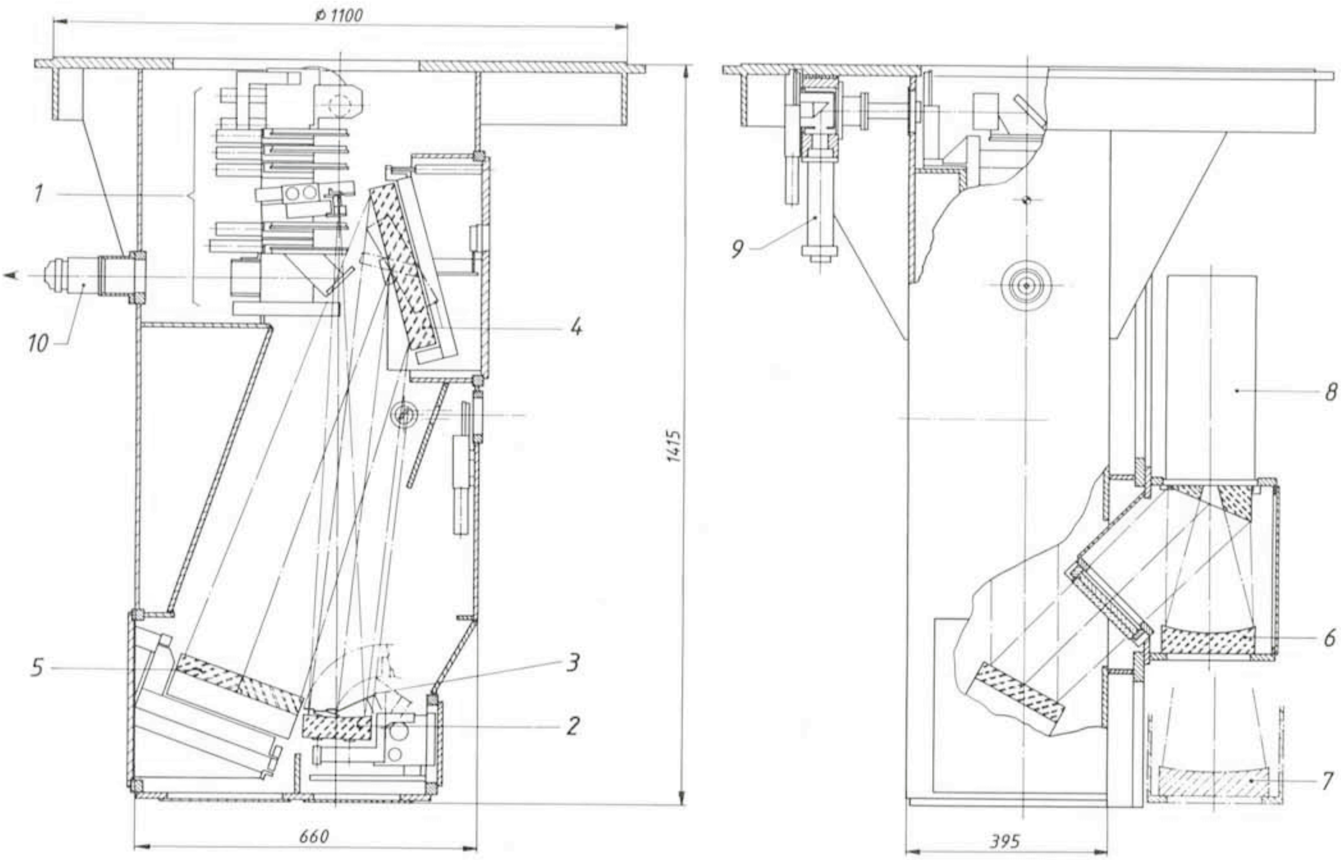


Fig. 1: *CASPEC Assembly: (1) slit area Fig. 2, (2) collimator, (3) Hartmann mask, (4) echelle gratings, (5) cross disperser grating, (6) short camera, (7) long camera, (8) detector, (9) comparison lights, (10) slit rear viewer.*

2 gratings. The wavelength range is limited by the efficiency of the detector, 0.38–0.65 μ for the chosen photocathode of the vidicon.

3. Mechanical Concept

The basic concept is a straight (not folded) very compact layout, leading to a fairly small and strong housing with modules for the different functions as shown in figure 1.

To change from one mode of observation to another requires the exchange of modules. Such a module is a grating with cell, adjustment mechanism and base-flange. Another module is a camera with detector and base-flange.

The echelle grating has a manually operated adjustment screw to centre the spectra on the detector. The tilt of the cross-disperser grating which is used to centre the desired wavelength band on the detector has remote control.

The slit area is one unit which is composed of several modules as shown in figure 2. This gives the possibility for a later exchange of some modules by others. All modules are equipped with remote control (motor and digital read-out). The adjustment ranges are given in table 2.

Table 2. Adjustment Range

Function	Range
Slit opening	0.07 . . . 2 mm
Dekker opening	0.1 . . . 20 mm
Collimator focus	± 3.5 mm
Cross disperser	± 5°

4. User Interface

The status of the instrument is completely controlled through the Instrument Computer and the standard Cassegrain area peripherals. The philosophy is very similar to what is being made for the Coudé Echelle Spectrometer.

A touch panel in front of a display plays the role of a "software" buttons set—the function of each button is given on the display.

A second display shows the status of the instrument. The form-filling technique simplifies strongly the introduction of new parameters.

A third display, which is a graphics one, permits the user to "play" with the data.

5. Data Reduction

The advantage of using a square format has to be paid for by a rather complex data reduction programme. A meeting was organized on this subject last March. J. Melnick, the chairman, reports an page 13 on the discussions of this meeting.

6. Assistance from the Review Team

The Review Team members (J. Andersen, L. Delbouille, E. Maurice, P.E. Nissen) received a very detailed information manual and a complete set of sub-assembly drawings. This gave rise to most fruitful comments and discussions, especially in the following aspects: flexure analysis, controls and electronic interface, data processing (one RT member initialed a small ESO workshop on this subject), image slicer exchange, Hartmann mask design. We feel we have been very much guided by this excellent cooperation of the RT members to whom we extend our grateful thanks.

7. Present Status (2.5.79)

The design is near completion and the bids for optical and mechanical parts have been received. The contracts for manufacture are in the process of being signed.

8. Future Plans

After the definition of the test procedures we have now started with the design of the test facilities. One part comprises the tests in Geneva (stability of spectrograph, functional test of the detector and of the instrument), the other for tests on La Silla. Also in the near future the control and handling aspects will be finalized.

The present planning of the main activities for the subsequent development is shown in table 3.

Table 3. Present Schedule

Activity	Dates	
Manufacture mechanics	May–Sept.	1979
Assembly mechanics	Oct.	1979
Assembly controls	Nov.–Dec.	1979
Manufacture optics	May–Dec.	1979
Optics test Geneva	Jan.–Feb.	1980
Improvements	March–May	1980
Integral test	June–July	1980
Shipment	Aug.–Oct.	1980
Installation La Silla	Nov.–Dec.	1980

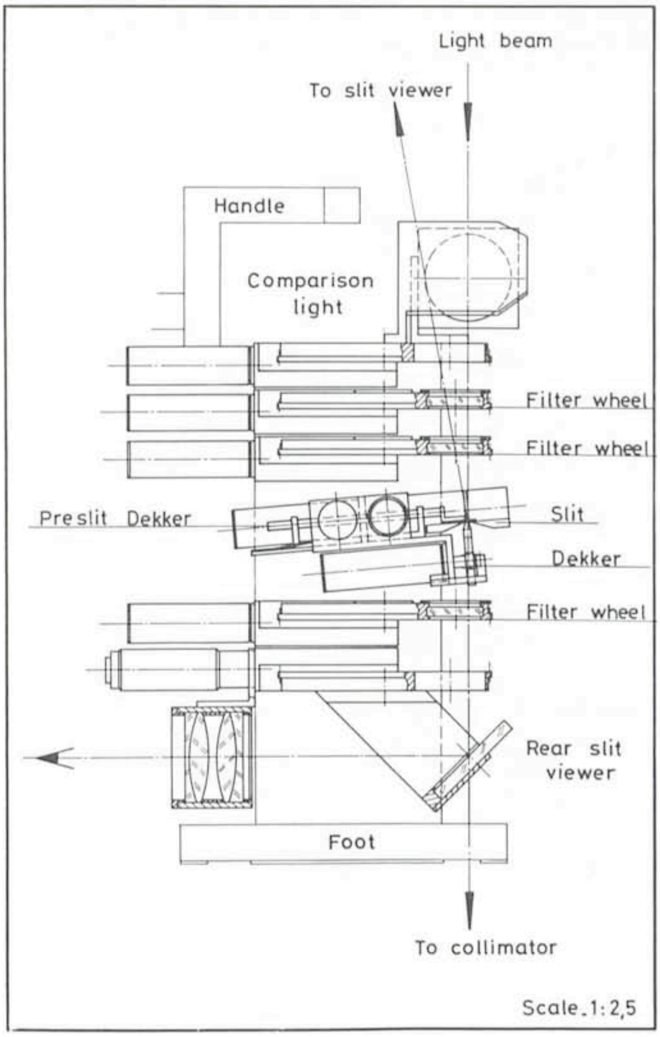


Fig. 2: *Slit area.* ▶

Relative Radial Velocities of Stars Determined from GPO Spectrograms

F. Gieseking

One of the first telescopes to be installed on La Silla was the GPO 40 cm astrograph. Although it is one of the "smallest" instruments at the ESO observatory, it is by no means less productive than the larger ones! On the contrary, the impressive results that have recently been obtained by Dr. Frank Gieseking of the Hoher List Observatory, near Bonn, proves the tremendous potential of this instrument. Thanks to the good accuracy of the measured radial velocities, large-scale investigations of stellar motions can now be carried out.

The General Problem

The *radial velocities* and the *proper motions* of stars (and their possible temporal variations) are fundamental parameters for the investigation of the kinematics and dynamics of stars and stellar systems like binary and multiple systems of stars, stellar associations, star clusters, the galaxy as a whole and clusters of galaxies. Proper motions, however, defined as the angular velocity of the tangential component of the space velocities, are important only in the solar neighbourhood. For example, a binary system, even with the large orbital period of 100 years, consisting of two solar-type stars, has a separation of less than 0.1 arcsecond if at a distance larger than 270 parsecs. With terrestrial telescopes such a system can only be resolved by application of laborious interferometric techniques like speckle interferometry. On the other hand, the error of the tangential motion of single stars as derived from proper motions is proportional to their distances. Typical values for the errors of average accurate proper motions indicate that already at distances larger than 800 parsecs the error of the tangential velocity is larger than ± 6 km s^{-1}.

Contrary to this, the error of radial-velocity measurements is in principle, *independent*, of the distance of the stars. Since the accuracy of radial-velocity determinations from spectra of medium dispersion (60 Å mm^{-1}) is of the order of ± 6 km s^{-1} (for early-type stars), we arrive at the conclusion that at distances larger than 800 parsecs the radial component of the space velocity can be determined more precisely than the tangential component. (At still larger distances the radial velocity soon becomes the only relevant kinematical parameter of stars and stellar systems.)

Unfortunately, however, at distances larger than 800 parsecs even the intrinsically brighter stars (B1V) are fainter than 8.5 mag in V. Since the measurement of radial velocities with conventional slit spectrographs is very laborious (requiring long observing times at large telescopes for the exposure of only one spectrum at a time), our data for stars fainter than 6 mag are still rather incomplete. We therefore come to the general conclusion that a more efficient method for radial-velocity determinations is urgently needed for a further progress in the investigation of the kinematics and dynamics of the stars.

The Fehrenbach Prism

The search for more efficient methods to determine stellar radial velocities is the search for more efficient methods to obtain stellar spectra. The most efficient astronomical spectrograph is the objective prism-telescope combination, because:

(1) The light losses are reduced to a minimum: In detail, the light losses of an objective prism by reflection and absorption are expected to be of the order of 30%, whereas in the case of the conventional grating slit spectrograph light losses by reflection of about 60% and transmission losses of about 85% are typical (Fehrenbach, Ch.: 1966, *Adv. Astron. Astrophys.* **4,** 1). (For slit spectrographs without image slicer the sometimes drastic light losses at the slit must be added.) This means that an objective prism has at least a tenfold greater transparency as compared with a conventional slit spectrograph.

(2) The objective prism allows the exposure of numerous stellar spectra at the same time: In detail, in a 4-square-degree field of a telescope of 4 meter focal length, well-exposed 100 Å mm^{-1} spectra of typically up to 100 stars can be expected.

From this example we see that an objective prism should be a thousand times more efficient than a conventional slit spectrograph. (For a realistic comparison for the case of the GPO astrograph, see below.)

Unfortunately, there are two serious drawbacks of the objective prism:

(1) Due to the absence of any comparison spectral lines, the wavelengths of the objective-prism spectra are a priori not calibrated.

(2) Since we have to do with a slitless spectrograph, the spectral resolution depends on the seeing.

Whereas the second problem cannot be overcome by terrestrial telescopes, there have been many attempts to calibrate the wavelengths of objective-prism spectra. After numerous failures, Pickering's (*Astron. Nachr.* **142,** 105, 1896) "reversion method" proved to be most attractive. Its principle is as follows: First, an exposure of the star field is made through the objective prism adjusted with the direction of dispersion parallel to declination. Then, the exposure of the same star field is repeated on the same plate after "reversion" of the prism by rotating it through 180° around the optical axis of the telescope. If the telescope has been slightly shifted in right ascension between the exposures, the plate contains two side-by-side spectra of each star, with the red end of one next to the violet end of the other. It should now in principle be possible to measure Doppler shifts of the spectral lines by comparing the positions of lines in one spectrum with those of the corresponding lines in the reversed spectrum.

But unfortunately, the relative positions of the lines in both spectra are not determined by the Doppler shift alone, because:

(1) They are partly determined by the performance of the reversion (the declinations of the plate centres of the normal and the reversed exposure cannot be made exactly the same [an accuracy of typically better than 0.05 arcsecond would be necessary]) and by instrumental influences like temperature effects, mechanical stability, etc.

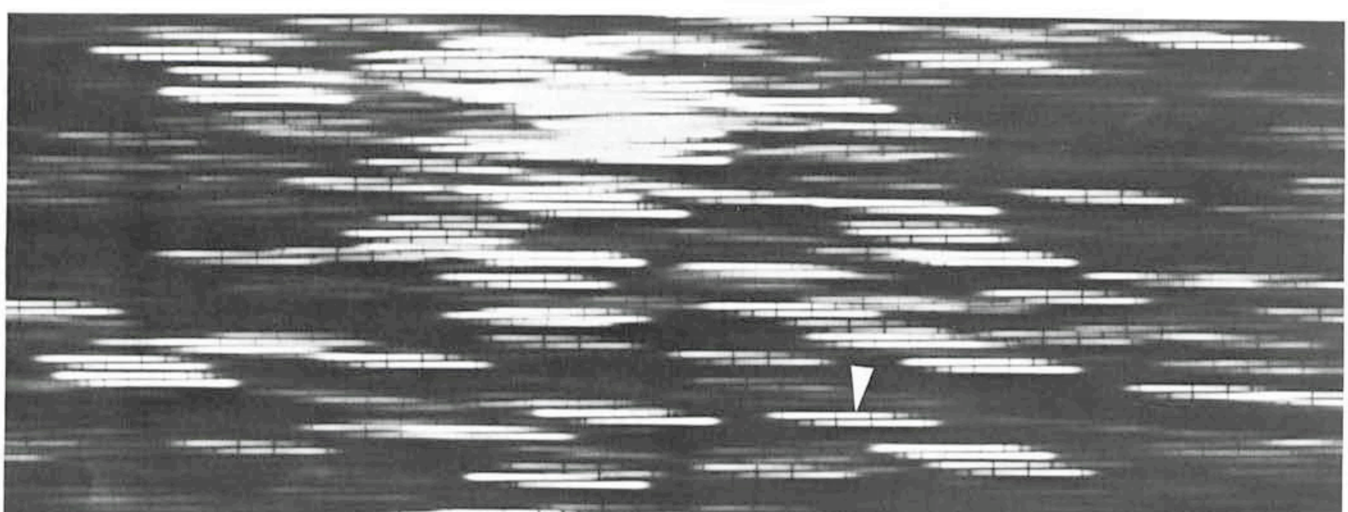


Fig. 1: *An enlarged 1.2 by 0.46 square-degree section of plate GPO 2557, which is approximately only 1/10 of the original plate. At top is the western part of the rich open star cluster NGC 3532. The total plate, exposed for 2 times 30 minutes, shows approximately 500 pairs of spectra. The spectra of more than 100 stars down to the 10th magnitude are exposed to sufficient density to be measured with high precision. The marked star is HD 95878 (see fig. 2). North is to the right, west is down.*

(2) The distorsion of a normal prism produces an apparent shift of the spectral lines, which in a 2-degree field is of the order of ± several thousand km s^{-1}!

The first problem, which cannot be overcome in practice, limits us to the determination of only *relative* radial velocities. Because of the second problem, the application of objective prisms for the determination of radial velocities was forgotten for several decades, until Charles Fehrenbach invented the distorsion-free, direct vision Fehrenbach prism. In simplest form, it is a compound prism, shaped like a plane-parallel plate, which consists of two prisms made of different kinds of glass. The components have different dispersive powers, but equal refractive indices for a certain wavelength in an accessible wavelength region. (For details the reader is referred to Fehrenbach [*Ann. d'Astrophys.* **10**, 257, 1947] or to the popular representation by Gieseking [*Sky & Tel.* **57**, 142, 1979]).

The radial-velocity astrograph of the European Southern Observatory is equipped with one of the six Fehrenbach prisms existing today. This "Grand Prism Objectif" (GPO) has a diameter of 40 cm and produces at 4 meter focal length spectra with a linear reciprocal dispersion of 110 Å mm^{-1}. With this instrument, the reversion method can now be applied successfully. The latest refinement of this method was supplied by the author, who introduced a modified reduction method for Fehrenbach-prisms spectrograms, which yields a considerable improvement of the measuring accuracy (*Astron. Astrophys.* **47**, 43, 1976 and *Sky & Tel.* **57**, 142, 1979).

Present Results

With this new reduction method, until now a total of about 8,000 relative radial velocities of more than 500 stars in 10 star fields (mostly in the region of selected open star clusters) have been determined. The investigated stars have photographic magnitudes fainter than 6 mag and brighter than 10.5 mag. Their spectral types are mostly between late B and early A. As expected, the measuring accuracy depends on the density of the spectra and therefore (with the exposure time as an additional parameter) on the brightness of the stars. With an exposure time of 2 times 30 minutes the observation errors of the radial velocities of stars brighter than 9.7 mag lie between 4 km s^{-1} and 9 km s^{-1}. This is approximately half the error to be expected for radial-velocity measurements of early-type stars from slit spectra with a comparable dispersion of 110 Å mm^{-1}. Since the strictly *relative* measuring principle of the reversion method with a Fehrenbach prism is affected mainly by *statistical* observation errors, the accuracy can be significantly improved by accumulation of observations. This is contrary to the slit-spectrum technique, which is also affected by systematic errors. (This is demonstrated by the fact that the external error of the measurements is expected to be twice the internal error.) Since for each star on the average 15 observations are available, the observation error for about 300 stars with (assumed) constant radial velocities can be brought down to the region of ± 2 km s^{-1}. Herewith the quality of the relative GPO velocities of stars fainter than 6 mag becomes comparable to that of most published "conventional" radial-velocity data of stars brighter than 6 mag.

For a realistic estimate of the efficiency of the GPO method we have the opportunity to compare for a number of stars in NGC 6475 the GPO radial velocities with (by chance) almost equally accurate slit-spectrum measurements. Though the slit spectrograms were obtained with a fast grating spectrograph at a 90 cm reflector, the GPO was faster by a factor 5 per star, after reduction to equal telescope aperture. After inspection of the whole GPO material, on the average 35 stars per field were found, which could be measured with the accuracy in question. Therefore, the total gain in efficiency is of the order of 150 to 200 (which in rich fields could further increase by a factor of 2).

We therefore come to the conclusion that the GPO method offers the first really promising, efficient method for the determination of the radial velocities of the fainter stars.

The present GPO material has so far been analysed with two kinds of study in mind: The first aspect is the investigation of spectroscopic binaries. If the dependence of the measuring error on the density of the spectra is considered carefully, the GPO data establish the most homogeneous, large set of relatively accurate radial velocities published so far. Therefore, the identification of variable radial velocities is possible with very high statistical significance. A careful statistical analysis of the observed overall error distribution yielded the first reasonable estimate of the frequency of spectroscopic binaries. This number may provide an important contribution to the complex problem of the overall binary frequency and the frequency distribution of the semi-major axes of binaries, which in turn is a measure of the frequency distribution of angular momentum. Besides the possibility of a *statistical* identification of spectroscopic binaries with even extremely small amplitudes, an *individual* identification of spectroscopic binaries proved to be reliable down to radial-velocity amplitudes of K = 12 km s^{-1}. The observations of one of the numerous spectroscopic binaries discovered in this way on GPO plates are illustrated in the figures with this article.

The second aspect is the investigation of the kinematics and dynamics of open star clusters. So far only the study of the most extensively observed cluster NGC 3532 (see fig. 1) has been completed. Here, relative radial velocities of a total of 82 field and cluster stars could be determined with a mean error of only ± 1.77 km s^{-1}. With these GPO measurements, NGC 3532 becomes the second open star cluster (besides the Pleiades), for which accurate radial velocities of a larger number of stars are known. Moreover, NGC 3532 is the first open cluster for which reliable membership probabilities were calculated on the basis of a statistical analysis of the observed radial-velocity distribution of the stars. Besides this essential contribution to the separation of field and cluster stars—which is especially important in the halo of the cluster—the GPO radial velocities proved to be accurate enough to estimate even the true internal motion of the cluster, as far as the investigated cluster stars are concerned. This, however, is the key to the dynamical properties of the aggregate, like its dynamical mass, the mass distribution or the structure of the cluster halo and the evaporation of cluster stars. These results will be published in a series of forthcoming papers.

Future Programmes

First of all the investigation of NGC 3532 should be extended to fainter stars. Furthermore, similar studies should be carried out also for several other open star clusters and additional observations in all fields investigated so far, and an extension of the observing programme to other open clusters and stellar associations are therefore highly desirable. One of the principal aims would be to

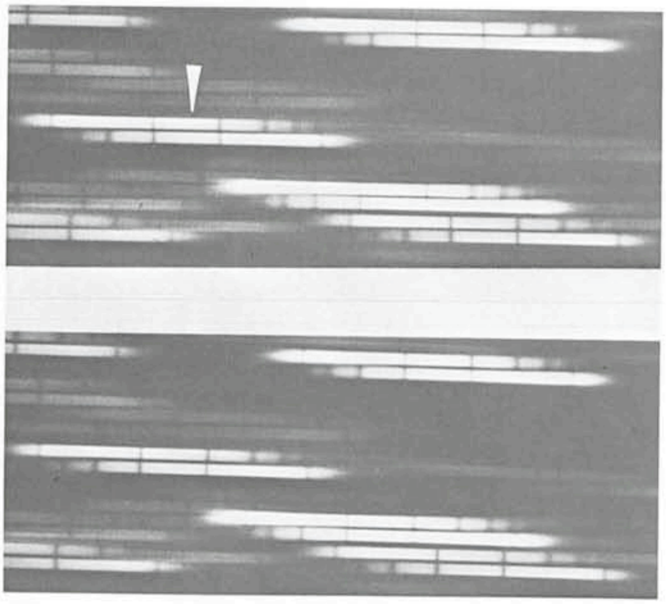


Fig. 2: *The figure at top represents a further enlargement of plate GPO 2557, taken on March 16, 1977, showing the region around HD 95878 (see fig. 1). The figure below shows the same section on plate GPO 2564, taken in the next night on March 17, 1977. Note the large relative Doppler shift of spectral lines of HD 95878 between the two observations (as compared with the line positions of surrounding reference stars). Measurement yields a difference in radial velocity of 165 km s^{-1} with an expected error of a single observation of $\pm$ 7 km s^{-1}. This star is one of the numerous spectroscopic binaries, discovered by the author on GPO plates.*

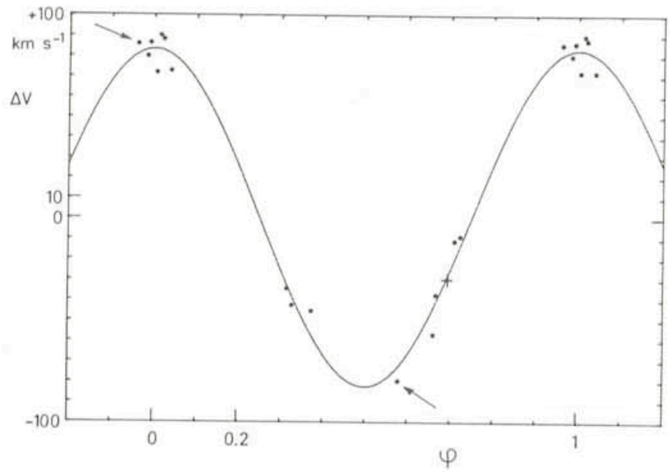


Fig. 3: *The relative radial velocity curve of HD 95878 as derived from the measurement of 17 GPO plates of the field around the open star cluster NGC 3532. The relative radial velocities determined from the spectra shown in figure 2 are identified by arrows. The zero point is arbitrary, but can be calibrated easily by one accurately known radial velocity in the field. The cross marks two independent measurements.*

compare the results for different clusters and eventually to correlate them with other physical parameters of these aggregates. In this context a comparison of the kinematical properties of stellar associations and open star clusters would be of special interest, because it may provide new insight into the dynamical evolution of these stellar systems. Beyond this, the discussion of the velocity distribution of the field stars and its dependence on spectral type and distance of the stars may provide important contributions to our knowledge of the kinematics and dynamics of our galaxy. For all kinematical investigations just mentioned, radial velocities are of special significance, if they can be combined with reasonably accurate proper motions to yield the space velocities of the stars.

Concerning the investigation of spectroscopic binaries, additional observations are also desirable: If for example membership probabilities for a larger number of open clusters are determined, the interesting question on possible differences of the binary frequencies in open clusters, stellar associations and the general star field can probably be answered. Furthermore, on the basis of a sufficiently extensive observation material, the correlation between binary frequency and spectral type and eventually other physical parameters of the stars can be investigated. Finally, continued observation of all star fields is desirable as well for improvement of the orbital elements of known and newly discovered spectroscopic binaries as for detection and investigation of long-period spectroscopic binaries (periods larger than about 200 days). For the latter a good detection probability can be predicted, since after construction of normal points, the individual identification of long-period variability of the radial velocity may be reliable down to radial velocity amplitudes of only K = 4 km s^{-1}.

The application of the objective prism for the determination of the radial velocities of the stars has opened new frontiers. The future will show how successful this instrument will be to contribute to the answers of numerous questions, a few of which have been outlined above.

Since 1977 all observations have been obtained by ESO night assistant Gorki Roman. I herewith gratefully acknowledge his very careful conduction of my observing programmes at the GPO.

Assembly of the Coudé Echelle Spectrograph (CES)

D. Enard, ESO Optics Section, Geneva

The coudé echelle spectrometer has already been described in the *Messenger* No. 11 of December 1977. It is a very high resolution spectrograph with a resolving power up to 100,000 fed by either the 3.6 m or the Coudé Auxiliary Telescope (CAT). Henceforth it will be complemented by the CASPEC which will provide a resolving power of 20 to 60,000 (cf. page 27).

After considerable delay in the delivery of several components, the assembly of the CES started early in April. The instrument is being assembled and tested in the ESO Optics Laboratory in Geneva, which, as a matter of fact, has become rather congested, as shown by the photographs.

Because no equipment has yet been installed at the 3.6 m coudé focus, the whole instrument including the computer, is assembled in Geneva for a complete test before it will be shipped to Chile. However, the temperature stability of the laboratory is not very good and may somewhat limit the measured performance level.

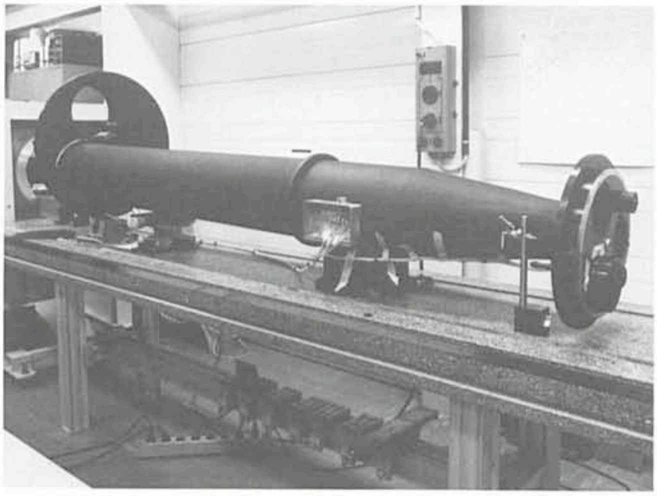


Fig. 1.

Figure 1 shows the CAT focal reducer being tested. After completion of some minor modifications, the focal reducer will be shipped to Chile where it will be aligned on the common 3.6 m/CAT telescope axis defined by the "centre" of mirror 5 of the 3.6 m and the "centre" of mirror 3 of the CAT.

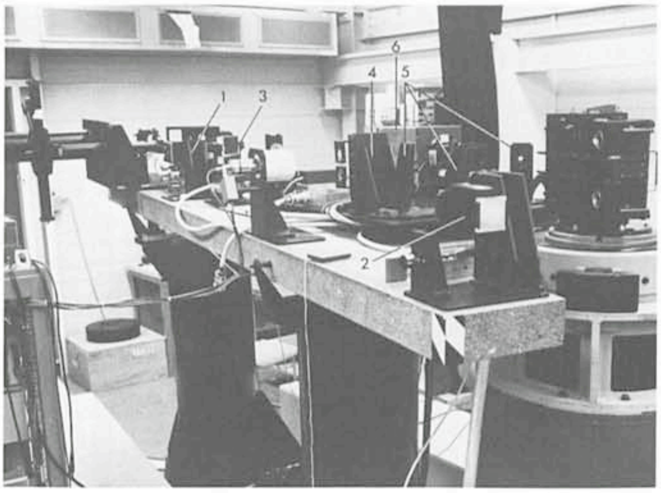


Fig. 2.

Figure 2 shows the marble supporting the entrance slit and the associated facilities (calibration, viewer, etc. . . .) and the pre-disperser. One can see the entrance slit (1), the collimator unit (2), the prism unit (3) and the exit slit (4), the double pass system (5) and the scanner detector (6).

Figure 3 shows the grating on its turn-table and Figure 4 the collimators and the multichannel camera. The Digicon detector will be attached below the camera.

The optical alignment and completion of the last mechanical modifications will continue until early July. Complete integration with electronics and software and initial instrument assessment will take another 2 to 3 months, and the official presentation to the Review Team will take place in October. Installation on La Silla could start in January 1980 and, therefore, the CES and CAT could become available at the same time, i.e. in April 1980.

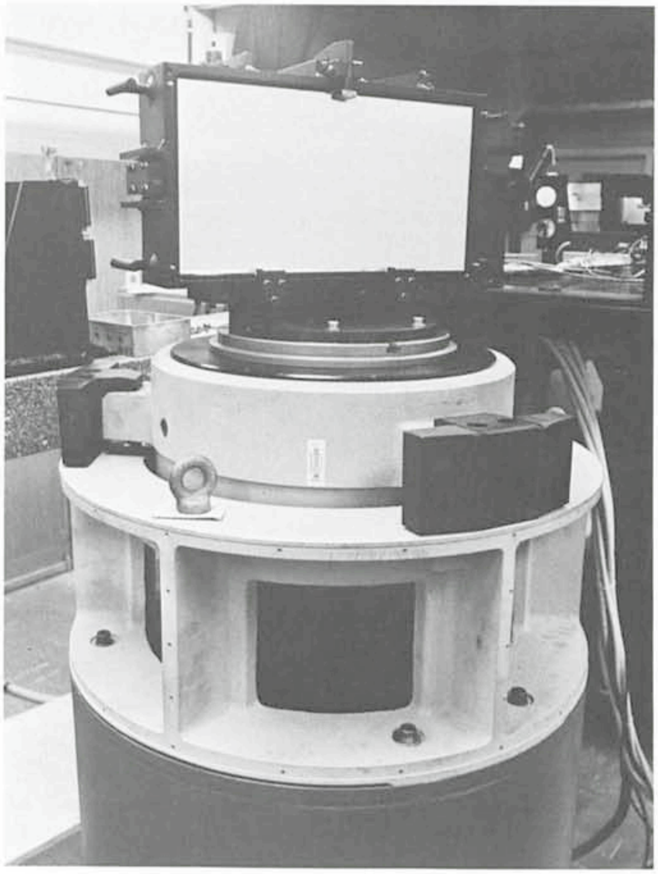


Fig. 3.

Fig. 4.

OUT THERE

Beyond the Milky Way?!

How far do bars extend?

(ESO Scientific Preprint No. 53—Title)

Television Detector System Development at ESO

P. Crane and W. Nees

The traditional picture of an astronomer with a long beard, gazing through his telescope and solving the riddles of the Universe, is no longer true. First of all, the beard would all too easily get mixed up with the computer terminal keys and be a definite danger near rapidly spinning magnetic tapes. And nowadays few astronomers really look *through the telescopes; the important task of detecting light from (faint) objects is more accurately and efficiently done by electronic detectors. Dr. Phillip Crane and electronics engineer Walter Nees at ESO in Geneva are developing such a detector and explain how it works and what it can do.*

We describe below the programme of developing a television-type detector system that has been going on at ESO/Geneva for about 2 years. The major emphasis of this programme has been to provide a modern detector system for the Cassegrain Echelle Spectrograph (CASPEC), so much of the following discussion relates specifically to this particular application.

Television systems have many attractive features for optical observations. They allow efficient detection of photons. In fact, many television detectors permit the detection of photons to be recorded with signal levels which are high enough that the resulting data are photon-noise limited. Another advantage of television detector systems is that they allow the observer to review his data very soon after they have been obtained. Since the data are usually recorded in digital format, the reduction by computer techniques is facilitated.

A SEC for the CASPEC

For the above and other reasons, it was decided to build a television detector system. At about the same time, the need arose for a detector to be used in conjunction with the CASPEC, cf. page 27. Apart from photographic plates and conventional image tubes, one television-type detector would fill the requirements of the CASPEC, a 25 mm magnetically focused "SEC"-Vidicon tube manufactured by the Westinghouse corporation. The term "SEC" stands for *S*econdary *E*lectron *C*onductivity and refers to the technique for storing the photon signal internally in the tube (see below for more details). For the CASPEC application, the major advantages of the SEC tube are the flat image plane, the high resolution and low distortion, and the capability of operating without significant cooling. Some technical details of the SEC tube are given in table 1. A picture of one of these tubes is shown in figure 1.

The particular tube which has been chosen was originally developed at the Princeton University Observatory through contracts with NASA for space-borne applications such as the Space Telescope (ST). The same tube with a different front window and photocathode is being flown in a balloon UV-echelle spectrograph by the Space Science Laboratory at the University of Utrecht in Holland. A very similar tube will be flown by NASA in conjunction with the Solar Maximum Mission. Although this tube will not be flown on the Space Telescope, a similar larger version was a very strong competitor for the Wide Field Camera Instrument on the Space Telescope. The basic detector on the IUE (International Ultraviolet Explorer Satellite) is also a SEC-type tube but of considerably different design.

Although the system which is being built at ESO is primarily aimed at developing the SEC-tube for the CASPEC application, the electronics have been designed in a very general way so that a wide variety of TV-type detectors could be used with the same basic electronics. For example, silicon vidicons, silicon intensified tubes (SIT) and many other tubes could be used in a wide variety of operating modes. The electronics are designed to interface through standard CAMAC bins and several special-purpose CAMAC modules have been constructed. The entire detector system is designed for completely remote control and operation.

How the SEC Works

We describe below some of the details of television tubes and some of the applications which the ESO device will

Table 1: Characteristics of SEC-Vidicon Tube

Tube type:	Westinghouse SEC-tube WX-31958
Photocathode:	Tri-alkali with S-20 spectral response. Quantum efficiency ~ 18 % at 4400 Å falling to ~ 1 % at 7500 Å.
Focus:	Image and beam section magnetically
Deflection:	Magnetically
Target storage area:	25 × 25 mm square
Resolution:	At MTF 30 % 1,000 TV-lines/picture height or 20 LP/mm equivalent
Target gain:	~ 60
Dark current integration:	~ 2 pA/min

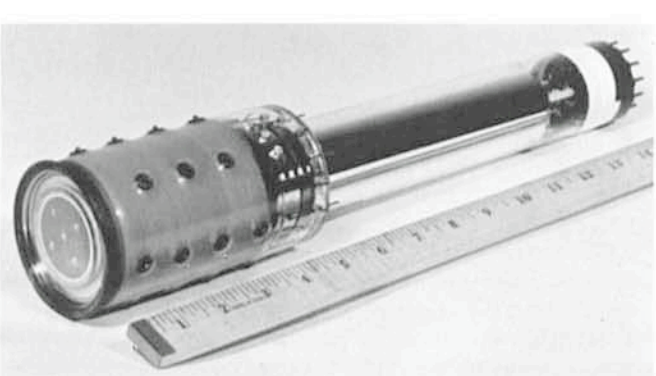


Fig. 1: *A SEC tube.*

find in the Cassegrain Echelle Spectrograph. There are, in general, two classes of television camera tubes: The vidicon plumbicons which store one electric charge per detected photon, and the SEC- and SIT-vidicon tubes which provide a prestorage gain mechanism whereby many (10–500) electric charges are stored per detected photon.

The basic parts of a SEC-type tube are: the image section, the target area, and the electron gun readbeam section (see fig. 2). Incident photons release photoelectrons at the photocathode. These photoelectrons are accelerated towards the target in an electric field and focused in a magnetic field. They strike the target with about 7,5 Kev of energy and release between 50 and 100 secondary electrons. The target consists mainly of a fluffy layer of potassium chloride (KCl) supported on an aluminium oxide (Al_2O_3) substrate, but separated from it by an aluminium signal plate. The secondary electrons are collected on this signal plate leaving behind in the KCl an electrical image of the distribution of incident photons. By scanning a finely focused electron beam across the target, it can be recharged and by detecting the recharging current, it is possible to derive a signal which is proportional to the total number of photons incident at the corresponding point on the photocathode.

Since the recharging currents are often extremely small, it is of utmost importance that the first stage of the video amplification chain have an extremely low noise. The system being built at ESO will have an equivalent noise level of less than about 5 photoelectrons per resolution element referred to the photocathode.

The television tube will be used in the integrating mode where the read beam is turned off during the time an exposure is being made and the image section is turned off during the time the tube is being read out. The tube will also be run in the "slow-scan" mode in which it takes roughly 20 seconds to scan and read out a complete 1,000 element by 1,000 line frame. This operating mode can be compared to the continuous scan 25 frames per second operation of a commercial-type television camera. Clearly the electronics to control an integrating slow scan system will not be very similar to a commercial television camera. A typical operating sequence would be:

1. PREPARE, the target is erased of any previous residual exposure and prepared to a fixed charge state;
2. EXPOSE, the read beam is off, and the photocathode high voltage ($\sim$ 7,5 KV) is on. Photoelectrons are storing up a charge image on the target;
3. READOUT, the electron beam scans the target. The measured target recharge signal is, after amplification, sampled and converted into 12 bit binary words at intervals of about 15 microseconds each. (1,000 words per scan line and 1,000 scan lines per complete frame). For further processing the digital image data 1,000 × 1,000 or 10^6 words are stored on computer disc, or magnetic tape.

The Cassegrain Echelle Spectrograph will make full use of the 25 mm square active area of the SEC tube. The optical system of the CASPEC has been designed to take advantage of the resolution of the SEC, so that a 1.3 arc second slit will project into 30 microns on the SEC photocathode, when the R = 17,000 grating is used. Figure 3 shows a typical vidicon frame (simplified) as it would appear to the CASPEC user.

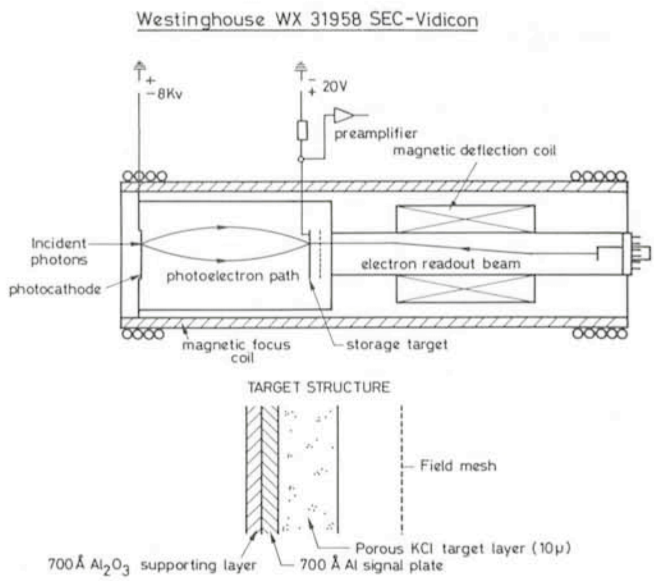


Fig. 2: *Schematic drawing of the main parts of a SEC tube.*

What the SEC May Do

The data coming from this detector-spectrograph combination will provide new information at high resolution on faint objects. Thus, for example, the chemical composition of galaxies and the stars and nebulae which make up these galaxies can be studied to even greater distances. Maybe these data will provide clues to evolutionary processes in galaxies? Other observations might include the study of absorption-line systems in quasars with higher spectral resolution than previously possible.

These applications require extremely sensitive and efficient instruments such as the one described here. Of course it is too soon to be sure, but we hope that the combination of a modern detector, an efficient telescope and spectrograph and fast efficient data-reduction techniques will make this into one of the most productive astronomical instruments on La Silla or elsewhere.

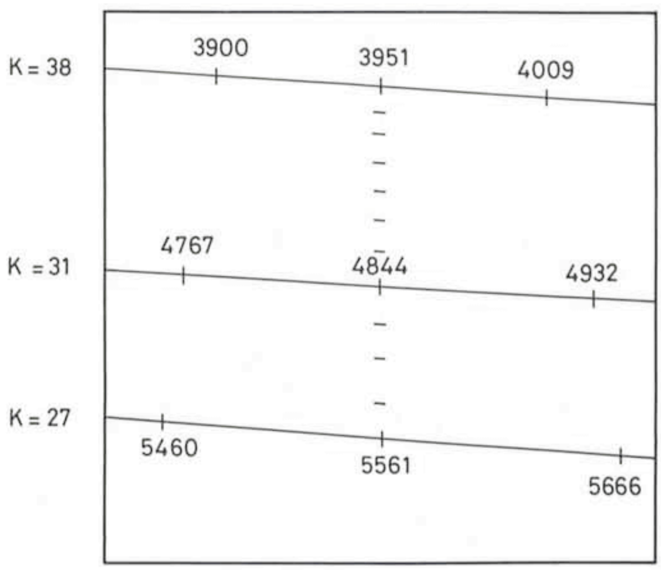


Fig. 3: *Schematic of an echelle spectrum. K is the echelle grating order. Wavelengths are shown in Ångströms. Intermediate orders are shown by tick marks. The circumscribed square is the 25 mm × 25 mm target area of the SEC Vidicon.*

Collaboration on the Use of the 4 cm and 9 cm McMullan Electronographic Cameras at the Danish 1.5 m Telescope

K. Gyldenkerne, R. Florentin Nielsen and D. McMullan

Two electronographic cameras have now been operating at the Danish 1.5 m telescope on La Silla during several months. They assure an efficient use of this fine telescope and many exciting photos have already been obtained. Drs. K. Gyldenkerne and R. Florentin Nielsen of the Copenhagen University Observatory and Dr. D. McMullan of the Royal Greenwich Observatory explain how these cameras work and inform about some of the far-reaching observing programmes that have been initiated.

The commissioning of the Danish 1.5 m telescope at the European Southern Observatory (ESO) at Cerro La Silla in Chile has been reported by Andersen, Florentin and Gyldenkerne (1979), who described the first tests of the telescope and gave a brief summary of its auxiliary instrumentation. Additional test periods include various observational programmes using direct photography, spectro-photometry, and photometry with these instruments. In particular, the 4 cm and 9 cm electronographic cameras developed and constructed by D. McMullan and his collaborators at the Royal Greenwich Observatory (RGO) (McMullan et al. 1972, 1976; McMullan and Powell 1976, 1979) are being used extensively for direct electronography. The observations with these cameras on the 1.5 m telescope are part of a collaboration between the RGO and the Copenhagen University Observatory (CUO).

A basic requirement for the optical specification of the Danish 1.5 m telescope was that it should have a Ritchey-Chrétien mirror system with a useable field of a little less than one degree and thus be complementary to the ESO 1.5 m spectroscopic telescope. Furthermore, it was anticipated by the initiators of the telescope project, Professors A. Reiz and B. Strömgren, that an electronographic camera would be available with such a large cathode area that it would cover the uncorrected 80 mm diameter (20′) Cassegrain field.

During the telescope construction period it became clear to the Danish scientists responsible for the auxiliary equipment that the electronographic cameras developed at the RGO would be very suitable for the 1.5 m telescope. After the Austin conference on "Electrography and Astronomical Applications" in 1974 (Chincarini, Griboval and Smith 1974) it was decided to initiate a collaboration between the RGO Physics Laboratory and the CUO Astroelectronics Laboratory on the further development of the cameras. The principal goal was to provide a Danish 4 cm camera and to use this camera and the first RGO 9 cm camera on the Danish telescope during its test period. In the winter of 1974–75 R. Florentin Nielsen spent six months at the RGO Physics Laboratory and contributed to the completion of the first 4 cm camera, which was then taken to the Wise Observatory in Israel for regular observational use. Then, in 1976–78, a Danish engineer, Finn Johannessen, participated in the camera projects at the RGO for about 18 months. Finally, the present authors commenced the tests of the two cameras on the 1.5 m telescope in the fall of 1978. The cameras, the observational programmes for the test period, and some of the results are described here.

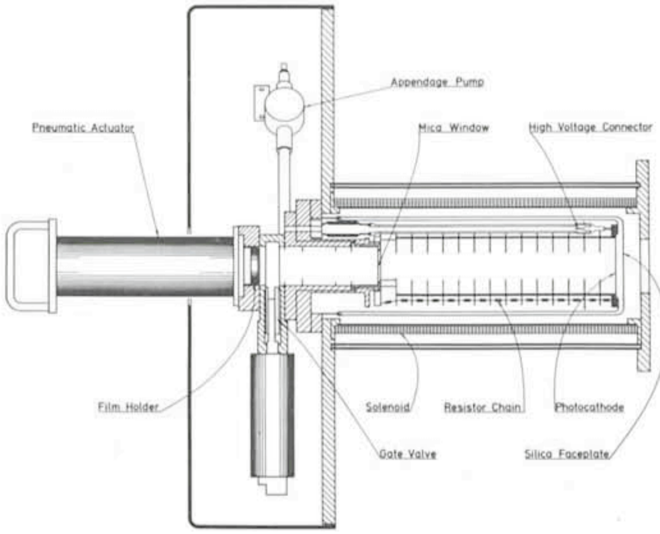


Fig. 1: *The RGO 4 cm electronographic camera (schematically).*

The Electronographic Camera

The performance characteristics of an electronographic system can be summarized as follows:

(1) The detective quantum efficiency may approach the responsive quantum efficiency of the photocathode, because every photoelectron entering the emulsion leaves a developable track.

(2) The spectral range is wide, depending on the characteristics of the photocathode, with quantum efficiencies significantly higher than with photography over the entire spectral range (3000–9000 Å).

(3) There is no reciprocity failure.

(4) The detection process is linear; that is, the density of the developed image increases linearly with exposure, up to densities of 4 or 5 in the case of certain nuclear emulsions.

(5) The dynamic range of nuclear emulsions is high because of their fine grain and the possibility of exposing to high density. The fog level is very low.

(6) The spatial resolution can be better than what is needed in conventional astronomical recording.

The historical development of electronographic cameras will not be described in detail here but mention must be made of the pioneering work of A. Lallemand; however, the operation of his Caméra Électronique is rather complicated and time-consuming. Another pioneer, J. D. McGee, developed the "Spectracon" mica window image tube which is very easy to use and is commercially available but has the disadvantage that its photocathode area is limited to 25 × 15 mm². The cameras developed at RGO are also of the mica window type but the design permits the incorporation of larger photocathodes, 44 mm and 93 mm diameter respectively in the two available versions.

The 4 cm camera is shown schematically in figure 1. The photocathode is normally of the S.20 type which has a spectral response extending into the near infrared; ideally it should be formed on the silica glass faceplate but for the time being a separate thin silica substrate is used because of technical difficulties (which however should be overcome soon). The processing of the photocathodes is carried out in a way which prevents contamination of the tube interior with alkali metals and results in very low dark current. The photoelectrons are accelerated to 40 keV and focussed by parallel electric and magnetic fields onto the mica window which is 40 mm diameter and 4 μm thick. Its purpose is to isolate the photocathode from the gases evolved from the nuclear emulsion which would cause an immediate loss of photosensitivity, while permitting a large proportion of the accelerated photoelectrons to pass through. The window is protected from atmospheric pressure by a vacuum lock through which the electronographic film (nuclear research emulsion on a Melinex base) is introduced and pressed into contact with the mica by an air pressure of ~ 15 Torr. The resulting mechanical stresses in the mica are very small and there is no danger of breaking the window.

The loading and unloading of the film through the vacuum lock is carried out by an automatic electropneumatic system which incorporates a number of safety interlocks to safeguard the tube against operator error or faults in the control system. The films commonly used are Ilford L 4 fine-grain nuclear research emulsion and the more rapid Ilford G 5 emulsion. The resolution under optimum conditions is 60 line pairs per mm corresponding to 10 μm or 0.15 arc second at the 1.5 m telescope f/8.5 Cassegrain focus.

The tube is of demountable construction, so that in the event of failure, for example of the photocathode, the tube can be reprocessed easily (and at a moderate cost). However, because of the stringent leak testing procedures that are followed, the photocathode should have little loss in sensitivity over a period of years unless a small leak opens up or the cathode is damaged by exposure to too high a light level.

Operation of the tube is easy, and it can be used under the most humid conditions and at observatories at the highest altitudes. Further details regarding the use of the tube and its maintenance are given in an "Operational Manual" and a "Maintenance Manual". The loading of the film and the dark-room work are done as in normal photography, and the development and fixing techniques are similar to those for IIIa-J plates.

In the 9 cm electronographic camera the diameter of the mica window is 85 mm but a demagnification in the electron optics makes the useful cathode diameter 93 mm. Since it has not so far been possible to make the large tube envelope of fused silica (as with the 4 cm tube) Pyrex glass is used and this causes a lower sensitivity in the ultraviolet. Otherwise the construction of the larger tube differs only in minor respects from the small one, and the same control electronics is used for control and supply of both cameras.

A standard set of optical filters is provided and mounted in two wheels in front of the camera. Large area filters which can be used with both cameras include the standard Johnson broad-band U, B, V filters, a red filter, and a "dark sky blue" (DSB) filter. The latter has a very sharp bandpass transmission curve 800 Å wide centred at 4900 Å and is used in order to reduce the effect of night sky emission lines. In addition a set of standard Strömgren intermediate-band filters (u, v, b, y) and another red filter are available for the 4 cm camera only. There are also spare positions in the smaller wheel for special filters to be used with the 4 cm camera.

The Observations

Various electronographic programmes were planned for the test period; we shall briefly mention these and describe a few results in more detail.

In the initial test period in November 1978 R. Florentin Nielsen in collaboration with Karen T. Johansen observed a series of first rank E0 galaxies in clusters of galaxies, mainly of the Bautz-Morgan type III having similar richness. This is a pilot programme for the study of the evolution of elliptical galaxies for selection of an evolution parameter in cosmological distance scale determinations.

In a search of faint extensions of galaxies (Disney 1976) R. Florentin Nielsen initiated a galaxy morphology programme. The galaxies observed cover a wide range of types und were selected from the Hubble Atlas. Observations were made partly with the 4 cm and partly with the 9 cm camera to match the angular size of the galaxies. V and DSB filters, and in a few cases also B and R, were used; the DSB filter was particularly useful in obtaining maximum contrast to the sky background and thus reaching a very low limiting surface brightness.

In the second moon-free period K. Gyldenkerne in collaboration with J.G. Bolton (Parkes) and co-workers made electronographic observations (V and DSB filters) of selected faint radio sources for a more precise morphological classification of optical counterparts than what is possible in normal photography. In another dark period P.A. Wehinger (Heidelberg), Susan Wyckoff (Ohio State University) and K. Gyldenkerne using a special filter (Schott OG5 70) searched for underlying structure surrounding low redshift quasars and also studied structure and orientation of radio galaxies in the optical area with respect to their radio structure, i.e. double and triple radio lobes.

B. Thomsen and S. Frandsen (Aarhus) also studied "metric" diameters of galaxies belonging to selected clusters. In addition, they carried out U, B, V, R photometry (R red filter) of BL-Lac objects with the purpose of detecting outer areas of galaxies possibly surrounding these objects. Thomsen and Frandsen are also studying globular clusters belonging to nearby galaxies (B, V, R) in order to compare the spatial distribution with the surface density of the other halo stars, to determine the luminosity function for globular clusters belonging to different galaxies, and, if possible, to derive a correlation between cluster colours and distance from the galaxy centre.

P. Grosbøl made u, b, y, R observations of spiral galaxies in order to compare the observed colour distributions with those calculated theoretically by himself and C. Yuan on the basis of the density-wave theory.

The above observations were all made on dark nights. In addition, standard sequences were observed in various fields. Thus K. Gyldenkerne in collaboration with J.G. Bolton, R. Cannon and A. Savage started observations of sequences down to 20 mag for the application to the quasar search programme described by Bolton and Savage (1978).

The first moon period in December 1978 was taken up with a programme of narrow-band electronography of hot-spot galaxies. The work is a collaboration between D.J. Axon (University of Sussex), K. Taylor (RGO) and K. Gyldenkerne.

The first results of this programme were most promising. The nucleus of NGC 1808 was studied in detail, electronographic images being obtained in the majority of the prominent emission-lines (Hα, [N II], [S II], [O II], [O III], Hβ, etc.) together with some intermediate continuum bands. Examples of these data, which are being prepared for publication (Gyldenkerne, Axon and Taylor 1979) at this time, are presented in figure 2.

As further indication of the power of this telescope-detector system, we obtained sky-limiting exposures of NGC 1808 in the Johnson V band and as a result discovered a beautiful system of filaments emanating from the disc

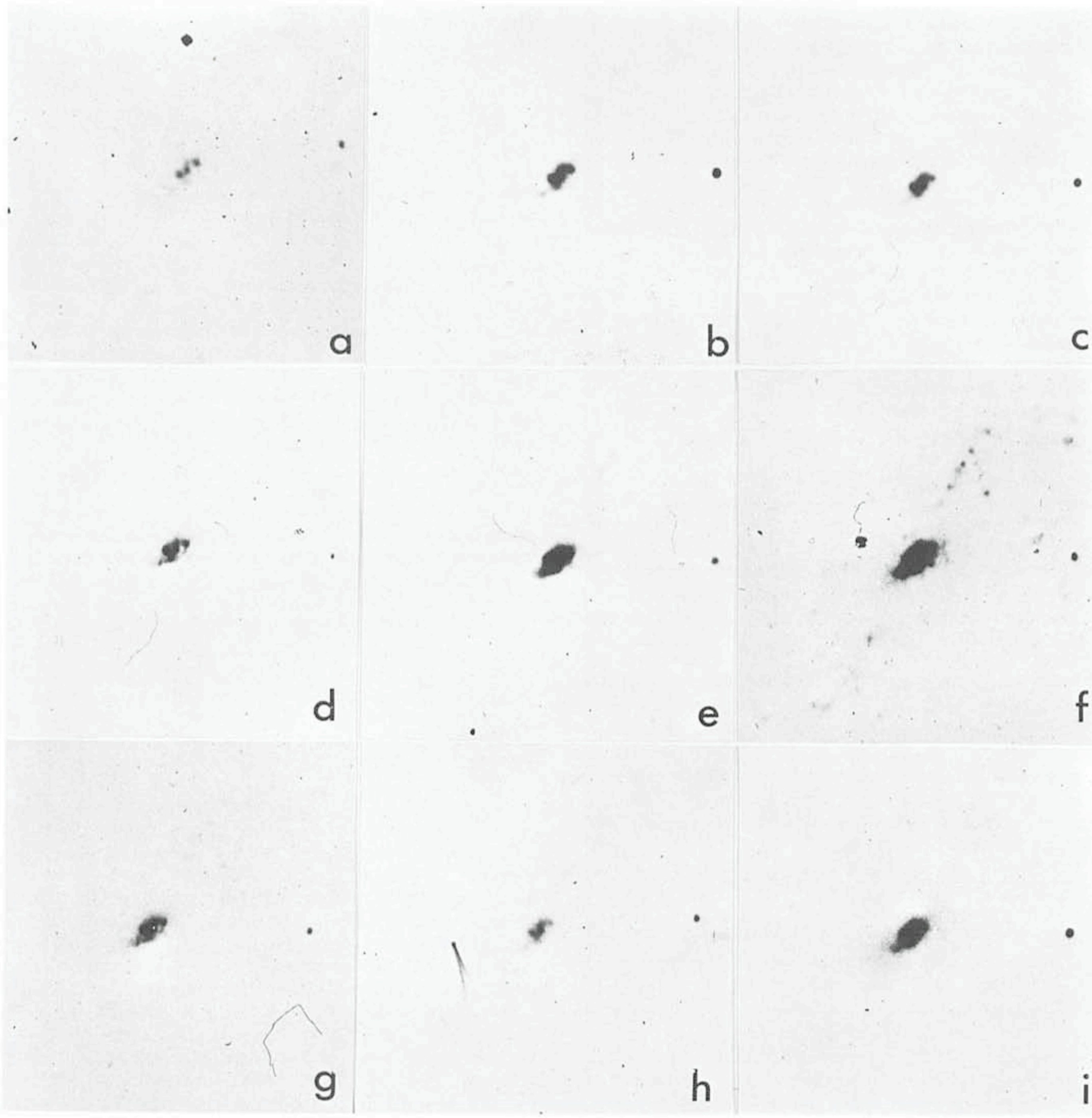


Fig. 2: *Narrow-band electronographic exposures of the active galaxy NGC 1808, obtained with the 4 cm McMullan camera on the Danish 1.5 m telescope. Emulsion Ilford G 5. Filter halfwidths around 15 Å. (a) Negative 6547: [O II], 60 min; (b) Neg. 6546: [O III], 60 min; (c) Neg. 6551: continuum near 6400 Å; 30 min; (d) Neg. 6545: Hα, 60 min; (e) Neg. 6550: Hα, 180 min; (f) Neg. 6548: Hα, 360 min; (g) Neg. 6556: [N II], 90 min; (h) Neg. 6544: [S II], 30 min; (i) Neg. 6549: [S II], 150 min. Note the difference between the lines, due to differences in temperature and pressure in the central regions. The Hα photos show H II regions. There are some unavoidable plate faults; the "comet" in (h) is one of these.*

region of the galaxy, very similar to the filaments in that other famous southern hot-spot galaxy NGC 1097 (Wolstencroft and Zealey 1975).

Summary

The experience with the 4 cm and 9 cm cameras in combination with the 1.5 m telescope has been extremely satisfactory. The power of the large camera is illustrated by figure 3 which should be compared with the 30-minute electronograph of the same area shown in *Messenger* No. 16, p. 1. The Ilford emulsions used from the beginning of the test period have turned out to be of good quality and with very few defects occurring, so that practically all the films provided could be used.

With the good seeing experienced in the 1.5 m telescope dome and the very fine external seeing occurring occasionally, coupled with the high quality of the telescope optics (Andersen and Niss 1979), the electronographic resolution mentioned above will permit a very faint limiting magnitude with this combination of instruments. Limits of about 26 magnitude for stars and 27 magnitude per square arc second for extended objects should be obtained under optimum weather conditions.

The collaboration described has thus been successful. It should be added that the achievements during the period in question have also, at least partly, encouraged the production of similar electronographic equipment for other non-British telescopes such as the ESO 3.6 m telescope on La Silla.

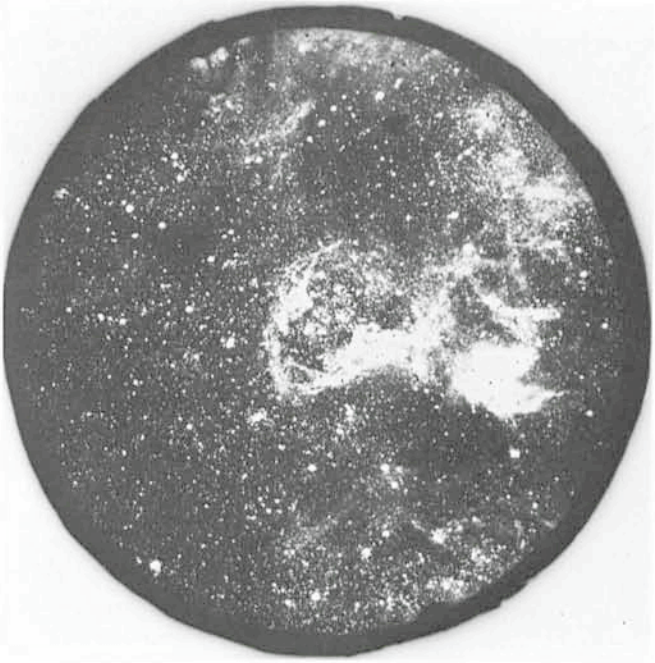


Fig. 3: *A 90-minute exposure of a region around NGC 2081 in the LMC, taken with the 9 cm McMullan camera on the Danish 1.5 m telescope. Emulsion Ilford G 5 and filter "Dark Sky Blue". The exposure may be compared with the one shown on page 1 of Messenger No. 16.*

Acknowledgements

The authors thank staff members at RGO and at CUO for all their assistance. The Danish Natural Science Research Council awarded a special grant for the Danish part of the project and financed Finn Johannessen's work at RGO. A NATO Research Grant has provided essential support for the Danish-British collaboration.

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LATEST NEWS

Discovery of a New Eclipsing Dwarf Nova: OY Carinae

The weather at the beginning of the night April 29/30, 1979 was not excellent on La Silla: Most clouds were gone, but many of them were just waiting near the horizon and threatened to come back. After twilight I pointed the ESO 1 m telescope to the southern dwarf nova OY Car, which is a faint variable star of about 16^m. The first photoelectric measurement, however, revealed $14^m.8$, a bit brighter than normal, and it seemed to brighten up rapidly. Of course, this is not unusual for a dwarf nova: OY Car just was beginning one of its eruptions. I left the telescope on the star monitoring it continuously in 3-second time intervals. After five minutes, however, a new surprise showed up: the intensity began to drop! I checked the diaphragm: the star was properly centred. I looked at the sky: No visible clouds in the field. But the signal diminished more and more, and within a few minutes the star was five times fainter than before! This did not last long: the intensity began to rise again, even faster than the decline, and reached its previous value five minutes later. Could this have been caused by the unstable weather conditions? I kept the telescope on OY Car and found out that the darkening of this star repeated periodically every 91 minutes: no cloud is known to pass so regularly!

There was no doubt that I had discovered a new eclipsing dwarf nova with an extremely short period. Figure 1 shows the first eclipse ever observed: the star was still faint ($\sim 15^m$) at this time. Two totality phases appear like "steps" in the lightcurve. According to recent dwarf nova models, the first "step" corresponds to the total eclipse of the central parts of the disk and of the white dwarf, while the second

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 six countries: Belgium, Denmark, France, the Federal Republic of Germany, the Netherlands and Sweden. It now operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where ten telescopes with apertures up to 3.6 m are presently in operation. The astronomical observations on La Silla are carried out by visiting astronomers—mainly from the member countries—and, to some extent, by ESO staff astronomers, often in collaboration with the former.

The ESO Headquarters in Europe will be located in Garching, near Munich, where in 1980 all European activities will be centralized. The Office of the Director-General (mainly the ESO Administration) is already in Garching, whereas the Scientific-Technical Group is still in Geneva, at CERN (European Organization for Nuclear Research), which since 1970 has been the host Organization of ESO's 3.6-m Telescope Project Division.

ESO has about 120 international staff members in Europe and Chile and about 150 local staff members in Santiago and on La Silla. In addition, there are a number of fellows and scientific associates.

The ESO MESSENGER is published in English four times a year: in March, June, September and December. It is distributed free to ESO employees and others interested in astronomy.

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Editor: Richard M. West
Technical editor: Kurt Kjär

EUROPEAN
SOUTHERN OBSERVATORY
Schleißheimer Straße 17
D-8046 Garching b. München
Fed. Rep. of Germany
Tel. (089) 3204041-45
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and deepest "step" coincides with the coverage of the "hot spot". The second lightcurve shown in figure 1 corresponds to the next night when OY Car had reached the maximum brightness of its eruption ($\sim 12^{m}.4$). Only a partial eclipse is observed because the eclipsed body (the disk) is now much more extended than before, and cannot any more be covered totally by the faint red secondary star. Since we see the hot spot radiation separated from that of the disk at certain eclipse phases, we can calculate the relative contribution of both components to the total light, and can follow up this ratio throughout the outburst. This will have important consequences for the dwarf nova outburst mechanism which is still not definitely known.

The discovery of this eclipsing binary was not a pure accident: in January 1979, when I took spectrograms of several dwarf novae with the Image Dissector Scanner at the 3.6 m telescope, OY Car turned out to show a strong, double Balmer emission with a separation of ~1,500 km/s of both emission peaks. This is typical for cataclysmic binaries with high orbital inclination and, thus, justified a search for eclipses. The rest was good luck: fair weather conditions, the begin of an outburst and—last but not least—an excellent cooperation of Holger Pedersen who was scheduled for half of the observing nights, but kindly left me the critical hours for OY Car.

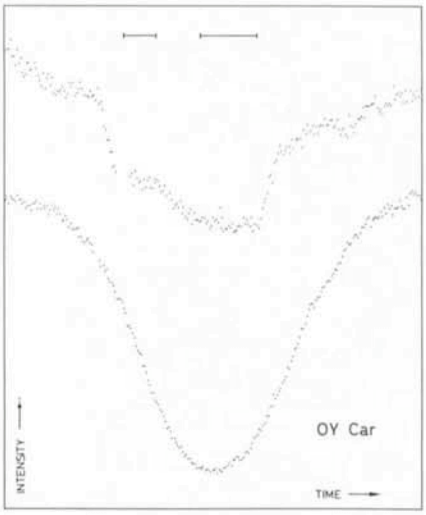

Fig. 1: *Eclipse lightcurves of OY Car, observed on April 29/30, 1979 (upper curve) and April 30/May 1 (lower curve) with the ESO 1 m telescope. The upper curve shows two totality phases which are indicated by bars (explanation see text). Each curve covers a total time interval of about 13 minutes.*

Nikolaus Vogt

ALGUNOS RESUMENES

La calidad del telescopio danés de 1.5 m sobrepasa las expectaciones.

Desde fines de noviembre del año pasado un nuevo instrumento se encuentra a disposición en La Silla: El telescopio danés de 1.5 m.

En una serie de placas tomadas durante una noche de excelentes condiciones atmosféricas a principios de marzo del presente año, el tamaño de las imágenes variaba de 1 segundo de arco hasta 0.6 segundo de arco. La mejor placa—con una exposición de una hora—muestra bonitas imágenes circulares de 0.5 segundo de arco! Es éste un resultado casi increíble, que comprueba la excelente calidad de este nuevo telescopio.

δ Crucis es variable!

Durante una reciente estadía en La Silla el Dr. Eric W. Elst del Observatorio Royal en Uccle, Bélgica, ha descubierto que una de las estrellas en la Cruz del Sur, δ Crucis, es variable.

Naturalmente hay muchas otras estrellas variables, sin embargo, el presente caso es particularmente interesante porque la amplitud máxima en la curva luminosa tiene una magnitud de sólo 0.006! Esto explica el porqué hasta ahora la variabilidad de la estrella no había sido detectada antes, a pesar de que esta estrella había sido observada muchas veces.

El descubrimiento es una demostración de la excelente ubicación de La Silla y del buen rendimiento del telescopio de 61 cm de Bochum y su fotómetro, con el cual se efectuaron las observaciones.

Nuevas series de diapositivas de ESO

Durante los próximos meses se dispondrá de dos nuevas series de diapositivas.

La primera de éstas consiste de 20 diapositivas de 5 × 5 cm que muestran las instalaciones en La Silla. Incluyen edificios, telescopios y vistas del lugar. Una descripción completa en varios idiomas explica las diapositivas.

La segunda serie contiene algunas de las mejores fotografías que han sido tomados con la cámera del foco primario del telescopio de 3.6 m (corrector Gascoigne). De entre más de 1.000 fotografías, se eligieron 20 diapositivas en blanco y negro (nebulosas, galaxias, etc.).

El precio por una serie de diapositivas es de DM 18.– (o su equivalente) en Europa, y US$ 10,– por correo terrestre a todos los demás países, o US$ 12.50 para su envío por vía aérea (pagadero por adelantado).