No. 30 – December 1982

TWENTY YEARS ESO

On the 5th of October 1962, the ESO Convention was signed in Paris by representatives of Belgium, France, the Federal Republic of Germany, the Netherlands and Sweden. More than a year later, on the 17th of January 1964, the Convention went into effect, following parliamentary ratification in the required majority of countries. In 1967, Denmark also joined. In the early days (partly before the formalities were completed), site surveys were made which led to the choice of La Silla as the observatory location, and work was started on the La Silla infrastructure and on the Schmidt telescope and the 3.6 m telescope. Some other telescopes were ordered from industry. After it was realized that ESO did not have the necessary (technical) management capabilities to bring all its projects to a successful completion, discussions took place with CERN which led in 1970 to the founding of the T(elescope) P(roject) Division in Geneva, partly staffed with CERN personnel. As a result, the 3.6 m telescope was completed in 1976.

Fundamental decisions about the future of ESO were taken at the end of 1975: It was decided to continue the TP Division at roughly the same size and with the task to develop the instrumentation. In addition, the Scientific Division was created which would give the organization its scientific identity. By 1980, ESO moved to Garching where the German government provided a new building.

Equally important changes took place in Chile. While originally a centre had been founded in Santiago, 600 km from the Observatory, it became increasingly clear that it was difficult to give La Silla the necessary priority from such a distance. As a result, in 1975 the decision was taken to move all scientific-technical facilities to the mountain.

In the last few years, a new strong impetus was given to ESO. Two new countries, Italy and Switzerland, decided to join and completed the ratification procedures earlier this year. Partly related to this, it was decided to add the 2.2 m telescope of the Max-Planck-Gesellschaft to the La Silla telescope park and to construct a 3.5 m New Technology Telescope. Moreover, the European Space Agency decided to place the European Coordinating Facility for the Space Telescope at ESO. These developments indicate that ESO has been able to obtain the confidence of the European community as an effective cooperative organization.

It is important that ESO has shown that it can develop telescopes and instrumentation and stimulate scientific research at a level comparable to the best available elsewhere. Perhaps, however, its most significant contribution is to European integration. Of course, the fact that persons of different nationalities work together in relative peace is all to the good. But the task of ESO goes far beyond this: ESO has to make its contribution to creating the confidence that Europe can set its own aims in science and technology and accomplish these successfully. Only on the basis of this self-confidence can an advanced and independent Europe be built.

L. Woltjer, Director General

Professor M. K. Vainu Bappu (1927–82)

It was with great sadness that we received the news of the death, on 19 August 1982, of Professor M.K.V. Bappu, President of the International Astronomical Union and Director of the Indian Institute of Astrophysics, Bangalore, India. Professor Bappu was spending a few months with ESO in Munich, doing research within solar and stellar spectroscopy and at the same time preparing for the XVIIIth IAU General Assembly. A heart ailment necessitated a major surgical intervention, which was apparently successful. However, post-operative complications set in, and after a heroic struggle, assisted by the foremost medical expertise, Professor Bappu expired in the early evening of 19 August.

Few astronomers ever were as esteemed and liked as Professor Bappu. Combining a great scientific insight in many areas of astronomy and an outstanding talent for organization, he won friends on all continents, wherever he travelled. His very human approach and charming appearance will always be remembered by those who had the good fortune of making his acquaintance. By his own example, he showed how it is possible to link a thorough, advanced knowledge of exact sciences with a poetic, nature-loving mind and thus to achieve a rarely seen harmony between these two aspects of life.

A major reason for this was undoubtedly his great familiarity with both East and West. Born in India, Professor Bappu studied in the USA and after several, brilliantly successful years at Caltech, he returned to his native country, turning down offers from other places. During the next decades, he built up the science of astronomy and astrophysics in India, and without his efforts, it would not have reached the internationally recognized, high level it has today. While making many important contributions within the fields of stellar and solar astronomy (e.g. the "Wilson-Bappu" effect), he also fully appreciated the importance of obtaining continuous support to astronomy by maintaining close contacts with government officials and by successfully impressing upon all authorities the central role of astrophysics in modern science.

Professor Bappu leaves behind many ideas and much unfinished work which will now be taken up by others. There is no doubt that his inspiring example has influenced many people and we can only regret that he did not live to see all of his projects come to realization.

Our sympathy goes to Mrs. Yemuna Bappu who was at her husband's side in Munich. We can do little to console her in her great sorrow, but the memory of our beloved friend and highly valued colleague will remain forever in our hearts. Professor Bappu's foresight and the full implications of his many achievements shall become even more obvious with time.

Richard M. West

Another Gravitational Lens?

J.-S. Chen, Peking Observatory and ESO, and P. A. Shaver, ESO

Following the discovery of the Q0957+561A,B pair and subsequent interpretation as a gravitationally lensed QSO, several searches for similar objects have been made, but only two cases have so far been confirmed. In collaboration with astronomers in Edinburgh, one of us (J.-S. Chen) started a QSO survey programme two years ago using low-dispersion objective-prism plates taken with the UK Schmidt telescope at Siding Spring Observatory. Three fields have been systematically searched and about 500 QSO candidates identified. Among these only one gravitational lens candidate was found. The images (Fig. 1) are close together (7″), bright (17.5 m_v), stellar, and blue, and the objective-prism spectra contain strong emission lines at very similar redshifts.

0128-531A,B

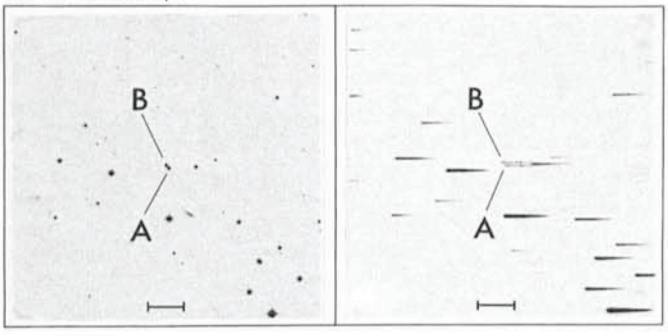

Fig. 1: *The 0128-531A,B pair, on a IIIa-J + GG385 direct plate (left), and a IIIa-J objective-prism plate (right), both taken with the UK Schmidt telescope. The horizontal bar is 1 arcmin.*

Spectra obtained recently with the IDS on the 3.6 m telescope at La Silla, however, conclusively reject the gravitational lens hypothesis. Indeed, these objects are not even QSOs. They are extragalactic H II regions, at redshift z = 0.0885. The strong emission lines seen in the objective-prism spectra are [O II] λ 3727. The Hβ, [O III] λλ 4959, 5007, and other strong lines seen in the IDS spectra in Fig. 2 are shifted outside the window of the IIIa-J objective-prism plate.

Several extragalactic H II regions have been misinterpreted as QSOs and included in QSO catalogues (for example, B234, B272, and Q0242-387 in the Hewitt and Burbidge catalogue). Such objects are often referred to as blue compact galaxies, and are thought to be protogalaxies because of the low metal abundances. The burst of first-generation star formation results in both a very blue continuum and strong ionization of the parent gaseous clouds. Extragalactic H II regions are therefore important in understanding the early evolution of galaxies, and the chemical abundances in the early universe (particularly primordial helium).

The 0128-531A,B extragalactic H II regions are very close together indeed, both in position ($8h^{-1}$ kpc projected separation for H_o = 100h km s^{-1} Mpc^{-1}), and in redshift (△V = 40 ± 50 km/s). Are they really isolated, or are they part of one system, perhaps an underlying galaxy? If more such pairs can be found, it may be possible to estimate their masses from the relative velocities. Although it is not a gravitational lens system, therefore, 0128-531A,B will be of special interest in exploring a quite different type of phenomenon.

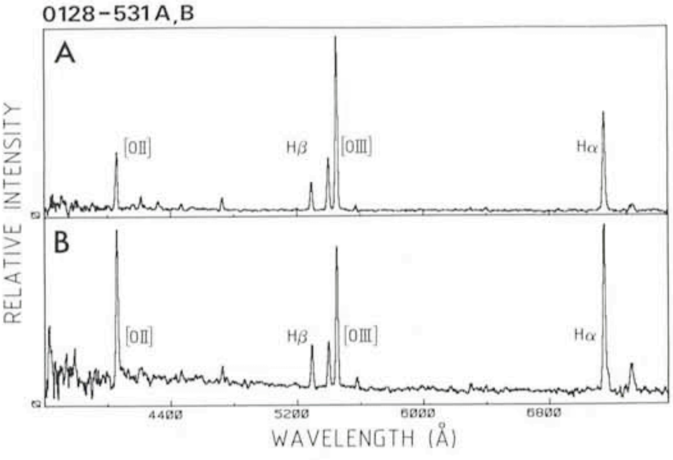

Fig. 2: *Low-dispersion IDS spectra of 0128-531A and B, obtained with the ESO 3.6 m telescope. The resolution is 15 Å FWHM.*

An Absorption Feature and Filamentary Structures in the Central Galaxy of the Centaurus Cluster, NGC 4696

H. E. Jørgensen and H. U. Nørgaard-Nielsen, Copenhagen University Observatory

It has been known for a long time that clusters of galaxies are often extended X-ray sources. It is now generally accepted that the X-ray emission is due to thermal bremsstrahlung (free-free radiation) from a tenuous ($n_e \sim 10^{-3}$ cm^{-3}), hot ($T \sim 10^8$ K) intracluster gas. For several clusters the X-ray gas consists of both a hot and a cool ($T < 3 \times 10^7$K) component. The cool intracluster gas may be cooling, resulting in instabilities in the inflowing gas, giving the filamentary structure as observed around NGC 1275, the central galaxy of the Perseus Cluster (Fabian and Nulsen, 1977, *Mon. Not. R. Astr. Soc.*, **108**, p. 479). The system of filaments in M87 in the Virgo Cluster is also considered as evidence of matter falling into the galaxy (Ford and Butcher, 1979, *Astrophys. J. Supp.*, **41**, p. 147).

Since the Centaurus Cluster has a low temperature X-ray component of $kT \sim 2.4 \pm .3$ keV it could be another case of a cooling core with filaments, as pointed out by A. C. Fabian and Nulsen. We shall here report very preliminarily on some very interesting optical features in NGC 4696, the central galaxy in the Centaurus Cluster.

NGC 4696 was observed on July 6 – 7, 1982, with the new ESO CCD camera during its testing phase on the Danish 1.5 m telescope at La Silla by H. Pedersen. A blue (Johnson B) 20 min. exposure and a red (broader than Johnson R and maximum around 7700 Å) 10 min. exposure under good seeing conditions (~ 2″) were obtained.

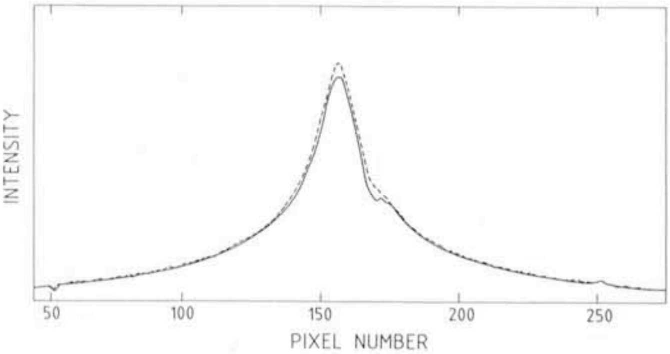

Fig. 1: *The profiles through the "horse shoe" south of the centre of NGC 4696. —— blue exposure; – – – – red exposure (unit along the x-axis: ″47).*

In Fig. 1, we have given the red and the blue profiles through the central region of the galaxy. We have normalized the two exposures so that they agree in the outer parts of the galaxy. It is clearly seen that blue light seems to be missing in the central region. Profiles through different parts of the central region confirm this conclusion. Fig. 2 shows the residual "Red" light (the red exposure minus the normalized blue exposure). A fairly regular structure running east-west 6″ (~ 1 kpc) south of the nucleus is very evident and obviously it extends in a "horse shoe" around the nucleus to the west and north-west. Indication of this feature was found by Shobbrook (1966, *Mon. Not. R. Astr. Soc.*, **131**, p. 351). The horse shoe is typically redder than the galaxy by Δ (B - R′) $\sim ^{m}\!.12$ corresponding roughly to Δ(B – V) $\sim ^{m}\!.05$. The most obvious way to interpret this structure is that the redden-

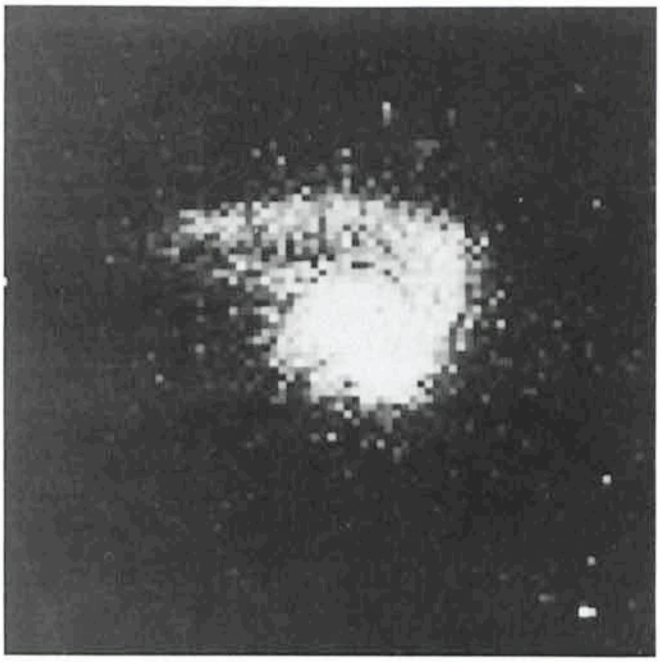

Fig. 2: *The residual red light in NGC 4696. Orientation: South up, east to the left. Angular size of the figure: 40″ × 40″.*

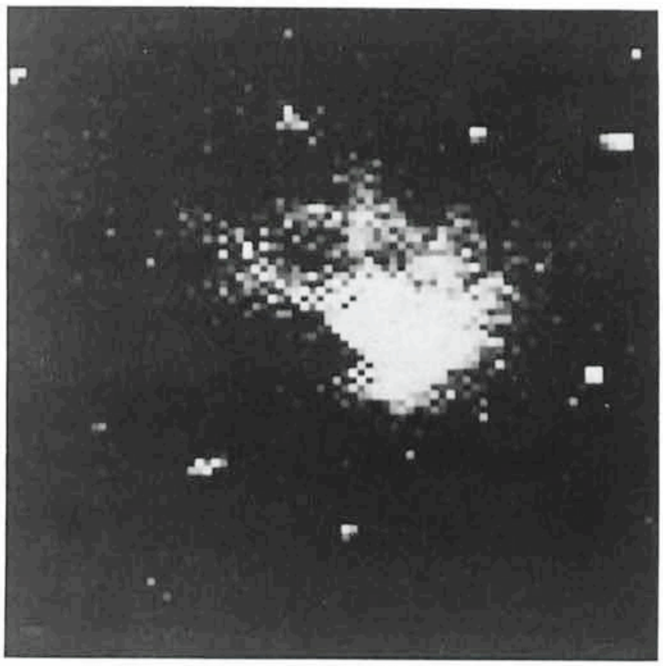

Fig. 3: *The H_α + [N II] exposure of NGC 4696. Same orientation and angular size as Fig. 2.*

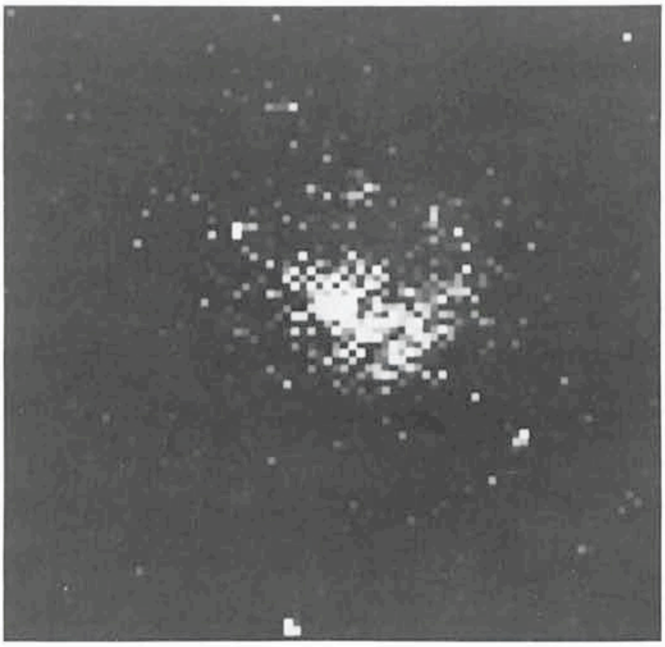

Fig. 4: *The [S II] exposure of NGC 4696. Same orientation and angular size as Fig. 2.*

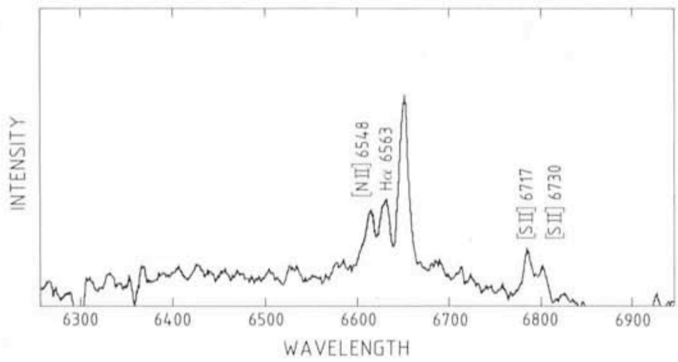

Fig. 5: *The IDS spectrum of the spectral region around H_α + [N II] and [S II] for the area of the "horse shoe" north-west of the centre of NGC 4696.*

ing is caused by an absorbing dust lane. The dust lane which extends more than 180° around the centre could be situated in gas compressed in a shock due to the motion of the galaxy through the hot intracluster medium. Numerical simulation of this phenomenon has been given by Gisler (1976, *Astron. Astrophys.*, **51**, p. 137), who obtained structures similar to the one we observe.

On May, 28–30, 1982, we observed NGC 4696 with the CCD camera on the Danish 1.5 m telescope through filters covering redshifted H_α + [N II] and [S II]. The band width of the filters was ~ 100 Å. A "continuum" band around 6900 Å was also observed.

In Fig. 3 we show the H_α + [N II] exposure of NGC 4696 with the continuum subtracted. Several filaments are clearly seen south and west of the nucleus. This agrees with results very recently obtained by A. Fabian and collaborators with the AAT (private communication). Fig. 4 shows the [S II] exposure of NGC 4696 again with the continuum removed. Filamentary structures south and west of the nucleus are evident also in the [S II] light.

The data in Fig. 2, 3 and 4 suggest a strong connection between the absorption feature and the filamentary structure since only very faint emission is seen outside the absorbing dust lane.

IDS spectra at a dispersion of 116 Å/mm were obtained in different positions of NGC 4696 on May 25–26, 1982, using the 3.6 m telescope. As an example we display in Fig. 5 the spectrum of a 4″ × 4″ region 5″ north-west of the centre where we noticed strong emission in Figures 3 and 4. The similarity to emission lines from filaments in M 87 as observed by Ford and Butcher is striking, indicating similar physical conditions in the filaments.

The optical observations, presented here together with the X-ray observations suggest that we are in fact observing cooling intracluster gas accumulating on the central galaxy of the Centaurus Cluster.

These observations make up the first part of a survey of clusters with a low temperature X-ray component.

Follow-up observations in the UV of NGC 4696 by IUE will be performed in the near future.

IUE Observations of Variable Seyfert 1 Galaxies

C. Boisson and M. H. Ulrich, ESO

Introduction

The emission spectrum of Seyfert 1 nuclei is similar to that of faint quasars. The ionization of the gas is attributed to a central source emitting a non-thermal radiation (X, hard UV). These spectra are characterized by broad hydrogen and other permitted lines; sometimes strong narrow forbidden lines and cores to the permitted lines are also seen.

The width of the broad permitted lines, typically 3,000 to 10,000 km s^{-1}, is due to high relative velocity of the emitting clouds (or filaments). Although the clouds, with a density > 10^9 cm^{-3}, are optically thick in the Lyman continuum, the whole nebula has only a small coverage factor of the central source (10 % at most). The permitted emission lines are thought to originate at a distance of ~1 pc, or less, from the central source, while the narrow line-emitting region, of considerably lower density (Ne ~ 10^4), is located at much larger distances, ~100 pc to 1 kpc (Fricke, K.J., and Kollatschny, W., *The Messenger,* **26,** 9).

Ultraviolet (UV) observations of Seyfert nuclei are interesting for several reasons. The study of highly ionized species, such as C IV, Si IV, NV, which are observed in the UV, but not in the optical, gives us some knowledge of the range of ionization in Seyferts. Furthermore, the stellar contribution in the UV is small, facilitating the study of the non-thermal continuum. Moreover, comparing with ground-based observations of highly ionized gas in high-redshift quasars, luminosity effects in the line ratio can be investigated (since quasars are more luminous than Seyferts).

The monitoring of NGC 4151, using the International

Ultraviolet Explorer (IUE), has shown that the nucleus of this galaxy has several interesting properties (see Bromage, G.E. *et al.*, 3rd European IUE Conference, 1982, ESA SP-176 and reference therein).

To investigate if these properties are common to all Seyfert 1 nuclei, we have selected seven objects, all known for their brightness variability at optical wavelengths: NGC 3516, NGC 5548, Akn 120, NGC 3783, NGC 4593, NGC 7213, ESO 113-IG45(F9). To our own IUE data of these objects, we have added some spectra from the data bank and examined those already published.

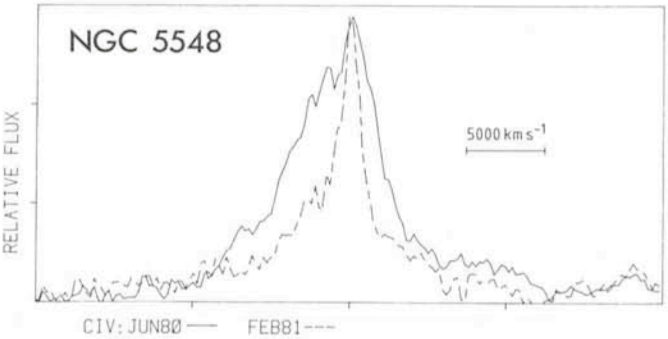

Fig. 2: *The profile of the C IV λ* 1549 line after subtraction of the continuum and normalization peak intensity.

The Continuum

The IUE spectra, covering the interval λλ 1150 – 3200 Å, have been analysed chosing continuum points when emission or absorption lines, particle events or fiducial marks were expected to be absent. The reddening was assumed to be time-independent and to follow Seaton's law (Seaton, M.J., 1979, *MNRAS* **187,** 173p). The appropriate reddening correction cannot always be determined precisely: the maximum value is assumed to be the one producing a bump at 2200 Å in the reddening corrected continuum, the minimum value being obviously the galactic absorption. The dereddened continua were fitted in terms of power law $F \propto \nu^{-\alpha}$, using the minimum possible value for the absorption.

Our study of the continuum shows that NGC 4151 is not atypical, other Seyferts exhibiting similar properties, namely: (i) the UV continuum varies both in shape and intensity between different epochs, (ii) it hardens when the intensity increases. This behaviour was already seen in Akn 120 (Kollatschny *et al.*, 1981, *AA* **102,** L25), NGC 4593 (Clavel *et al.*, 1982, *MNRAS* in press) and NGC 7469 (Elvius *et al.*, 1982, ESA SP-176 proceedings).

In several instances, even after reddening correction, the continuum shows a break near 2000 Å. In this case two power laws are needed to fit the continuum, the spectrum being harder at λ < 2000 Å (e.g. NGC 5548, Fig. 1). This resembles the spectrum of many quasars and suggests that, longward of 2000 Å, the UV continuum, in Seyfert spectra, is part of the 3000 Å bump commonly seen in quasar spectra. As to the origin of this bump, several suggestions have been made, e.g. Balmer lines, optically thin Balmer continuum emission, two photon and Fe II emission (Grandi, 1982, *Ap.J.* **255,** 25; Malkan and Sargent, 1982, *Ap.J.* **254,** 22). When a break occurs, the temporal variation in the continuum shortward of 2000 Å is of greater amplitude than longward. For some objects, when the intensity of the continuum is very low, one power law is sufficient, the short wavelength component having faded (Fig. 1).

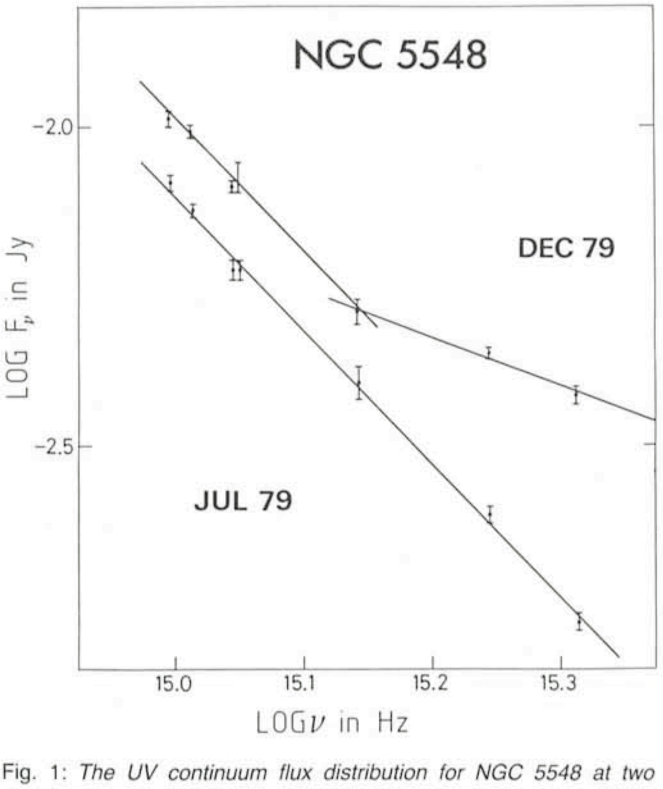

Fig. 1: *The UV continuum flux distribution for NGC 5548 at two epochs.*

The nature of this last component is uncertain. In most quasars, an excess of ultraviolet continuum remains even after subtraction of a combination of the 3000 Å bump eventual constituents. It has been proposed that optically thick thermal emission (e.g. black-body) as well as partially thick Balmer continuum can contribute to the extra component. One possible interpretation of the optically thick thermal emission is that it comes from an accretion disk (Shields, 1978, *Nature* **272,** 706). Examples of such exceptional objects are 3C 273 among quasars and ESO 113-IG45 among Seyferts.

The fact that such a component is never seen in BL Lac spectra even far from their brightness minimum, suggests that (black-body or not) it is related to the existence of a broad line region.

Simultaneous observations in at least the UV and visible are required to give a more quantitative description of the continuum. Extending them at other wavelengths would be even better.

The Emission Lines

In the "classical photoionized model" of broad line formation in quasars, the side of the clouds facing the central ionizing source emits C IV λ 1549, whereas the back part shielded from the Lyman continuum, emits Mg II λ 2800, Fe II lines and the bulk of the Balmer lines. In this model, one of the most important parameters that govern the spectrum is the ionization parameter U_H, i.e. the ratio of ionizing photon flux to the medium density. This parameter is determined by using the intensity ratios of the three intense lines Lyα, C IV λ 1549, C III] λ 1909. The hypothesis underlying this computation is that these lines are formed at the same place in the medium and so they should have the same velocity profiles. Up to date this has been found to be true for quasars (see Davidson and Netzer, 1979, *Rev. Mod. Phys.*, **51,** 715, for more detail).

In NGC 4151, the emission line profiles and intensities vary

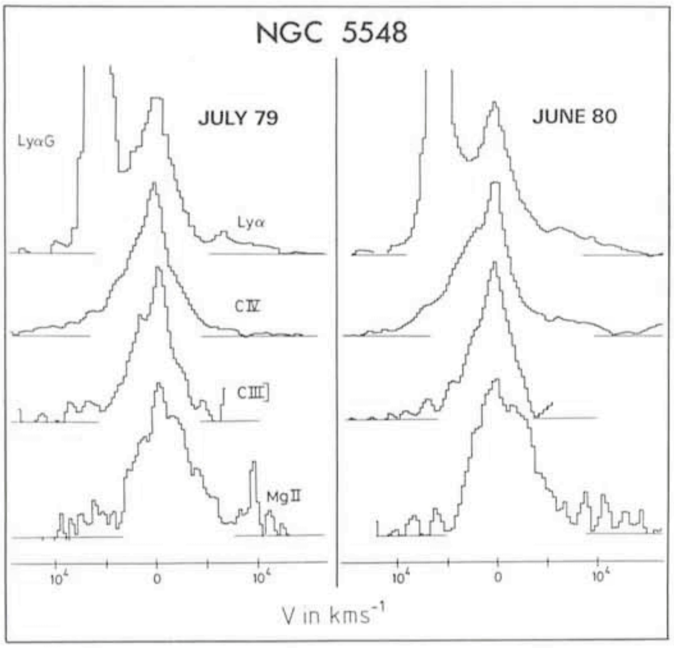

Fig. 3: *The profiles of the main UV lines in NGC 5548, June 1980 and July 1979 scaled in velocity.*

with the intensity of the continuum. The C IV λ 1549 intensities are well correlated with the continuum at 2500 Å, but show a time-lag of ~15 days between the variations of the continuum flux and the lines, this delay being due to light travel time in the C IV region. The C III] λ 1909 intensity remains constant, suggesting an emission region larger than a light year. There is only an insignificant correlation between Mg II λ 2800 and the continuum at 2500 Å (Ulrich *et al.*, 1983, preprint).

In all the objects we have looked at, there is a general trend for emission lines and widths (Fig. 2) to vary in the same sense as the continuum, those from highly ionized species varying more than those from less excited ions, but no tight correlations are found.

A striking point is that, at a given epoch, comparison of the profiles of the most intense broad lines (C IV, Mg II, C III]) with a good signal-to-noise ratio, reveals differences in the width of the lines (Fig. 3). For NGC 3516 and NGC 5548 (Ulrich and Boisson, 1983, *Ap.J.*, in press), as for NGC 4151, we can distinguish at least 3 regions:

(1) emitting the wings of C IV only, with the largest velocity dispersion (~2 10^4 km s^{-1});

(2) emitting Mg II and C IV of FWZI ~ 10,000 km s^{-1}, C III] not being detected;

(3) emitting the 3 lines of FWZI ~ 4000 km s^{-1}.

For the others, the subdivision in (2) and (3) is less clear. One should also note that sometimes, when the continuum is faint, all the lines are "narrow". It seems that, the emitting region being small, one is witnessing the lightening or the extinction of shells located at different distances from the centre.

From this point of view, Seyfert galaxies appear different from quasars. This difference could be an absolute luminosity effect and observations of faint quasars are needed to test this hypothesis.

Conclusion

In the 7 Seyferts analysed, as in NGC 4151, (i) the continuum becomes harder when it brightens; (ii) there is a general trend for emission lines and widths to vary in the same sense as the continuum, (iii) matter appears not to be distributed in the broad line region (BLR) of Seyferts as it is in quasars: for Seyferts we can distinguish regions where the gas has different physical conditions and velocities.

The Variability of RR Tel

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Introduction

In the course of its history, RR Tel has been described as a member of different stellar classes. In fact, it is a galactic nova for which only one outburst has been recorded and whose lightcurve before that outburst is one of the best known.

Spectroscopically, the star has also been extensively observed in the various wavelength ranges. Present infrared variations are well established and interpretations of the nature of RR Tel point to a symbiotic object containing a Mira variable and a dust component. A blue component is also believed to be present. We will show how simple photometric observations carried out at ESO, together with other sources of data, bring an interesting complement to this model.

First Observations

RR Tel was discovered as a variable by W.P. Fleming (*Harvard Circ.* **143,** 1908) from 19 Harvard plates spread over 13 years. At this time, she suggested the star (then named HV 3181) might be of the SS Cyg type, also called U Gem type.

In 1945, S. Gaposchkin derived a period of 386.73 days from 40 acceptable observations (*Harvard Ann.* **115,** 22) and this period of about 387 days was adopted by Kukarkin and Parenago in their 1947 catalogue where they presented the star as a semi-regular variable.

The outburst had occurred in November 1944, but it remained unnoticed until the South African amateur astronomers P. Kirchhoff and R.P. de Kock discovered in 1948 that the star had increased from fainter than twelfth to about the sixth magnitude.

The pre-outburst behaviour of the star can be appreciated in Fig. 1 reproduced from the work of M.W. Mayall (*Harvard Bull.* **919,** 1949, 15) who examined all Harvard plates available when the star brightening was discovered. This led to more than 600 positive observations of the star between 1889 and 1947 which pointed out the occurrence of the outburst at the end of 1944, as well as the stronger variations which preceded it.

Actually there is little evidence of periodicity in the variations from 1889 to 1930, where the observed amplitude was about 1.5 magnitude with a maximum varying between 12.5 and 14. Later, however, the periodicity became evident and the amplitude increased up to three magnitudes approximately.

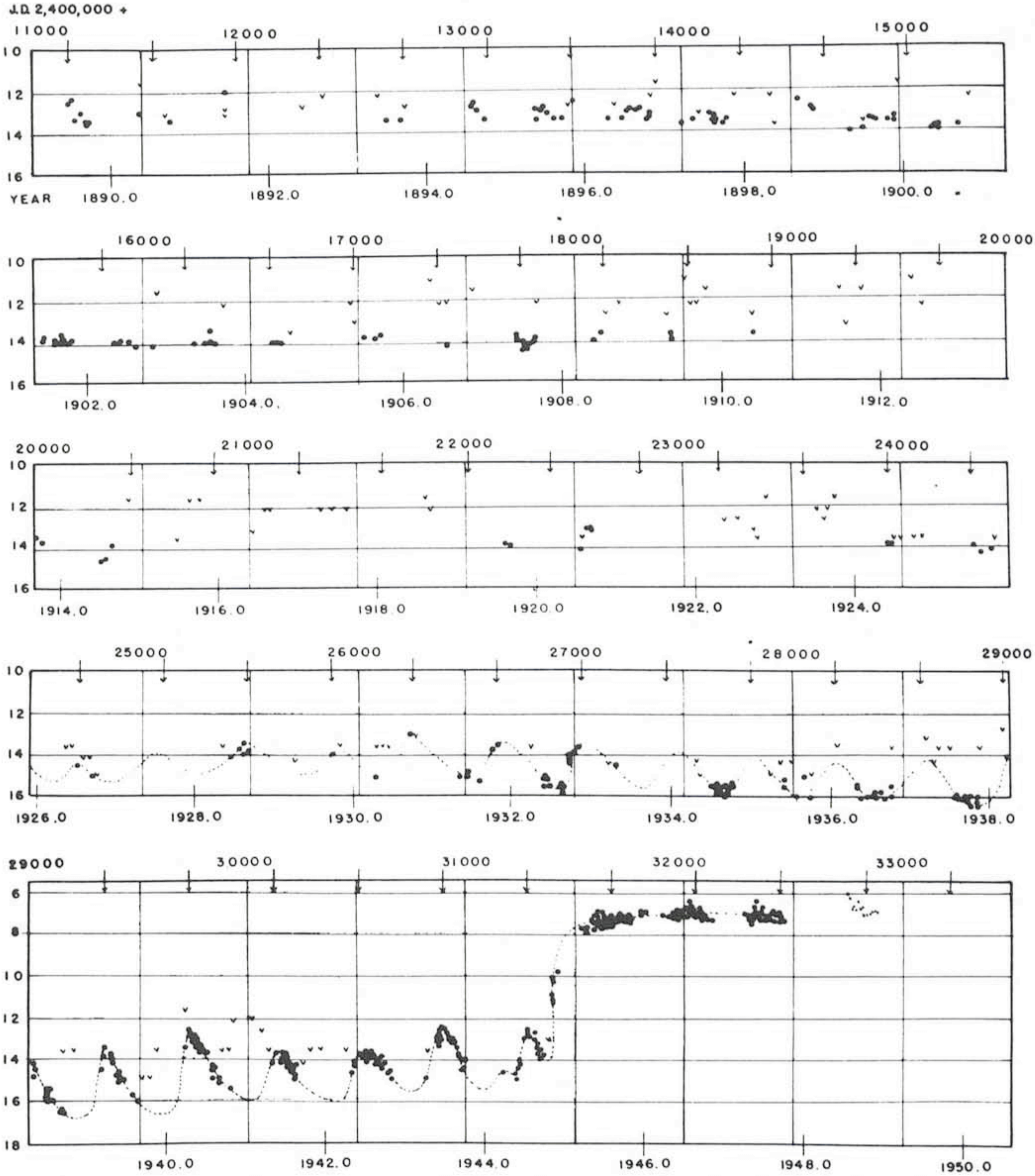

Fig. 1: *The variations of RR Tel from 1889 through 1947, reproduced from the work of M. W. Mayall (1949,* Harvard Bull. **919,** *15).*

The outburst brought the star close to magnitude 6 where it remained from 1944 to 1949. RR Tel started to fade in June 1949.

Infrared Connection

The star had obviously become an interesting object. In the fifties started a phase of intense spectroscopic investigations in the visible, in the infrared and recently even in the ultraviolet range with the IUE satellite.

In the UV (refer to the paper by Heck et al. in the December 1978 issue of this journal – No. 15, p. 27 – or to the detailed description by Penston et al. to appear soon in the *MNRAS*), the spectra display thousands of emission lines, making RR Tel an extremely interesting object for atomic physics.

Obviously, we will not review here in detail the studies carried out during 30 years in the other spectral ranges. An excellent synthesis of the successive evolutionary stages of RR Tel has been published by A.P. Thackeray in 1977 (*Mem. Roy. Astron. Soc.* **83,** 1). The visible spectrum was characterized by nebular lines of different ionization stages of intensity increasing with time.

The first suggestion that RR Tel was a symbiotic object came from K.G. Henize and D.B. McLaughlin in 1951 (*Astrophys. J.* **114,** 163) who believed the star was composed of a long-period variable (presumably of class M) and of a typical RT Ser slow nova, although they retained the single-variable hypothesis as possible because of the increase of the amplitude before the outburst.

Later, M.W. Feast and I.S. Glass (*MNRAS,* **167,** 1974, 81) concurred in the presence of cool M5III star (reinforced by the discovery of TiO bands in the spectrum by B.L. Webster) and of an infrared dust shell to explain the energy distribution of RR Tel. They also attributed the pre-outburst periodic variations to a semiregular pulsation of the cool component.

In 1977, M.W. Feast and his collaborators reported large JHKL photometric variations of the stellar component (*MNRAS* **179,** 499) which could be attributed only to a Mira-type variable in their opinion. The presence of a Mira near minimum light was then confirmed by D.A. Allen et al. (*MNRAS* **182,** 1978, 57P) from a detection of intense steam (H_2O) and weak CO absorption bands which are characteristic of many Mira variables. They also deduced, from period-spectral type relations for Miras that the present cool component does not differ radically from the pre-outburst variable.

Quite recently (paper in press in the *MNRAS*), M.W. Feast and his collaborators derived a periodicity of 387 days in the JHKL photometric data collected during the epoch 1975–1981 (see Fig. 2), that is a period very close to that obtained by S. Gaposchkin from photographic pre-outburst records. They also found the present J index compatible with a Mira photographic magnitude of 13–14 in the pre-outburst phase, which would mean that the Mira has been present at all times with a constant period and a constant mean luminosity, the variation going from $\sim 13^m$ to $\sim 17^m$ or fainter. There would be another component of radiation whose intensity varies on a different scale and which would be presumably responsible for the outburst.

Post-outburst Variability in the Visible Range

To the best of our knowledge, and curiously enough, no extensive study has been made on the variability in the visible range, for the post-outburst phase. On the contrary, brief mentions in the literature point towards no evidence of variability in that range or at least towards no evidence since the outburst of this 387-day period found in the infrared.

During the simultaneous spectrophotometric joint ground and space observations carried out in June 1978 (see the papers by Heck et al. and Penston et al. mentioned earlier), variations of the order of $0\overset{m}{.}034$ r.m.s. have been suspected from night to night and within a night from uvby data collected at the 50 cm ESO telescope and from the Geneva $UVB_1B_2V_1G$ data collected at the Swiss 40 cm telescope on La Silla. The fluctuations were larger than what would be expected from the intercomparison of the reference stars and from the fit to the standards. The paucity of points prevented any detailed study of these variations.

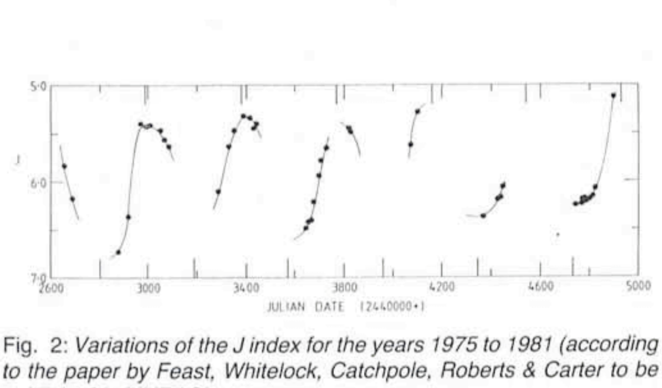

Fig. 2: *Variations of the J index for the years 1975 to 1981 (according to the paper by Feast, Whitelock, Catchpole, Roberts & Carter to be published in* MNRAS*).*

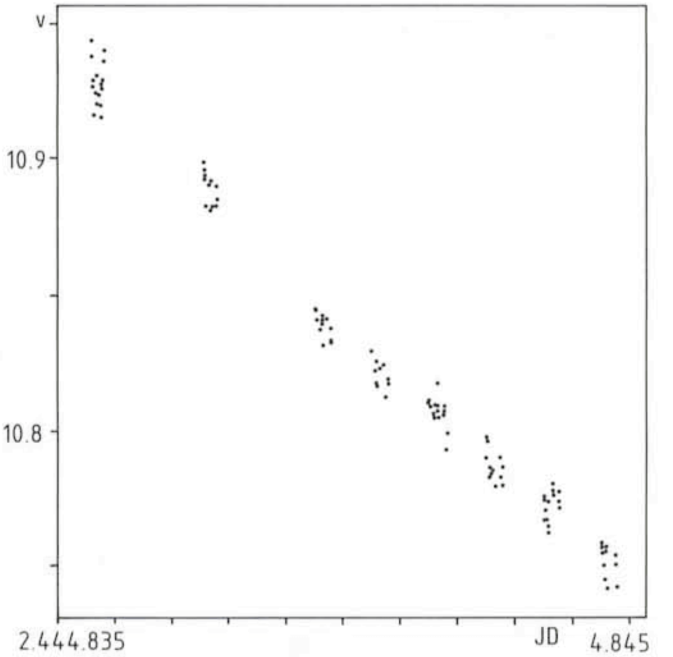

Fig. 3: *Variations of the V magnitude from observations in the uvby system at the 1 m ESO telescope in August 1981.*

The Star was re-observed in bad conditions (low on the west horizon at sunset) in December 1978 with the 50 cm ESO telescope. Very careful reductions of the data did not show significant variations.

It was then interesting to attempt to clear up these conflicting results and to establish the form of the possible variations with a more powerful instrument. A first tentative took place in August/September 1980, but could not be carried out properly because of what an observer has to face sometimes: bad weather and instrumental failures. The few data collected seemed however to indicate a slight faintening of the V magnitude.

Another attempt, quite successful this time, was carried out in August 1981 with the 1 m ESO telescope equipped with a standard one-channel photometer working in the uvby system. The results are summarized in Fig. 3, displaying a clear brightening of RR Tel during the period of observations.

These results have to be directly compared with Fig. 2. In August 1981, the brightening in V corresponds clearly to the brightening in J, but the tendencies would be opposite in September 1980 if the trend detected in V is real. In 1978, the V magnitude had no clear behaviour, while the J one was varying steeply at the time of the visible observations. In conclusion, there is apparently no evident correlation between the V and J variations, except in 1981.

Also RR Tel has been repeatedly observed by the IUE satellite, and Fig. 4 reproduces the B magnitudes deduced from the counts recorded at the time of the observations by the IUE Fine Error Sensor (FES). A Fourier analysis performed on these data gave a period equal to 395 (± 5) days. If a Fourier analysis is applied to the J values listed by M.W. Feast and his collaborators for the epoch 1972–1981, a period of 390 days is found, which is very close to the previous one. Also the location

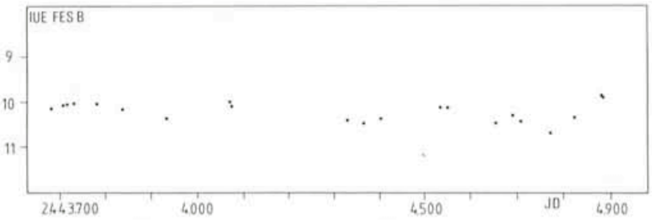

Fig. 4: *IUE FES B magnitudes from 1978 to 1981.*

of the maxima in time on the J and IUE FES B lightcurves agree very well.

Another interesting curve can be obtained from the records of the American Association of Variable Stars Observers. Fig. 5 displays the available visual estimates averaged by groups of 50 days for the years 1949 to 1963. Further monthly averages were also available to us for the epoch 1972–1977. Apart from a general decline after the outburst, a periodicity is also clearly visible.

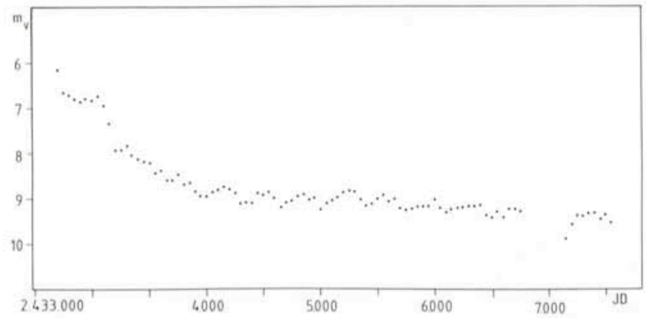

Fig. 5: *50-day averages from the AAVSO visual estimates for the years 1949–1963.*

Although visual estimates are less precise than photoelectric measurements, Fourier analyses of these data can provide quite reliable determinations of the period because of the large number of cycles covered by the time basis available. For the whole 1949–1963 range, a mean period of 355 days has been derived, but a more detailed analysis shows that this period decreased from about 377 days just after the outburst to about 345 days at JD 2,437,000 (1960). It is really a pity that no infrared data were available at that time to check whether this shorter period was also appearing in that range. From the visual averages between 1972 and 1977, it was impossible to determine clearly a period.

Conclusions and Comments

When they are overlapping, the observations of RR Tel in J and IUE FES B magnitudes are coherent, leading to a period of the order of 390 days, that is very close to the value of 387 days proposed by S. Gaposchkin in 1945 from forty pre-outburst observations. The V values for 1981 are also in agreement and those for 1978 and 1980 are too uncertain to be declared in definite disagreement. There are also strong suspicions on the occasional presence of short-time scale variations in V.

Moreover, it is certain that the period in the visible range did not remain constant from the pre-outburst phase until nowadays. It has been shorter immediately after the outburst and has been decreasing at least until 1960. No data are unfortunately available in the infrared range during this period. So the hypothesis by Feast et al. that a Mira has been present at all times with a constant period cannot be checked then. Nevertheless, the spectral evidence of H_2O and TiO bands supports the Mira presence, as well as the very pre-outburst behaviour.

The visible variations from the outburst until nowadays, however, cannot be accounted for directly by the Mira if this component remained constantly between 13^m and 17^m. It is easy to show that such variations would be completely masked by another component of radiation as soon as this would be brighter than about 11^m.

The variations of this blue component contributing to the visible light might have been related to the rate of mass loss. The interesting point is that it seems now to have returned to the Mira periodicity after a long time of different behaviour. This could indicate the end of a crisis.

A.R. Walker (1977, *MNRAS* **179,** 587) proposed that the outburst had been triggered by an increased mass accretion from the implied Mira because of the necessary rate of mass loss. A more sophisticated model has recently been proposed by G.T. Bath (*MNRAS* **182,** 1982, 35): RR Tel would be a case in which modulated bursts of mass transfer and associated accretion events were occurring within the underlying binary star prior to the major eruption in 1944. The outburst itself would have been caused by a sudden onset at a super-critical rate. In that picture, RR Tel could be the missing link between dwarf novae, classical novae and symbiotic stars.

The Diffuse Interstellar Medium and the CES

R. Ferlet, LPSP, Verrière-le-Buisson

Introduction

Representing a few per cent of the mass of our Galaxy, but 30–40 % in the case of the Small Magellanic Cloud, it is well recognized that diffuse matter in space plays a decisive role in the evolution of galaxies. Primordial gas—together with material ejected in stellar winds, novae, supernovae, planetary nebulae and other types of evolved stars, and enriched in heavy elements through nucleosynthesis—has accumulated to form a complex and violent medium with an amazing variety of physical conditions, containing regions with densities ranging from 10^{-4} to 10^6 particles cm^{-3} and with temperatures from 10 to 10^6K. From time to time, part of this interstellar medium collapses to form further generations of stars. This simple picture of evolution is altered by possible accretion of intergalactic gas and by matter circulation between different parts of a given galaxy, including a gaseous halo; activity in the galactic nucleus may also play a role.

With the exception of the H II regions surrounding the massive, young stars, the planetary nebulae and the centers of dense molecular clouds, the interstellar atoms, ions and molecules are in their ground states (because densities and the

UV interstellar radiation field are low) and they are best observed through the resonance absorption lines they form in the spectra of target stars. These lines are extremely numerous and sensitive to low column densities, but most of them occur in the far UV range, especially below 1200 Å; their analysis provides unique clues for understanding the galactic history outlined above: kinematics, ionization and elemental abundances in the diffuse interstellar medium.

In 1904, Hartmann first noticed two steady absorption lines, due to Ca II, in the spectrum of the binary star δ Ori which were recognized as interstellar by Slipher in 1909. Until 1951 with the discovery of hydrogen through its 21 cm line, only Ca II, Na I and very few other ions and molecules (CN, CH, CH^+) were observable in the visible. Nevertheless, they allowed, with the increasing resolution of the spectrographs, the detection of multiple components toward many lines of sight; thus, the random radial velocities of the absorbing regions with respect to each other have been shown to be around 6 km s^{-1}. However, the revolution in our understanding of the interstellar medium came from the space era and in particular from the UV astronomy.

Astronomers seem now to agree—without anything better, this is a criterium!—on the broad lines of the Mc Kee and Ostriker's model (1977, *Ap.J.*, **218,** 148). Briefly speaking, let us say that most of the interstellar volume is filled with a one million degree, diluted ($\sim 10^{-3}$ atoms cm^{-3}) gas which was evidenced by the oxyen VI absorption lines near 1035 Å and recently by the OV II X-ray emission lines. This gas is produced in overlapping cavities by supernovae explosions and strong stellar winds. The residual space is essentially made of relatively cold (10 to 10^4K) denser (10 to 10^3 at. cm^{-3}) gas forming irregular clouds of the order of a few parsecs. These diffuse clouds (a few per cent of the total volume but a significant fraction of the total mass) are continually modified by their mutual collisions; they are swept up by shock waves and evaporating by thermal conduction.

A Difficult Problem

Apart its structure, the other fundamental advance in our knowledge of the interstellar medium refers to its chemical composition. To go from absorption line observations to the abundance of the corresponding elements is often a very complicated way which involves three steps: first to determine the column density for each observed line; then add the contribution from the different ionization states for a given element, and if one of them is not observed, try to calculate its contribution; finally, to normalize the total abundance to hydrogen which has to be observed in some way.

Introduced in 1948 by Strömgren, the usual method for partly resolving the first problem is to build a curve of growth (COG), which is the logarithmic relation between the measured equivalent width of absorption lines (normalized to the wavelength λ) and the product Nfλ where f is the oscillator strength and N the column density (cm^{-2}) of the corresponding ion on the observed line of sight. While this method can give rather accurate *integrated* column densities (within a few tens %) when the line is weak (linear part of the COG) or when it is completely saturated (damping part of the COG), the results are often up to several orders of magnitude in error either if the line shows saturation effects (flat part of the COG) when N depends strongly on the velocity dispersion b within the absorbing region, or/and if the line of sight intercepts several interstellar clouds. Unfortunately, these two cases represent the large majority of observations.

In order to overcome these difficulties, we have pointed out, in collaboration with C. Laurent and A. Vidal-Madjar of the LPSP and D. York of Princeton University, a new method for analysing interstellar absorption lines. Contrary to the equivalent width which is an absorption measurement integrated over the whole line of sight and independent of the instrumental resolution, our method makes use of the information contained in the line profiles. It is based on fitting observed lines with theoretical Voigt profiles calculated by varying the parameters of the different clouds on the line of sight (number of clouds, their radial velocities, b-values and column densities) and convolved with the instrumental function (see Ferlet et al., 1980, *Ap.J.*, **235,** 478, for the first application to a wide range in f-values of atomic nitrogen lines observed with the Copernicus satellite towards γ Cas). Thus, for the first time, it is possible not only to determine the velocity structure of a line of sight observed with a spectral resolution insufficient to fully resolve the true line profile, but also to evaluate more accurate parameters for *each* detected cloud.

The second step on the way to true abundances is to add the contributions from different ions of a given element. It is sometimes easy: elements like N, O, Ar should exist in diffuse clouds only in atomic form; this has been demonstrated for nitrogen (Ferlet, 1981, *AA*, **98,** L1). However, in some cases one cannot observe the dominant ionization state: for instance, only Na I, K I, Li I are observable and one must compute through ionization equilibrium the contribution of the second ion from observations of another similar element such as Ca I/Ca II, Mg I/Mg II. But this increases a lot the uncertainties.

The last step is to normalize abundances to hydrogen which in general is present in atomic and molecular forms. As H I and H_2 give some heavily saturated lines with damping wings, their integrated column densities can be well known, but it is almost impossible to distinguish the different clouds unless by using the profile fitting method described above. By performing such an analysis toward γ Cas, we have for instance pointed out a striking variation of the argon abundance from cloud to cloud (Ferlet et al., 1980, *Ap.J.*, **242,** 576).

Abundance Variations

Generally speaking, from extensive studies of cold clouds within 1–2 kpc of the Sun, it appears that heavy elements are selectively depleted when compared to solar values, sometimes by a factor of more than 1,000, this depletion being more pronounced for refractory elements like calcium, iron, aluminium, titanium. . . . The question is then where are the missing atoms? The more probable, and the simplest, explana-

Preliminary Announcement

The 1st ESO-CERN Symposium will be held in the week of November 21st, 1983 at CERN (Geneva) on the subject:

Large Scale Structure of the Universe, Cosmology and Fundamental Physics

The Scientific Organizing Committee is composed of G. Setti (ESO) and L. Van Hove (CERN), co-chairmen, J. Audouze, J. Ehlers, E. Fiorini, H. van der Laan, D. Nanopoulos, M.J. Rees, D.N. Schramm, D.W. Sciama and G. Tammann.

The attendance to the Symposium will be limited to approximately 150 participants.

tion is that these atoms are contained in a solid phase of more or less small grains well mixed in the gas. In fact, this dust has been known since the thirties by its effects on the background stellar light, namely absorption, reddening and polarization. Studies of these phenomena provide an estimation of the dust mass—nearly 1 % of the mass of the interstellar medium, which is roughly equal to the mass of the missing species measured in the gas phase, within the COG uncertainties. This is quite satisfactory for mind! More specifically, dust grains should consist of oxydes and/or silicates, others of graphite, with almost no nitrogen compounds, this important and abundant volatile element being nearly undepleted (Ferlet, 1981, *AA*, **98,** L1).

Also, it is worthwhile to notice that depletion can vary considerably from one line of sight to another. In few cases, UV instruments could resolve high velocity clouds and find almost no depletion, a fact already known as the Routly-Spitzer effect in the visible: a very much lower ratio of Na I/Ca II column densities in high velocity clouds. This suggests a mechanism to destroy grains (for returning Ca to the gas) related to the cloud velocity, perhaps the passage of a shock wave.

Further advances in this area will come from precise knowledge of *individual* properties of the interstellar clouds in order to study what are the formation and destruction processes of dust grains, to understand the interstellar chemistry, to establish possible abundance fluctuations which will give accurate insights on the history of local nucleosynthesis. In that respect, the variable abundance of the rare gas argon that we outlined toward γ Cas could be very promising.

The abundance variations of the interstellar deuterium are another unexpected discovery due to the Copernicus observations. Unlike all elements heavier than 12, deuterium has a non-stellar origin and is supposed to be ashes of the very early phases of the Universe. Its production is strongly dependent on the baryonic number, and the evaluation of a primordial D/H ratio provides one of the very few crucial tests on the geometry of the Universe, in the frame of the Big Bang. As deuterium is very easily destroyed in stellar interiors, one expects that its interstellar abundance is about constant, at least on a small scale. On the contrary, profile fitting analysis (see e.g. Laurent, Vidal-Madjar and York, 1979, *Ap.J.*, **229,** 923) have evidenced real variations of at least a factor of two and even more in the very nearby interstellar medium. Also, York and Jura (1982, *Ap.J.*, **254,** 88) pointed out a possible correlation between D/H and Zn/H, — zinc being observed only slightly depleted (within the COG uncertainties) and thus taken as an approximate measure of the gas metallicity — as might occur if deuterium is manufactured in stars rather than only in the Big Bang. Obviously, all these results open the question of the cosmological interpretation of the observed deuterium abundance. Various models have been put forward to explain them (Bruston et al., 1981, *Ap.J.*, **243,** 161), including deuterium depletion onto grains, but none is especially convincing.

The Galactic Halo

Although the far-UV Copernicus data were at the origin of the bulk of our knowledge on the interstellar medium, they were restricted to space within 1 kpc of the Sun. Also, 1 kpc is characteristic of the extent of the epicyclic orbits around the Galaxy, and we might expect important abundance gradients beyond this distance. With the IUE satellite, some observations of other interstellar media have been made possible but only in the strongest lines above 1200 Å and at the cost of a lower spectral resolution. Therefore, all the related problems we mentioned in the data analysis are still more severe. Nevertheless, here are some exciting results concerning the Galactic halo.

Pettini and West (1982, *Ap.J.*, **260,** 561) have demonstrated the ubiquity of C IV and Si IV in the near halo (below ~3 kpc from the galactic plane), while C IV is generally not observed in the Galactic disk (Laurent, Paul and Pettini, 1982, *Ap.J.*, **260,** 163). Suggesting a temperature of 8×10^4 K if in collisional equilibrium, this halo component corotating with the disk appears qualitatively similar to the hot Galactic corona originally postulated by Spitzer in 1956 to explain the high velocity clouds observed in H I 21 cm; it could be very much relevant to the origin of the narrow QSO absorption lines.

Observations of sight-lines penetrating the entire halo (unfortunately, they are still very few within the present instrumental capability, except OB stars in the Magellanic Clouds), are clearly consistent with a corotating halo. There is also growing evidence that the Magellanic Cloud sight-lines may not be typical of halo gas: in these directions, the occurrence of high velocity interstellar components seems much more frequent. Last, a portion of the famous Magellanic Stream has been detected in the visible by York and Songaila (1980, *Ap.J.*, **242,** 976) in absorption in the spectrum of the Seyfert 1 galaxy ESO 113–IG 45 (Fairall 9), and further IUE studies show that abundances are broadly consistent with those in the Magellanic Clouds, ruling out a primordial composition.

Use of the Coudé Echelle Spectrograph (CES)

Although the UV range provides a great wealth of interstellar absorption lines, its use has suffered up to now from the lack of spectral resolution and of efficiency of space instruments. The High Resolution Spectrograph onboard the Space Telescope will open a new step but will be limited to wavelengths above 1150 Å and also by the expected little time devoted to this particular field. On the contrary, the European project Magellan, if selected by ESA, will give access to the wavelength range 300–1500 Å with a resolution of 0.03 Å down to magnitudes as faint as 16 for an unreddened O9 star at 1000 Å. In any case, both projects must be prepared by ground-based observations. The great advantage now given by ground-based instrumentation is the possibility of obtaining very high resolution, and we have largely demonstrated before how great this need is in particular to interpret the currently available UV data. Even the profile fitting method is more efficient if one can get a priori an idea of the velocity structure of a given line of sight. Unfortunately, only very few ions and molecules show interstellar absorption lines in the visible.

Optimized to give a resolving power of 10^5 or 3 km s^{-1} in its multichannel mode, and more in its scanner mode (one can note for instance that a resolution below 1 km s^{-1} is required to be able to observe the hyperfine structure of Na I), the Coudé Echelle Spectrograph (CES) offers another important characteristic for absorption spectroscopy, namely a very clean instrumental function. Indeed, the stray-light level in the classical coudé ruled gratings degrades spectra, giving rise to more than 20 % error in measured equivalent widths. The third advantage of the multichannel mode is provided by the actual detector, a Reticon silicon photodiode array cooled to 136 K, which has a responsive quantum efficiency near 70 % at 6000 Å. This, together with a possible immediate reduction of the data, makes it a very fast and friendly system for the detection of very weak features in strong continuum signals (Enard, 1981, *The Messenger*, No. 26, 22).

For one year now, we have used the CES + Reticon, fed by the 1.4 m Coudé Auxiliary Telescope. In the following, we illustrate some specific interstellar questions. One of the best suited laboratory for studying the violent interstellar medium is the Carina Nebula region. Several high-velocity clouds are seen, some also in the UV, and abundance determinations show that one of them has been contaminated by freshly

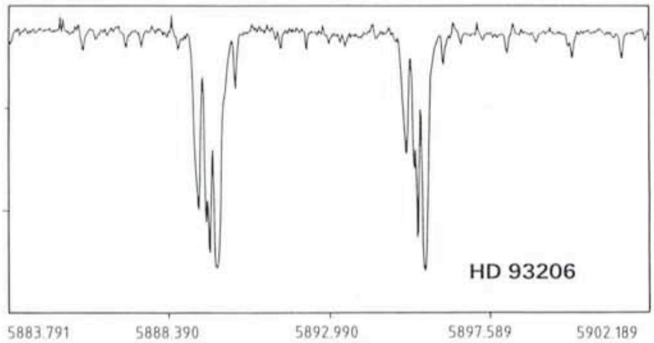

Fig. 1: *The interstellar Na I D lines toward HD 93206 in the Carina region, taken with the CES + Reticon at 10^5 resolving power in one hour. The wavelength calibration is based as usual on neon and thorium lines and/or on a standard star. Clearly 5 components are detected; all very weak lines spread over the spectrum are due to atmospheric water absorptions.*

processed material ejected by a recent supernova explosion (Laurent, Paul and Pettini, 1982, *Ap.J.,* **260,** 163). As an example of the information that CES data bring about the velocity structure, Fig. 1 shows the Na I D-lines toward HD 93206: five components are clearly detected.

Deuterium abundance variations have been recognized in the local interstellar medium, along with fluctuations in the H I densities. In order to explain these, Vidal-Madjar, Audouze, Bruston and Laurent have first postulated in 1977 (*La Recherche,* No. 80, p. 616) the presence of a very nearby interstellar cloud, coming roughly from the Sco-Oph direction toward the solar system with a velocity around 22 km s^{-1}. Further UV and X-ray data are currently interpreted as the evidence of the location of the Sun at the edge of such a cloud, and we have undertaken IUE observations since, thus, a unique opportunity is offered to study an interstellar cloud from inside. However, it is obvious that high resolution, high signal-to-noise ratio data are absolutely essential. Such a programme is also under way through observations in selected directions of several co-aligned stars at various distances. It is in course of interpretation; but within a few parsecs, no OB stars are available and only white dwarfs can be used to probe the very local medium. This requires a lot of time.

Still about deuterium, but now in more remote places, a recent profile fitting analysis of Copernicus data toward ε Persei (Vidal-Madjar, Ferlet, Laurent and York, 1982, *Ap.J.,* **260,** 128) revealed a surprising behaviour of the deuterium absorption features which led us to reanalyse all the published values of interstellar deuterium abundances. A strikingly clear trend has been discovered between these values and the luminosity class of the target stars, suggesting that for main sequence stars, D/H seems to be overestimated (due to some stellar wind H I material producing blended features with the D lines). Thus a probable D/H ratio of the order of 5×10^{-6} is derived, implying a more open Universe than previously thought (except if neutrinos are massive enough to close the Universe). On the other hand, it has been shown that stars more massive than 6–7 $M_\odot$ should retain their initial deuterium, although surface deuterium depletion may occur during and after the main-sequence stage. Therefore, search for deuterium in stellar atmospheres could provide valuable information on the initial D/H ratio as modified by stellar evolution. Fig. 2 shows the enlarged Dα region in the CES spectrum of the supergiant massive star Canopus (Ferlet, Dennefeld, Laurent and Vidal-Madjar, 1982, AA, submitted). No deuterium feature is seen at a detection level of 0.07 mÅ. Our derived D/H upper limit of 5.5×10^{-7} could mean that the initial D/H has been depleted by a factor of at least 9 through mass loss and/or mixing. The next step which will be performed soon is to look for deuterium in massive main-sequence stars. In the future (the Magellan project), a much expected observation for cosmology will be to determine the deuterium abundance in less evolved galaxies like the Magellanic Clouds.

Preliminary tests have shown that the brightest Magellanic Cloud OB stars are already within the capabilities of the CES, although close to the practical limit. The use of extragalactic sources as probes of the Galactic interstellar medium presents three clear advantages. Firstly, there is in general a sufficient velocity separation between the sources and the local gas to avoid confusion. Secondly, they provide unconfined lines of sight over long pathlengths through the Galaxy and the halo. Thirdly, all kinds of effects related to the target object—as the one discovered in deuterium observations toward ε Per and described above—are eliminated for the local gas. Furthermore, in the case of Magellanic Cloud stars, one can also probe the interstellar medium of less evolved galaxies, closer to primordial matter, and attack directly the problem of the deepness of the Small Cloud. Such a programme is going to be undertaken in collaboration with M. Dennefeld, E. Maurice and a group of Marseille's Observatory, partly as a complement of IUE results already obtained by L. Prévot et al. As a feasibility test, Fig. 3 shows the Na I spectrum toward the high latitude B1 star HD 119608. At least 4 components are well resolved, one having a velocity > 50 km s^{-1}, which would be completely blended in present UV data. Another preliminary observation of R 136 in 30 Doradus is also very promising: for instance, some high velocity components are revealed at intermediate velocities between local gas (near 0 km s^{-1}) and Large Cloud gas (around +280 km s^{-1}). For this kind of observations, the improvement

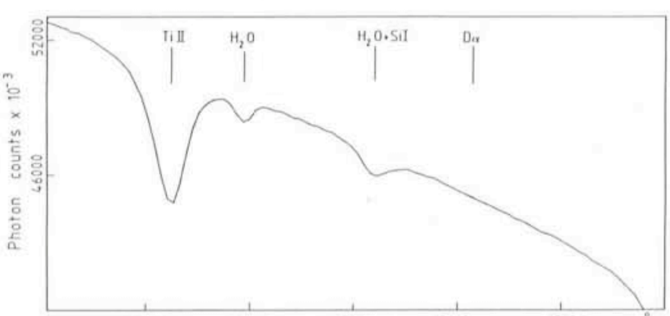

Fig. 2: *Enlarged portion of the Hα blue wing in the CES spectrum of Canopus, with some relevant stellar and atmospheric water lines marked. 29 exposures have been added and the actual signal-to-noise ratio is around 3700.*

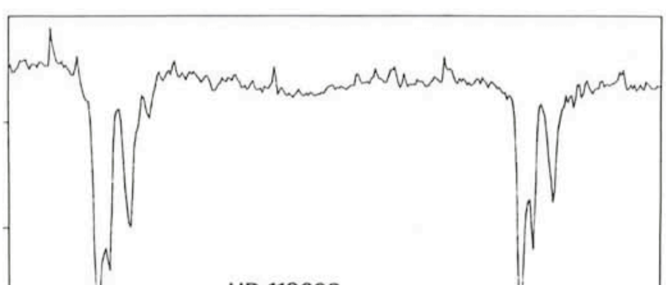

Fig. 3: *The Na I spectrum toward the high latitude B1 star (z~3 kpc) HD 119608, recorded in two hours at a resolving power of 10^5.*

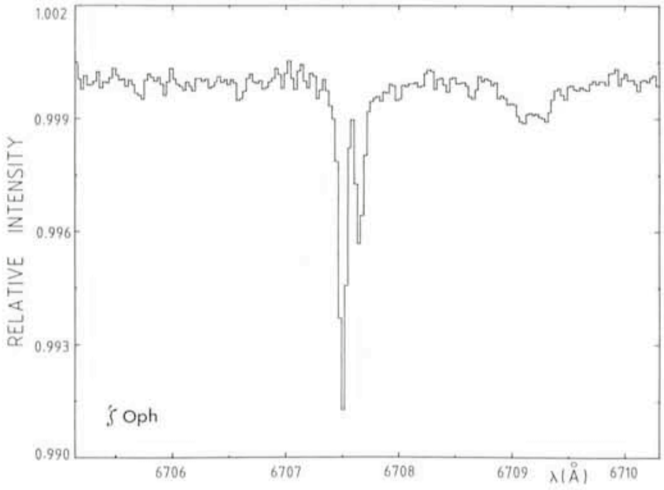

Fig. 4: *The interstellar lithium absorption line toward ζ Ophiucci, E(B-V) = 0.32. This spectrum is the sum of 34 exposures representing a total of 17 hours integration time. The signal-to-noise ratio (RMS) is ~3950. The intensities have been normalized to the continuum.*

expected soon will be to feed the CES directly from the 3.6 m prime focus through fiber optics and/or to implement a CCD detector instead of the Reticon.

Among other interstellar investigations, the last (but not least) we will speak about concerns the lithium abundance. As deuterium, the two isotopes of lithium are not of stellar origin. The existence of ^{6}Li is rather well explained by spallation reactions between galactic cosmic rays and interstellar gas. For the larger abundance of ^{7}Li, additional sources must be found. The main one is production during the primeval Big Bang, but complementary sites of creation have been proposed like red giants and nova outbursts. The interstellar lithium abundance and ^{7}Li/^{6}Li ratio are therefore key parameters to evaluate the relative weight of production and destruction processes, to check models of nucleosynthesis and of chemical evolution of galaxies, finally to provide a further test (beside deuterium and helium abundances) on the geometry of the Universe. The only accessible resonance line of lithium is the doublet of Li I at 6708 Å (151 mÅ of separation, the ^{6}Li I doublet being redshifted by 160 mÅ). The best result was obtained in collaboration with M. Dennefeld toward the 09.5 star ζ Oph which is known to shine behind a well studied interstellar cloud (Fig. 4). In order to derive the ^{7}Li/^{6}Li ratio for the first time outside the solar system, we have conducted a profile fitting analysis. In the best determined cloud, we find a temperature of less than 50 K. In this particular component, the solar ^{7}Li/^{6}Li (12.5) does not fit the data and must be replaced by a value between 25 and 180 (most probably 38). After correcting for the unobserved dominant ionization state Li II, the interstellar ^{7}Li/H ratio is found to be 1.2×10^{-10} (Ferlet and Dennefeld, 1982, *Ap.J.* submitted).

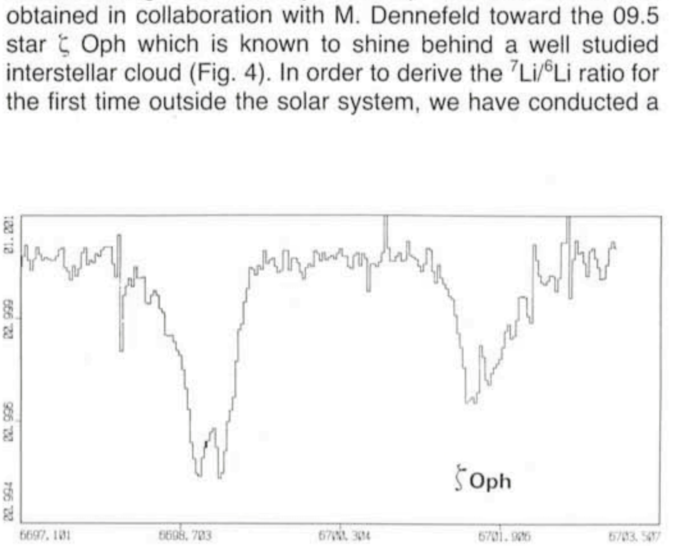

Fig. 5: *Possible new interstellar absorption lines due to the molecule CS^+ toward ζ Oph. Same spectrum as in Fig. 4. The equivalent widths of the two features are of the order of 3 and 2 mÅ.*

Finally, in the vicinity of the lithium lines, we have detected in several lines of sight faint absorption lines which could be due to the molecular ion CS^+ (Fig. 5). If the identification is confirmed—this requires accurate theoretical computations of laboratory wavelengths—the interstellar chemistry will have to thank the CES + Reticon for discovering an important new molecule.

Acknowledgement

It is a real pleasure to remind the most valuable help received from the ESO staff on La Silla. Special thanks are due to José Veliz and Robbie Spruit.

List of Preprints Published at ESO Scientific Group

September–November 1982

207. M.P. Véron-Cetty, P. Véron and M. Tarenghi: The Composite UV Emission Spectrum of Seyfert 1 Galaxies. *Astronomy and Astrophysics.* September 1982.
208. B. Reipurth: Star Formation in Bok Globules and Low-Mass Clouds. I. The Cometary Globules in the Gum Nebula. *Astronomy and Astrophysics.* September 1982.
209. S. D'Odorico and P. Benvenuti: Properties of a Luminous, Wolf-Rayet Type Object in the Core of the Extragalactic H II Region IC 132. *Monthly Notices of the Royal Astronomical Society.* September 1982.
210. P.A. Shaver, R.X. McGee, L.M. Newton, A.C. Danks and S.R. Pottasch: The Galactic Abundance Gradient. *Monthly Notices of the Royal Astronomical Society.* October 1982.
211. G.A. Tammann and A. Sandage: The Value of H_o. *Highlights of Astronomy,* vol. 6. October 1982.
212. I.J. Danziger, J. Bergeron, R.A.E. Fosbury, L. Maraschi, E.G. Tanzi and A. Treves: The UV Spectrum of the BL Lac Object PKS 0521-36. *Monthly Notices of the Royal Astronomical Society.* October 1982.
213. M. Rosa: Giant H II Complexes Outside our Galaxy at Optical Wavelengths. *Highlights of Astronomy.* October 1982.
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The Peculiar Ellipsoidal Variable TU Horologii

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The peculiar nature of the lightcurve of the sixth magnitude variable A-type star TU Hor (HR 1081 = HD 21981) was first discovered at ESO by H.W. Duerbeck from Bonn Observatory. In subsequent spectroscopic work in collaboration with A. and J. Surdej, Dr. Duerbeck demonstrated conclusively that TU Hor is a close binary star with an orbital period of about 0.936 days.

We have been observing TU Hor since 1978, with the Geneva Photometer attached to the Swiss telescope at La Silla. Our 1980 visual magnitude lightcurve is shown in Fig. 1a and is similar to that obtained by Duerbeck. Two characteristics are quite unusual for a close binary system: the two maxima are strongly unequal, since they differ by as much as 0.05 magnitude; in addition, the deepest minimum occurs less than half an orbital period after the other minimum, while one would expect a zero eccentricity for an early A-type binary system with so short a period. Both features are constant over a three-year interval: the lightcurve repeats itself very accurately and no additional cycle-to-cycle variations are observed.

We did also observe small but significant colour variations. Fig. 1b shows the variations of the colour index B_2-V_1 and a sinusoidal fit to these data. The amplitude is 0.006 magnitude (0.012 magnitude peak-to-peak). Since this colour index is a temperature indicator, the variations can be interpreted as variations of the effective temperature. A simple application of the calibrations of the Geneva Photometric System shows that an amplitude of 0.006 magnitude of the B_2–V_1 index for a single star with the same colours as TU Hor would correspond to an amplitude of about 75 K (about 0.8 per cent) for the variations of the effective temperature, which in turn would lead to light variations with an amplitude of about 0.035 magnitude. For a double star like TU Hor, the situation is somewhat more complicated: the temperature variations corresponding to the same observed colour variations are larger, but the resulting light variations can be expected to be of the same order.

In fact, when a sinusoidal curve with an amplitude of 0.030 magnitude and the phase determined by the colour variations is subtracted from the lightcurve, one obtains the resulting lightcurve shown in Fig. 1c. As a matter of fact, this resulting lightcurve has two equal maxima, and the phase difference between the two minima is exactly 0.50, i.e. it is a normal close binary lightcurve!

The observed variations of TU Hor can thus be interpreted as those of a close binary system, for which one of the components, in synchronous rotation, shows a peculiar temperature distribution on its surface. It is important to note that the orbital variations and the temperature variations are not in phase: maximum temperature is observed about 0.1 period before maximum light. This fact is responsible fot the peculiar phases of the minima in the observed lightcurve.

The phase difference between temperature variations and orbital variations seems to rule out a possible explanation: the temperature variations are probably not due to an anomalous reflection effect in this close system. It is also unlikely that the variations are due to a hot accretion spot, since the regularity with which the lightcurve reproduces itself during each cycle rules out the presence of much circumstellar material. I favour a third explanation and will develop it below.

Some similar cases are known in the literature: b Per, V 525 Sgr, RT Scl and AG Vir. It is a remarkable fact that all these systems are of spectral type A. It is tempting to search for a link between these binary systems and the peculiar A-type stars. The Ap stars are characterized by enhanced spectral lines of some elements compared to the spectral lines of normal stars of the same temperature and luminosity. It is generally admitted that the overabundances (and underabundances) are only superficial features and do not correspond to real anomalies of the star as a whole. The most successful theory that accounts for these anomalies is the diffusion hypothesis. In suitably quiet envelopes (Ap stars are indeed slow rotators) the relative importance of radiation pressure and of gravity will cause some elements to rise, while others will descent towards the interior. For many Ap stars, important global magnetic fields are observed. The influence of these fields on the peculiarities is thought to be twofold: first, a magnetic field tends to stabilize the atmosphere and so favours diffusion; second, by a process called magnetic braking, the interaction of the magnetic field with the interstellar medium removes angular momentum from the star, thus slowing down the rotational velocity, and again favouring diffusion.

In the Geneva System, a colour index Z has been defined (Cramer and Maeder, *Astron. Astrophys.* **88,** 135–140) which allows to separate the magnetic Ap stars from the normal stars. For normal stars, this index is essentially zero; for

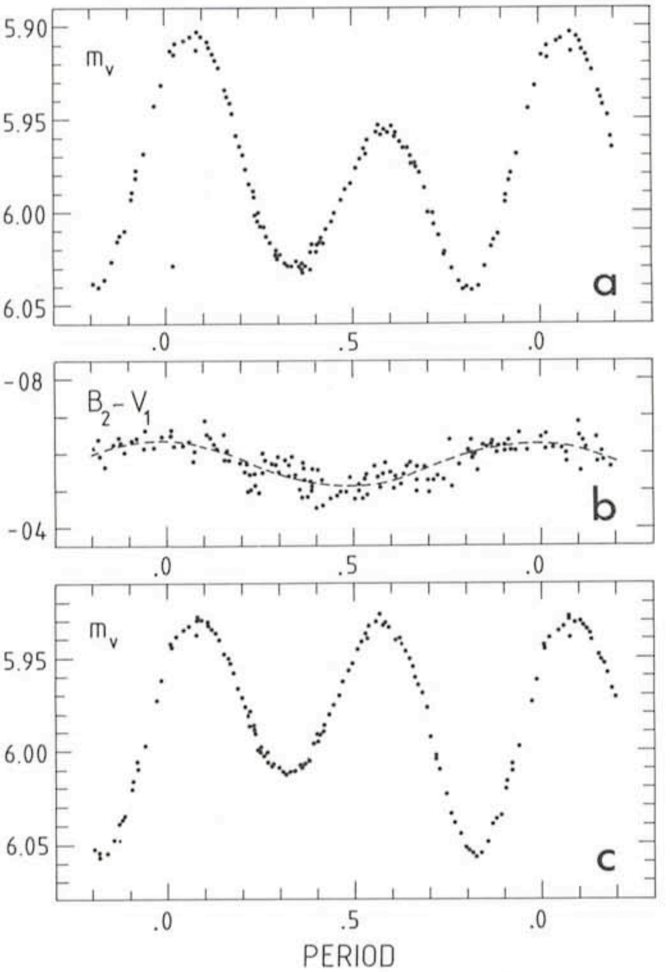


Fig. 1: *(a) visual magnitude lightcurve of TU Hor; (b) variations of the colour index B_2–V_1 through the phase and sinusoidal fit to the data; (c) lightcurve obtained by subtracting from the observed one a sinusoidal curve with an amplitude of 0.030 magnitude and a phase determined from the colour variations.*

extreme Ap stars it is smaller than −0.05. The value for Z is −0.016 in the case of b Per, it is −0.010 for TU Hor. The other peculiar binaries we mentioned have not yet been measured. So the Z-index for these stars does not indicate a pronounced Ap character. High-resolution spectra taken by Eric Maurice of ESO confirm that no strong peculiarities are present for TU Hor. Yet—since the value of the Z-index for TU Hor is a mean of more than 750 measurements—it possibly indicates a marginal, but genuine, peculiarity.

It can, however, be asked whether such a marginal Ap character can explain the large photometric variations. The mechanism generally admitted for the light variations of Ap stars is the oblique rotator model: the enhanced elements are not distributed homogeneously over the surface of the star, and the observed aspect changes during a rotation period. The light variations are then caused by the combined effects of blocking and backwarming. This mechanism cannot explain the observed behaviour of TU Hor, since the peculiarities, if they exist, are too small. However, several authors have argued that blocking and backwarming is not sufficient to explain the variations of some strongly magnetic stars, but that, in addition, a temperature variation up to some hundredths degrees, associated with the magnetic field, has to be invoked. This temperature variation is similar to that observed for TU Hor.

If the temperature variations observed in the case of TU Hor are due to a magnetic field, why then did this field not cause the strong peculiarities observed for most strongly magnetic stars? I believe that the answer lies in the close binary nature of TU Hor. The synchronous rotation imposed by the close companion has rendered magnetic braking ineffective and so diffusion has not been able to lead to strong peculiarities. Also, the tidal interactions could hinder diffusion.

This would then also explain the conspicuous lack of close binary systems among the known magnetic Ap stars. Several theories have been advanced to explain this discrepancy. It has been argued that magnetic fields cannot develop or would be destroyed in close systems. Another possibility is clearly that magnetic fields can exist in close binaries, but that the high rotation velocities imposed by the orbital motion and the tidal interactions reduce the importance of diffusion. Strong magnetic fields would then manifest themselves through the associated temperature variations, and this is precisely what is observed for TU Hor.

Spectra have been taken at the coudé focus of the ESO 1.52 m telescope in collaboration with Eric Maurice from ESO. These spectra will be useful to better describe the behaviour of this close binary. However, it can be doubted whether the Zeeman splitting caused by the supposed magnetic field will be observed directly. Indeed, the lines are not enhanced as in the magnetic Ap stars, and strong rotational broadening occurs. It can, however, be hoped that indirect evidence for a magnetic field can be found. Since b Per—a similar star—is a known radio source, it would be interesting to search for synchrotron radiation from TU Hor.

Astronomical Colour Printing at ESO

C. Madsen and M. Tarenghi, ESO

When the photographic labs in the new Garching Headquarters were planned, the installation of a colour lab was also foreseen. Following the removal from Geneva, a market survey of available colour equipment was carried out, leading to the purchase of a Durst 1800 Laborator enlarger featuring a CLS 2000 colour head and a negative carrier able to accommodate 25 × 25 cm originals, an Autopan 40–60 C processing machine and various equipment for process control.

The equipment was delivered in the course of 1981 and after trial runs, the processing machine was commissioned by the end of that year. The photographic process selected was the Cibachrome P-3 process, which has been described in detail elsewhere (Ilford AG: Cibachrome TB 29EN, TB 30EN [Ilford, Fribourg, 1979, 1980]). Suffice to say that one of the most significant advantages of this process is the very good sharpness achieved, due to highly limited light dispersion in the emulsion layers.

Following a period of producing plain colour prints from colour originals, we turned towards our ultimate goal, that of producing astronomical colour photographs. The motivations for astronomical colour photography are both scientific and aesthetic. A picture of a large area of the sky, of a complex nebula, or of an active galaxy shown in colour, gives immediate information on the distribution of different types of stars, or on different structures within a particular object; it is capable of clearly identifying various emission mechanics (continuum or lines), and of revealing the presence of peculiar objects, such as supernovae remnants. A beautiful object, such as a planetary nebula, becomes a polychromatic painting for an amateur astronomer and a source of important scientific information for a professional astronomer.

The Tri-Colour Method

As described elsewhere, ordinary colour film is not very suitable for astronomical photography. This difficulty has led many astronomers into obtaining their colour photographs from ordinary (b/w) spectroscopic plates. A study of the current methods of producing such composites from B-V-R plates lead us to chose the tri-colour method, the basic principles of which were described by Maxwell as early as 1861 (Malin, D.F., *Vistas in Astronomy,* Vol. 24, part 3, 1980, p. 220), who demonstrated that "white" light is composed of light of the three additive primary colours, blue, green and red. When printing colour pictures, this means that a colour print can be obtained by printing the original sequentially through standard broadband B-G-R filters. The colour balance is controlled by changing the relative amount of B-G-R exposures, whereas the density is determined by the total exposure. In the early days of colour photography the tri-colour method enjoyed much popularity, whereas now, with a few exceptions, it is generally regarded as being outdated. For most professional applications, the far more convenient and faster subtractive colour printing method is used. Contrary to the additive tri-colour method, the subtractive method only requires one exposure through one or two filters of the subtractive primary colours, yellow, magenta, and cyan.

As the tri-colour method requires three exposures (of one original), it goes without saying that it is possible to obtain a colour picture based on *three* (b/w) original films (or plates) which have been made with filters of the appropriate pass bands.

The tri-colour method consequently has proved to be very useful when it comes to working with astronomical plates, particularly when applied to a reversal process such as Cibachrome P-3.

When working with a reversal process, the "original" must be a positive transparency. For this reason, the original B-V-R plates are first printed onto b/w film to obtain three positive images. The intermediate copying stage allows for adjusting the positive films individually with regard to contrast and density. For the time being contact printing is used for this stage, at least when large fields are concerned. The intermediate positive films are superimposed on a light table by means of a 50 × microscope. After alignment of the films, registration holes are punched, and the films are then printed sequentially with B-G-R filters onto Ektachrome 6121 duplicating film. This too is done by contact printing, for which a Standard Klimsch Vakuprint VT 111 contact printer is used with a point light source and a filter turret fitted with Kodak Wratten 99 (B), 98 (G) and 70 (R) filters. Contact printing has of course the advantage of avoiding any loss due to the involvement of optical systems, but also requires the utmost care to ensure good registration during the printing phase.

Once the colour transparency is obtained with a proper colour balance, it is then printed by means of the Durst 1800 colour enlarger onto standard Cibachrome CPS-paper. Final colour corrections can be made with the CLS-2000 colour head, this time, however, according to the subtractive printing method.

Fig. 1: *A 4 × 4 degree picture of the Large Magellanic Cloud obtained with the ESO Schmidt telescope on La Silla. Three b/w plates have been used: IIa-O/GG-385/60 min; 103a-D/GG-495/40 min; 089-04/RG-630/60 min.*
There is a clearly visible difference in colour (or temperature) between the stars in the central part or those in a globular cluster, and the stars in the external regions. The red colour points out the H II regions with their intense H_α *emission and complex morphologies.*

Fig. 2 *is an enlargement of the Fig. 1 print centered on the 30 Doradus complex. Hot O and B stars of recent formation cause the ionization of the interstellar gas.* ▶

High Dispersion Investigation of CP Stars around the Hα Line

M. Gerbaldi, Institut d'Astrophysique de Paris and Université de Paris-Sud, Centre d'Orsay

What New Group of Stars are the CP Stars?

Nothing really new, only a terminology – Chemically Peculiar stars – which reflects the progress made both in the observational and theoretical fields of the study of stars from late B to early F type. The spectra of CP stars have in common anomalous intensities of the lines of several elements which can be interpreted as an anomalous chemical composition of their atmosphere due to surface phenomena. This terminology was first introduced by G.W. Preston in 1974 (*Ann. Review Astron. Astrophys.* **12,** 257).

CP stars are found among the whole upper main sequence and several subclasses have to be considered. From their spectra, they are generally grouped into the following classes: Helium-strong, Helium-weak, mercury-manganese, Bp including the Si λ-4200, Ap and metallic line stars. It is possible that the CNO stars represent a hotter class of these objects.

Why are Some Stars Chemically Peculiar?

The observations have shown that the atmospheres of the CP stars are more stable than those of the normal stars because of the slow rotation and/or because of the presence of a magnetic field. In such a frame, diffusion mechanism can occur and enable the production of anomalous atmospheric abundance (see for example the review presented at the IAU General Assembly in Montreal and published in the *Astronomical Journal:* S. Vauclair, *Astr. J.* **86,** 513, 1981).

This theory offers a coherent picture, and comparison between theoretical results and observations are consistent but there are still a number of remaining problems. The real situation is very complicated as diffusion mechanisms are affected by many parameters unknown or badly known, as rotation, turbulence, winds, magnetic fields. How all these parameters act together to produce the abundance observed is not yet well understood in spite of the large amount of results obtained up to now (see the last colloquium on this subject held in Liège in June 1981). Obviously more observations are needed.

To handle the problems in the best way, European astronomers have decided to unite their efforts (Mrs, Mr, Catalano, Derrider, Faraggiana, Floquet, Hensberge, Maitzen, Manfroid, Mathys, Morguleff, North, Renson, Schneider, van Santwoort, Weiss).

New instrumentation developed by ESO gives us the opportunity to extend our field of investigation. In 1982, the announcement of the availability of the Coudé Echelle Spectrometer (CES) fed by the 1.4 m Coudé Auxiliary Telescope (CAT) (D. Enard, *The Messenger* No. 26, p. 22, 1981) encouraged us to submit a programme centred on the observations of the Hα line of CP stars at high dispersion.

Why Shall We Observe the Hα Line at High Dispersion?

High-precision measurements of hydrogen line profiles are an important tool in understanding the structure of the atmosphere of early-type stars. The core of the Hα line is formed at a great height in the photosphere and therefore is very sensitive to deviation from local thermodynamic equilibrium and accelerated gas flows. The existence of hot outer regions can be detected by excess emission which occurs in the core of the Hα line. (For developments on that subject, see for example "Activity and outer atmospheres of the stars", F. Praderie, 11th advanced course, Swiss Society of Astronomy and Astrophysics, Saas Fee, 1981.)

Up to now, few observations suggest that some CP stars have outer regions at higher temperature than the one indicated by the continuum energy distribution. For example ultraviolet observations of α And (C. Aydin and M. Hack, *Astron. Astrophys. Suppl.* **33,** 27, 1978) indicated the presence of resonance lines of Si IV and probably of NV which are the signature of hot outer layers not usually observed in stars of such gravity and effective temperature.

But, with IUE observations, E. Böhm-Vitense and T. Dettmann (*Astrophysical Journal* **236,** 560, 1981) have reached a negative conclusion for 3 other Ap stars. Infrared excesses have been observed in some CP stars (Groote, D., Kaufmann, J.P., 1981, *Astron. Astrophys.* **94,** L23). O. Havnes (1981, 23rd Liège Astrophys. Coll. p. 403) analyses 3 different mechanisms for producing such infrared excesses in some CP stars, and his most likely explanation was that this infrared excess is produced by free-free emission from a gas shell around the star or from a polar stellar wind.

Those observations show the need of measurements of the Hα line profile in order to detect gas flow and/or hotter outer regions. CP stars being slow rotators, the core of the line can be precisely observed; this is not the case for normal stars where higher rotation obliterates moderate emission.

The Hα Line Profile with the CES

When you are among the first observers with a new instrument, you have in mind the obvious question, which is not necessarily trivial: how shall I reduce my observations? Don't worry if you observe with the CES system. F. Middelburg of ESO has developed a powerful system, called "IHAP", to handle it. Nevertheless, to reduce data, you have to feed the computer with some more data than only those obtained by observations: for example a wavelength table for the wavelength calibration. This is not a trivial job when you have observed in the 6550 Å spectral region with a resolving power of 100,000. Of course, there is a calibration source – a thorium

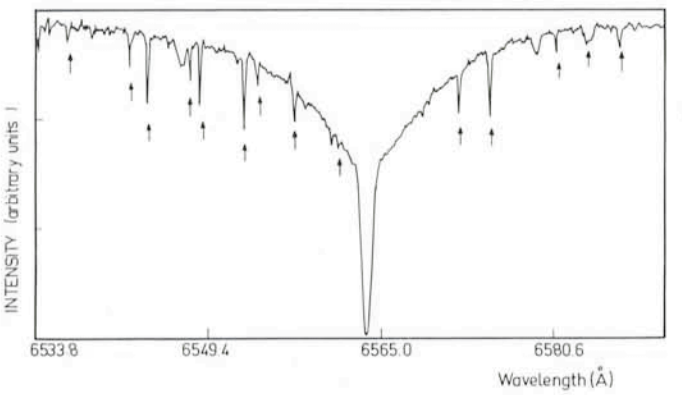


Fig. 1: *High-dispersion spectra of the star HD 17081 around the Hα line. Telluric lines shown with an arrow.*

lamp – but in the spectral range of interest there are too few lines, so it is more or less useless.

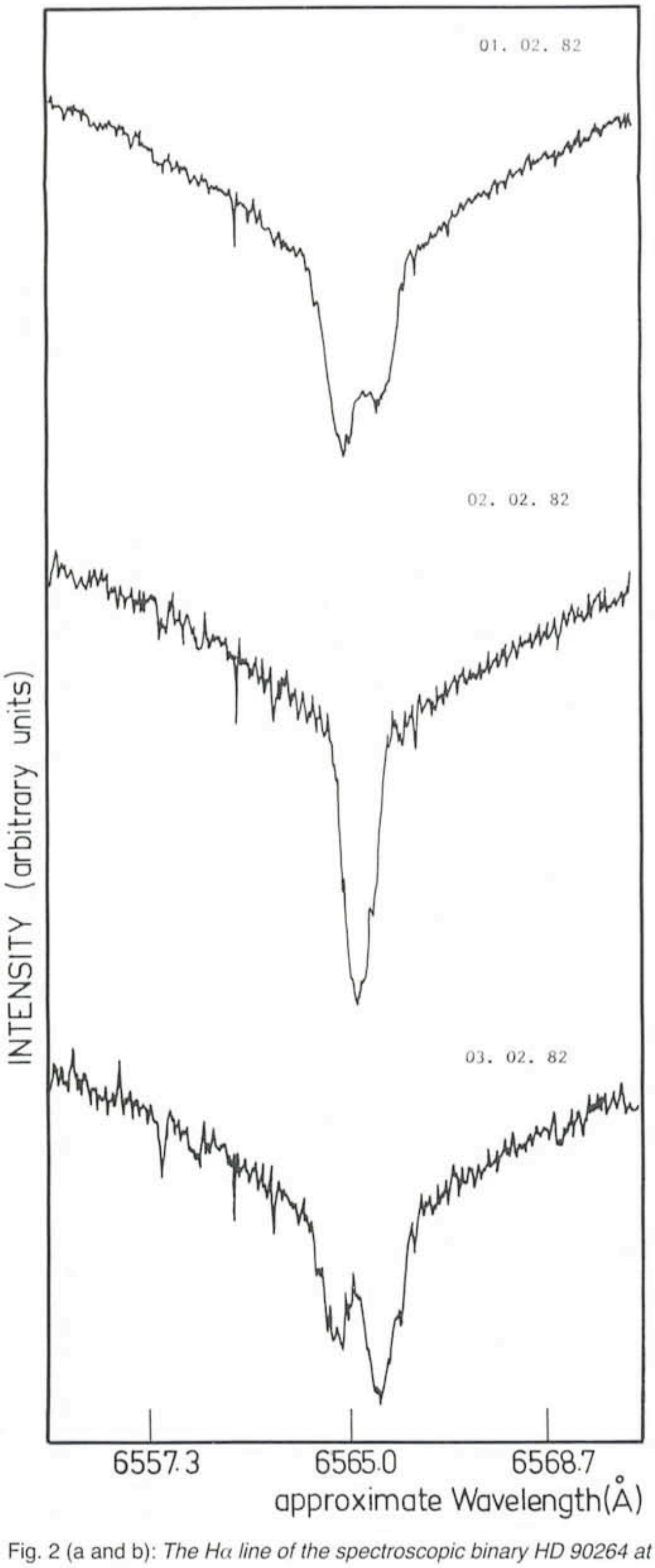
Happily nature is there! With such a resolution, telluric lines can be observed and they offer a free calibration spectrum with numerous well-spaced lines as can be seen in Fig. 1. But nothing is perfect! Some of them fall exactly in the Hα line. So, when for the first time of your life you see a high-dispersion profile of Hα of a CP star you are looking at it with a pounding heart: can you find in any little bump in the core a proof of the emission which would indicate the presence of a hotter outer region? Throughout the first night you are a bit anxious; something or nothing? If something is present in the core of the line: what is it? But, very soon, you have the answer during the observation of a star whith a large radial velocity which changes strongly the position of the Hα line: this small bump is only due to some telluric line. So we can say that none of the CP stars we observed present radical differences in their Hα profile, whatever their infrared excess.

We have observed with the CES 21 He-weak, BP and Ap stars. The He-weak stars are considered as being the extension of Bp Si stars to hotter temperatures. A quick look at the Hα line profile shows that there is no strong exotic feature. But our colleague Juan Zorec comments that some of those profiles are similar to those observed for some Be stars at certain phases of their variability. This aspect will be studied in detail with theoretical profiles of the Hα line.

The Hα Profile of the He-weak Star HD 90264

He-weak stars are defined as having abnormally weak helium lines. For more information on this subject see, for example, the introductory lecture given by Jaschek, C. and Jaschek, M. at the Colloquium on CP stars (23rd Liège Colloquium Coll. p. 417, 1981).

Among our programme stars, we observed HD 90264 which is also a double-line spectroscopic binary. Binaries are very common among Am stars and it seems that the tidal interaction is the braking agent which induces slow rotation for those stars. This scenario cannot act for the other CP stars, because their percentage of binary systems is more or less the same as that



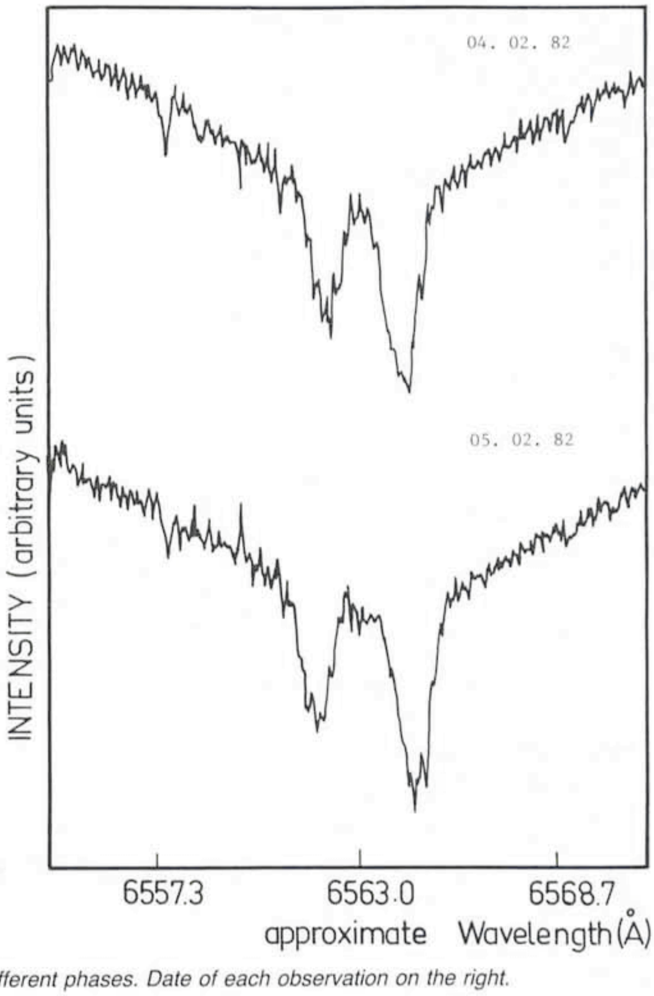


Fig. 2 (a and b): *The Hα line of the spectroscopic binary HD 90264 at different phases. Date of each observation on the right.*

of normal stars; some other mechanism must act in order to produce slow rotation: magnetic braking for instance.

Many metallic line stars have a companion which is also Am. This can easily be understood: very often the two components have nearly identical mass and luminosity so, due to their slow rotation, the diffusion process produces the same effect in each star. However, some cases are difficult to understand: for example the system 66 Eri has two stars similar in mass and luminosity but one of them is normal and the other is a Bp star.

But rather few CP stars—excluding Am stars—which are double line spectroscopic binaries have been analysed. To observe more such systems is important because it could help us to establish limits for the development of the CP phenomena either in physical condition of the atmosphere or in time scale. This is why we focussed our attention on the star HD 90264.

In spite of its magnitude ($m_v = 4.96$), the star HD 90264 is very poorly known. First quoted as being a spectroscopic binary in the radial velocity catalogue of the Lick Observatory (1912), it appears in the Wilson's radial velocity catalogue (1953) as a double-line spectroscopic binary. M. Jaschek, C. Jaschek and M. Arnal in 1969 classified it as a helium-weak star — (*P.A.S.P.* **81,** 650), of spectral type B9V. N. Houck classified it as a B8V star in the Michigan spectral catalogue.

The spectral type can also be obtained from colour indices. We estimated it from the values given by the Centre de Données stellaires. With uvby-photometry we found a spectral type B5 or B6V; using UBV photometry, M. Jaschek, C. Jaschek and M. Arnal also found a B6 type. This disagreement is the source of the definition of those stars: B-type stars for which the intensity of the helium line does not correspond either to the colour of the star or to the hydrogen line intensity.

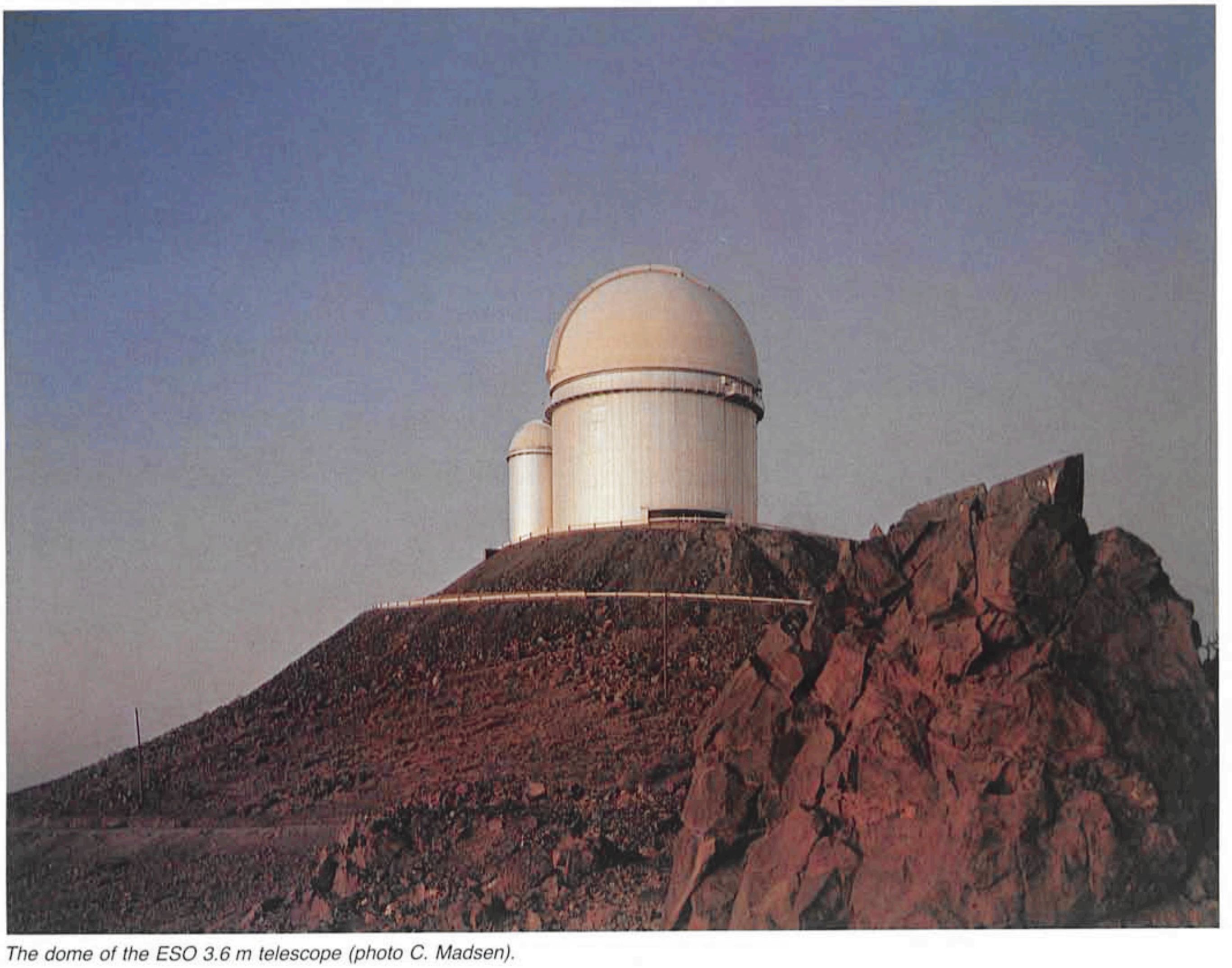
H. Pedersen and B. Thomsen (*Astron. Astrophys. Suppl.* **30,** 11, 1977) photometrically observed the behaviour of the He I λ 4026 Å line and suspected variability but could not find any definite period. F. Rufener informs us that, in the Geneva photometric system, this star shows no variability. The Hα profiles shown in Fig. 2 present different aspects due to the binarity. Apparently one quarter of the binary period is covered.

On 2 February the two components had the same radial velocity: one line is observed; on 5 February the Hα line of each component is clearly separated. From those profiles we have estimated an effective temperature of roughly 17,000 K for each star. The two components are certainly similar in mass and luminosity according to their Hα lines.

But now it is necessary to determine if both stars are—or not—CP stars. For such a purpose coudé spectra taken with the 1.5 m telescope will be the best. With spectra taken at different phases, it is possible to determine the nature of each component and to determine the parameters of the orbit. But an important question mark: How to have those spectra taken in spite of a too heavy demand of time at the 1.5 m telescope?

This question is not trivial and opens the door to a more general point: how to obtain very occasional observations of one object without applying for several telescope nights which would be ridiculous?

Last but not least, I want to express my thanks to all staff members and night assistants, and especially to Dr. E. Maurice and C. Aguirre.



The dome of the ESO 3.6 m telescope (photo C. Madsen).

Near-Infrared Photometry of Protostars

C.V.M. Fridlund, Stockholm Observatory

The Programme

For several years our group at Stockholm Observatory has been involved in a far infrared study of star-forming regions. This project, which is performed in collaboration with the University of Groningen in the Netherlands, consists of mapping molecular clouds, where we have indications of star formation, with a two-channel photometer. The photometer is fed by a 60 cm telescope which is carried to 35 km altitude by a helium-filled balloon. The two channels of the photometer are sensitive between 60 and 200 microns. In the clouds we are studying there are objects strongly believed to be protostars. These stars heat up the dust surrounding them, and the dust then reemits the stellar radiation at far-infrared wavelengths. In this way we can study this type of very young objects although they are totally obscured in the visual part of the spectrum. We have studied several objects in which known near-infrared (1 to 5 microns) sources are lying. In fact we used the existence of near-infrared sources as one of our indicators for on-going star formation. The balloon data made it possible to assign an accurate total luminosity to each of these sources.

Studies of T-Tauri stars have shown them to be variable, and since these stars are supposed to be low-mass young objects one would assume that even younger stars also should be variable, on a timescale that could be hours, days or years. A search for this variability would have to be done in the near infrared, since the sensitivity of the far-infrared photometer is not sufficient to spot any change less than a factor two in luminosity. All this is valid for low-mass stars, and it is not known if high-mass protostars also show variability, but since we had observed both high and low-mass sources with the balloon telescope, we decided to make a near-infrared study of these objects. In order to search for variations, we set up a programme where we would use the 1 m photometric telescope on La Silla to observe about 10 objects which met the following conditions. First, old near infrared observations should be available, so we have something to compare with, on a long timescale (a few to about 10 years). Secondly, they should have been observed with the balloon telescope so that we know the luminosity of the source and therefore its mass. In order to spot short timescale variations (hours, days), we decided to observe each object several times every night. The programme should also be repeated about a year later to search for further possible changes.

Observations and Results

The observations were performed in November 1980 and December 1981, each observing period consisting of 7 nights. We were lucky with the weather and lost only 2 of them. Reduction of the observations was made at Stockholm Observatory, with a software package developed by Dr. P. Lindroos. Preliminary reductions of the data showed that the mean extinction coefficients at La Silla (1) could be used and this gives us an estimated error in the K filter (2.2 micron) of 0.05 magnitude. Some of the results are presented in Table 1. The values given there for 1980 and 1981 are mean values of all observations in these years. Regarding short timescale variations we cannot conclusively prove anything. In several cases there seems to be a variation of the order of 0.1 magnitude in the span of one day, but since our error in K is only half that value, such a variation cannot be ascertained unless more accurate observations are performed, which means the use of the 3.6 m telescope. However, on the long timescale the situation is different. As can be seen from the table, several of the sources have varied significantly. This strengthens the case that we are here observing young objects. Both Rosette IRS and NGC 2264 IR, according to our balloon observations, are high-mass objects, and there seems to be a significant variation over the timespan of a few years.

Another part of the project was mapping in the K-band several areas where we would expect to find protostars from other indications, such as proximity to Herbig-Haro objects and CO temperature peaks. Several sources not previously reported in the literature were found, and the analysis of this part of the project is still taking place.

TABLE 1.

Object	K(1980)	K(1981)	K(Previous)	Ref
I1551 IRS5	9.43(6)	9.52(7)	8.94(10)	2
HH 1 CS-star	8.10(2)	8.26(1)	8.20(1)	3
Rosette IRS	6.99(1)	7.00(1)	7.41(20)	4
NGC 2264 IR	5.21(1)	5.18(3)	4.88(6)	5

Table 1: *The values listed are magnitudes in the K filter. For the 1980 and 1981 numbers, the digit within parentheses is the standard deviation in units of 1/100 of a magnitude. The column "K(Previous)" gives values that have been found in the literature as marked by the column Ref. The numbers in parentheses here are the quoted errors cited.*

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A New Infrared Telescope

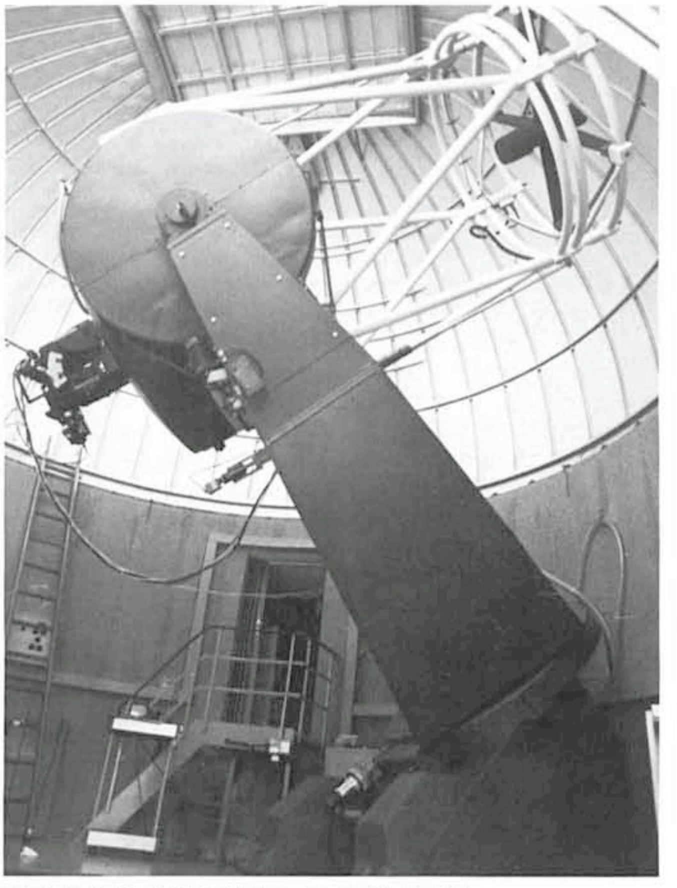
An important facility for Italian astronomy has been formally inaugurated on October 15, 1982 with the presence of the President of the National Research Council, E. Quagliariello, the Director General of ESO, L. Woltjer, H. Debruner on behalf of the Hochalpine Forschungs-Stationen and various other Italian and Swiss authorities. The new 1.5 m Cassegrain telescope is located on the Gornergrat (3,150 meters). The site can be easily reached from Zermatt by train under almost any seasonal condition. This point was proven on the day of the ceremony when an intense, early-fall snow storm amused and shocked some participants, at least those coming from sunny Italy!

The project to build this instrument arose within the Italian scientific community in the 70s and was well supported by C.N.R. A working group led by C. Occhialini-Dilworth and O. Citterio with participants from various institutions (Milano, Bologna, Firenze, Roma) led to the completion of the telescope in 1979. Its optics and mechanics were optimized in order to take full advantage of the site excellence for infrared work. Indeed, the statistics indicate that especially in the winter period the

Gornergrat has a very small amount of precipitable water (less than ~1 mm) and of course very low ambient temperatures (down to –20° C or so). After some time spent on the installation of the telescope and auxiliary facilities (a small workshop, electronic equipment for guiding and data acquisition with a PDP 11/34 computer), the facility is now in full use. For the purpose of operating the telescope, a Center for Infrared Astronomy has been established in Florence as a joint venture of the Arcetri Astrophysical Observatory and the National Research Council, under the general Direction of M. Landini. The main purpose of the Center is to operate the telescope as a national facility, to prepare the required advanced instrumentation and to carry out research in infrared astronomy. Concerning the instrumentation (in addition to what has already been developed in other Italian institutes), a Florence team led by P. Salinary is now busy making available for general observers in the near IR a new very sensitive InSb spectrophotometer (already operational) and a cooled spectrometer (which should become operational late in 1983). Additional future plans include the use of two-dimensional arrays and CCD development, subject to decisions about funding levels.

In any case, a new important facility is now available in Europe in one of the most exciting areas of modern astronomy and its use is not restricted to Italian astronomers despite the heavy booking of the first few months of observing time. Having joined ESO, being on the verge of inaugurating the first of two new 32 m radio telescopes (mainly for VLBI studies), the Italian scientific community looks forward to the use of the new telescope and to the increasing chance that the Ministry of Education will in the near future support the long awaited project of a national 3.5 meter optical telescope.

F. Pacini, Osservatorio di Arcetri



The new Italian infrared telescope on Gornergrat.

PERSONNEL MOVEMENTS

STAFF

Arrivals

Europe

NOETHE, Lothar (D), Systems Analyst/Senior Programmer, 1.1.1983

Chile

EICHENDORF, Walter (D), Astronomer, 1.1.1983 (transfer from Garching)
ZUIDERWIJK, Eduardus (NL), Astronomer, 15.2.1983

Departures

Europe

TKANY, Sylvia (D), Receptionist, 30.11.1982
MÜLLER, Karel (DK), Administrative Assistant (Accounting), 31.12.1982
MACFARLANE, Penelope (GB), Scientific Reports Typist, 9.1.1983
COIGNET, Gilbert (F), Electronics Technician, 28.2.1983

Chile

DE BREY, Eric (NL), Administrative Officer, 31.12.1982

FELLOWS

Arrivals

Europe

SADLER, Elaine (GB/Austr.), 15.1.1983

Departures

Europe

SOL, Hélène (F), 16.11.1982
KRAUTTER, Joachim (D), 30.11.1982
MOTCH, Christian (F), 28.02.1983

ASSOCIATES

Departures

Europe

WAMPLER, Joseph (USA), 31.12.1982

STUDENTS

Departures

Europe

BOISSON, Catherine (F), 26.12.1982

The Proceedings of the

Second ESO Infrared Workshop

which took place from 20 to 23 April in Garching, have just been published. The price for this 446-p. volume is DM 50.— and has to be prepaid.

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Digital Speckle Interferometry of Juno, Amphitrite and Pluto's Moon Charon

G. Baier, N. Hetterich and G. Weigelt, Physikalisches Institut der Universität Erlangen, Fed. Rep. of Germany

Introduction

The great advantage of Labeyrie's speckle interferometry (1970, *Astronomy and Astrophysics* **6**, 85) is its fascinating angular resolution. The resolution of conventional astrophotography is only about *1 arc second* due to the atmosphere. Speckle interferometry yields *0.03 arc second* in the case of a 3.6 m telescope or *0.08 arc second* in the case of a 1.5 m telescope. The achievable resolution is independent of seeing. However, the limiting magnitude depends on seeing. At 2 arc second seeing we have achieved the limiting magnitude 16^m.

In this paper we will report digital speckle interferometry of the asteroids Juno (9^m) and Amphitrite (11^m) and of Pluto/Charon ($14^m/16^m$). In addition to these measurements we will briefly describe preliminary results of the Seyfert galaxy NGC 1068 (11^m), the quasar 3C273 (12.7^m) and the triple QSO PG 1115+080 (16.2^m). In a subsequent paper we will discuss the measurements in more detail. Also our first application of the speckle masking method, which yields high-resolution images instead of autocorrelations, will be discussed in a following report.

Photon-Counting Speckle Camera and Image Processing

Speckle interferometry essentially is a Fourier analysis of large numbers of *short-exposure photographs,* called speckle interferograms. The end result of the speckle interferometry process is the high-resolution autocorrelation of the object. For a 10^m-object about 10^3 speckle interferograms have to be processed, for a 14^m-object about 10^4. Short exposures have to be used since only short exposures contain high-resolution information. The fine speckle structure, which is a random interferogram, carries the high-resolution information. Long exposures cannot be improved very much since in long exposures the fine speckle structure is washed out. The exposure time of speckle interferograms has to be 1/20 sec or shorter in order to "freeze" the atmosphere. Due to this short exposure, image intensifiers have to be used. In our speckle camera we use a Varo tube with a gain of 300,000 or an EMI tube with a gain up to $3 \cdot 10^6$. For objects fainter than about 10^m we work in the photon-counting mode. Further parts of our speckle camera are a microscope for producing an effective focal length of about 100 to 500 m, interference filters, and a prism system to compensate for atmospheric dispersion. We use a 16-mm motion-picture camera to record the intensity-amplified speckle interferograms. Figs. 1a and 3a show various speckle interferograms. Individual speckles cannot be recognized since the objects are too faint. In the ESO *Messenger* No. 18, p. 25, speckle interferograms of brighter objects are shown.

Speckle Interferometry of the Asteroid Juno

For the measurement of the shape of Juno we have recorded and reduced 1,450 speckle interferograms of Juno and 555 speckle interferograms of a point source. Speckle interferograms of a point surce are necessary to compensate the so-called transfer function of the speckle interferometry process. The speckle interferograms were recorded with the Danish

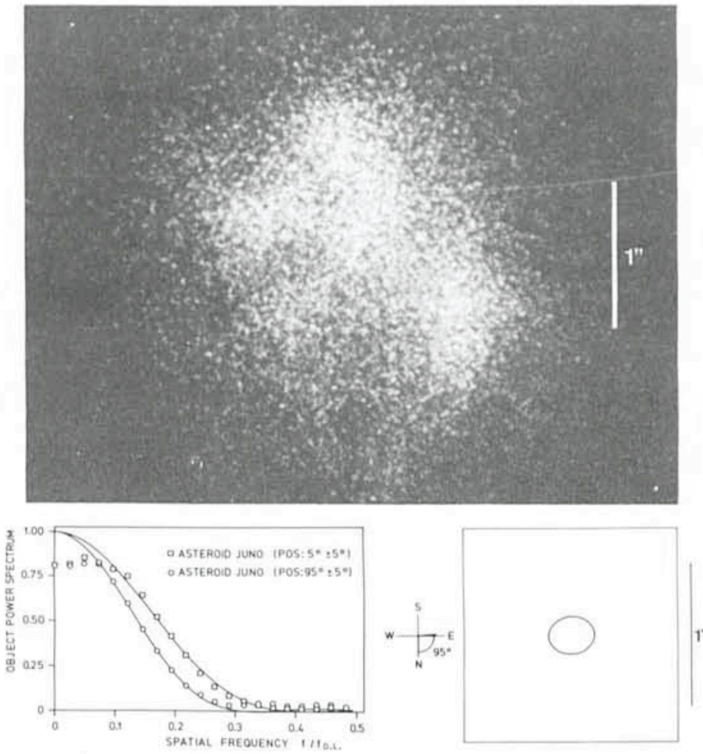


Fig. 1: *Speckle interferometry of Juno.*
a: *One of the 1,450 digitally reduced speckle interferograms.*
b: *Radial plots of the object power spectrum for two different position angles.*
c: *Calculated high-resolution shape of Juno (see text). The achieved resolution gain is a factor of about 20. We measured (epoch 24 Dec. 1979, 6^h10^mU.T.): position angle of the long axis: 95° ± 5°; long axis: 288 km ± 20 km (0.32"); short axis: 230 km ± 20 km (0.26"). (From Juno/Amphitrite article submitted to* Astron. Astrophys.*)*

1.5 m telescope. The exposure time per frame was 1/30 sec; the seeing was about 2 arc second. Fig. 1a shows one of the speckle interferograms. We digitized all speckle interferograms with our digital TV-image-processing system (256 × 256 pixels per frame). The time-consuming part of the speckle interferometry process is the Fourier transformation of all speckle interferograms. We use a PDP 11/34 computer. The computing time is 32 sec per frame. The image processing steps of this experiment are described in more detail in our Juno/Amphitrite article, which has been submitted to *Astronomy and Astrophysics*. The speckle interferometry process yields the power spectrum or the autocorrelation of the object. Fig. 1b shows radial plots of the power spectrum of Juno for two different position angles. Fig. 1c is the resulting image of Juno calculated with the assumption of an elliptical shape and a homogeneous surface brightness.

Speckle Interferometry of the Asteroid Amphitrite

In the speckle interferometry experiment of Amphitrite we have recorded and reduced 1,776 speckle interferograms of Amphitrite and 755 speckle interferograms of an unresolvable

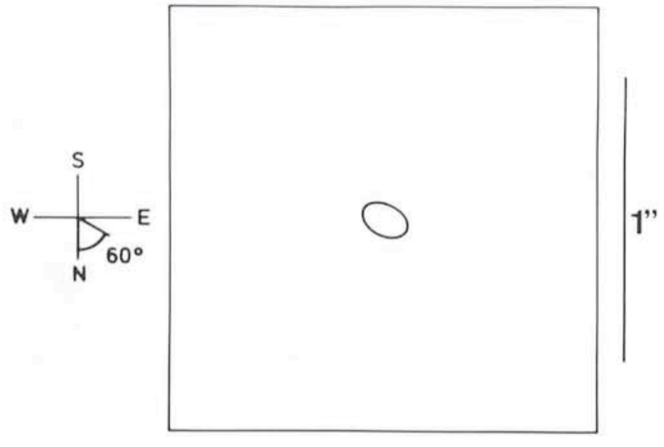


Fig. 2: *Speckle interferometry of the shape of Amphitrite. Epoch: 4 April 1981, 8^h30^m U. T.; long axis: 255 km ± 30 km (0.17"); short axis: 160 km ± 30 km (0.11"); position angle of the long axis: 60° ± 20°. (From Juno/Amphitrite article submitted to* Astron. Astrophys.*)*

star. The evaluation of the data consisted of the same steps as in the Juno experiment. Fig. 2 is the reconstructed image of Amphitrite calculated with the simplified assumption of an elliptical shape and a homogeneous surface. The power spectrum and the autocorrelation of Amphitrite show that Amphitrite has an elliptical shape at the achieved resolution of 0.08 arc second.

Digital Photon-Counting Speckle Interferometry of Pluto/Charon

We have measured Pluto/Charon in the nights of 2, 3 and 4 April 1981 with the Danish 1.5 m telescope. Fig. 3a shows one of the 15,000 recorded speckle interferograms. The exposure time was 1/20 sec per frame. Each speckle interferogram consists of about 50 photon events. In the case of such photon-counting data it is advantageous to use the following processing procedure, which was first proposed by A. Labeyrie et al. First the centres of gravity of all photons are calculated. Then the average autocorrelation of all interferograms is determined by calculating the histogram of the distances between all pairs of photon addresses. From this average autocorrelation the high-resolution object autocorrelation can be derived.

For the determination of the photon addresses we use a digital feedback loop in our image-processing system and a special pattern recognition algorithm. It is very impressive to observe on the computer monitor the shrinking of all photon dots to one pixel in about 1/5 sec. This fast pattern recognition algorithm is very flexible. It rejects ion events and scratches on film and it can separate photon pairs that are rather close.

Fig. 3 shows the Pluto/Charon measurements. Fig. 3a is one of the recorded speckle interferograms. Fig. 3b is the distribution of the photon addresses in Fig. 3a. Fig. 3c, 3d and 3e are the high-resolution autocorrelations of Pluto/Charon reconstructed from the speckle data of 2, 3 and 4 April 1981, respectively. In the time interval the autocorrelation peak of Charon moved about 41° around the central Pluto autocorrelation peak.

Photon-Counting Speckle Interferometry of the Extragalactic Objects NGC 1068, 3C273 and PG 1115+08

In addition to the measurements described in the preceding section, we have also performed speckle interferometry of many spectroscopic double stars and of various extragalactic objects. These measurements will be described in one of the next issues of the *Messenger*. In the following text we will briefly describe some preliminary extragalactic results.

Seyfert Galaxy NGC 1068

We have recorded about 80,000 speckle interferograms of NGC 1068 at various wavelengths. Up to now, part of the H-α data have been reduced. These measurements show an elliptical cloud that has a size of about 0.5 arc second. Presently we are processing the data recorded at other wavelengths. We hope to find an unresolvable nucleus, the mysterious central engine.

QSO 3C 273

The reduction of 16,000 1.5 m speckle interferograms show that 3C 273 is smaller than 0.09 arc second, as expected.

QSO PG 1115+08

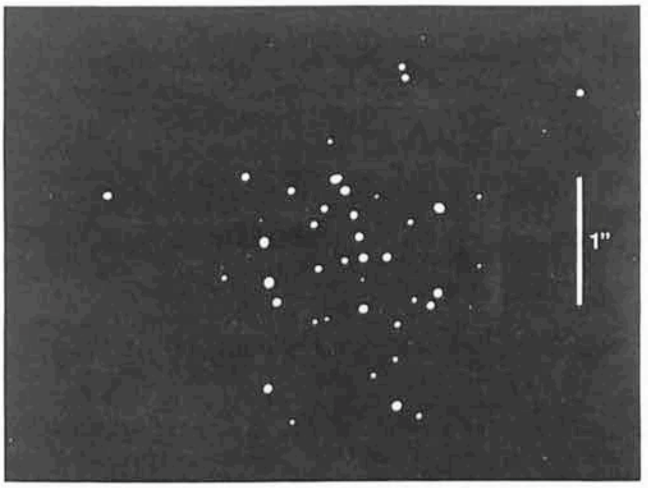
This famous quasar consists of three parts of magnitude 16.2^m, 18.1^m and 18.6^m, probably a gravitational lens effect. The 16^m-component is a double source with 0.5 arc second separation, first resolved by Hege et al. (1981, *Astrophysical Journal* **248,** L1). We have reduced 16,000 speckle interferograms recorded with the Danish 1.5 m and obtained exactly diffraction-limited resolution (0.09") for the brightest component.

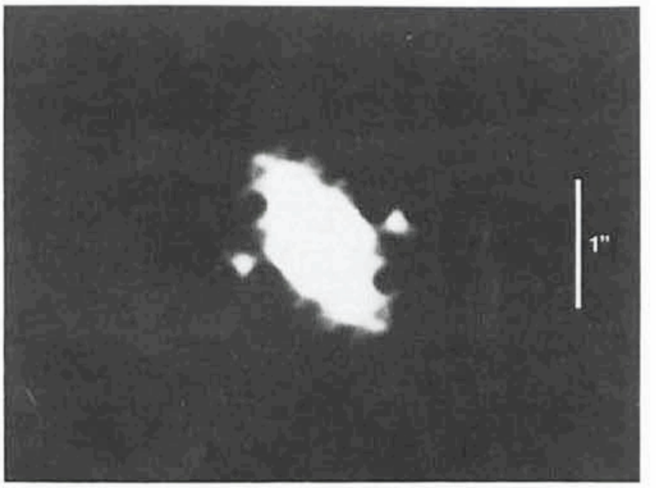
Image Reconstruction with the Speckle Masking Method

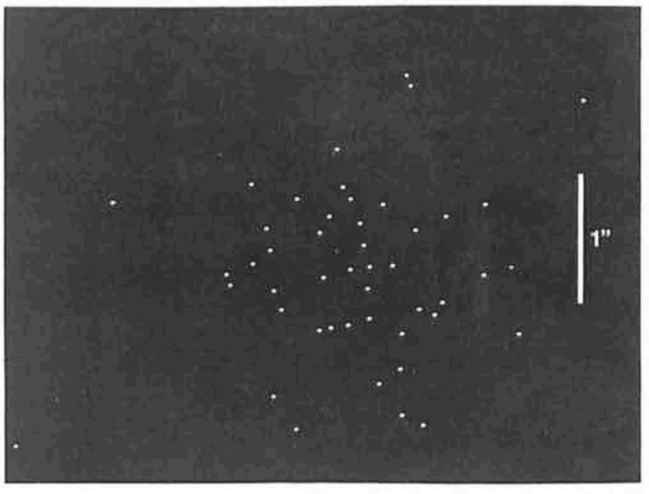
Speckle interferometry yields the high-resolution autocorrelation of the object. Direct images are usually not obtained. Therefore various authors have developed methods that yield direct images. One of these methods is the speckle masking method (1977, Weigelt, *Opt. Commun.* **21,** 55). We have applied speckle masking to speckle data recorded with the ESO 3.6 m telescope. The measurements yielded diffraction-limited images of many close spectroscopic binaries. The first image obtained is shown in our annual report 1982. We will publish some of these results in the next *Messenger* (with B. Wirnitzer).

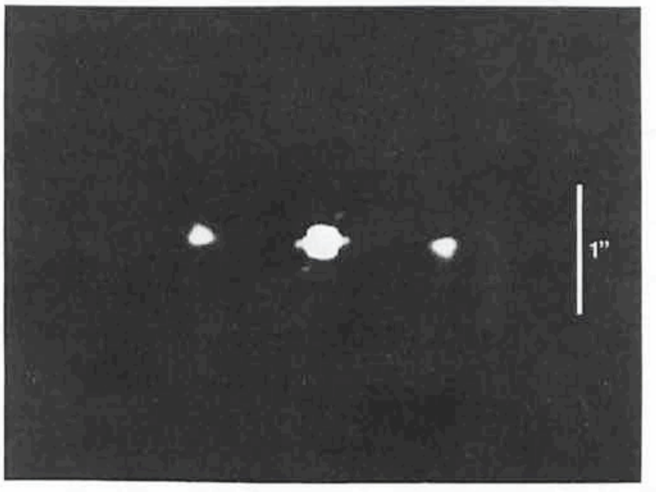
Speckle Spectroscopy

Another new method which we are currently developing is speckle spectroscopy (G. Weigelt, in: Proc. of the ESO Conf. on "Scientific Importance of High Angular Resolution at IR and Optical Wavelengths", Garching, 24–27 March 1981). This method yields images or autocorrelations of objective prism spectra with *very high angular resolution,* for example, 0.03 arc second in the case of a 3.6 m telescope. The raw data for this method are so-called spectrum speckle interferograms. In spectrum speckle interferograms each speckle is dispersed to a spectrum. For illustration Fig. 4 shows a spectrum speckle interferogram recorded in the laboratory. Similar images were also obtained with astronomical objects, but not with such nice colours. For actual speckle spectroscopy measurements the spectrum speckle interferograms are, of course, not recorded on colour film, but on black and white film and with a high-gain speckle camera. It is also necessary to use a restricted wavelength band instead of the whole visible spectrum. Speckle spectroscopy usually yields the autocorrelation of the high-resolution objective prism spectrum. If there is a point source near the object (less than about 5 arc second), then a direct image of the objective prism spectrum is obtained. There









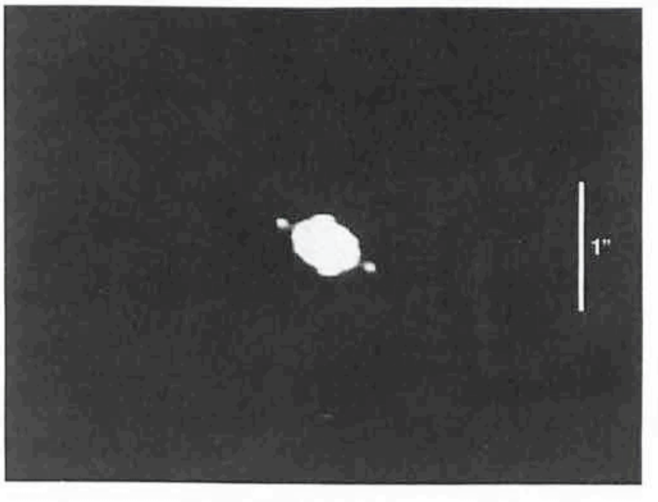


Fig. 3: *Photon-counting speckle interferometry of Pluto/Charon during the nights of 2, 3 and 4 April 1981.*

a: *One of the 15,000 speckle interferograms recorded with the Danish 1.5 m telescope. The bright dots are individual photon events.*

b: *Distribution of the photon addresses in 3a calculated by the described image-processing system.*

c: *High-resolution Pluto/Charon autocorrelation reconstructed from 3,000 speckle interferograms.*
Epoch: 2 April 1981, 6^h30^m U.T.; separation: 0.63" ± 0.03"; position angle: 188° ± 2°.

d: *Pluto/Charon autocorrelation reconstructed from 9,000 speckle interferograms.*
Epoch: 3 April 1981, 6^h00^m U.T.; separation: 0.95" ± 0.02"; position angle: 170° ± 1°.

e: *Pluto/Charon autocorrelation reconstructed from 3,000 speckle interferograms.*
Epoch: 4 April 1981, 7^h00^m U.T.; separation: 0.44" ± 0.08"; position angle: 146° ± 5°.

are several very interesting objects that are near a point source, for example R136a in the 30 Dor nebula, the discussed triple QSO and a few other quasars. Speckle spectroscopy can also be performed with the Space Telescope and the Faint Object Camera (see p. 106–108 in the above-mentioned paper). In the case of the Space Telescope there will be no problem to find a suitable point source in the isoplanatic neighbourhood of the object.

Conclusion

We have described speckle interferometry measurements of asteroids and of Pluto/Charon on three different nights. With the developed photon-counting image-processing technique we are now reducing speckle data of extragalactic objects. For NGC 1068, 3C273 and PG 1115+08 we have already obtained results. With 16,000 frames per object we have achieved the limiting magnitude 16^m at 2 arc second seeing. This means that 20^m can be achieved with larger numbers of speckle interferograms and better seeing. 20^m is also the number that was already predicted by A. Labeyrie in 1973.

Acknowledgements

We wish to thank A. W. Lohmann for numerous helpful discussions, the German Science Foundation (DFG) for financing the project and the staff members at La Silla for their assistance during the observations.

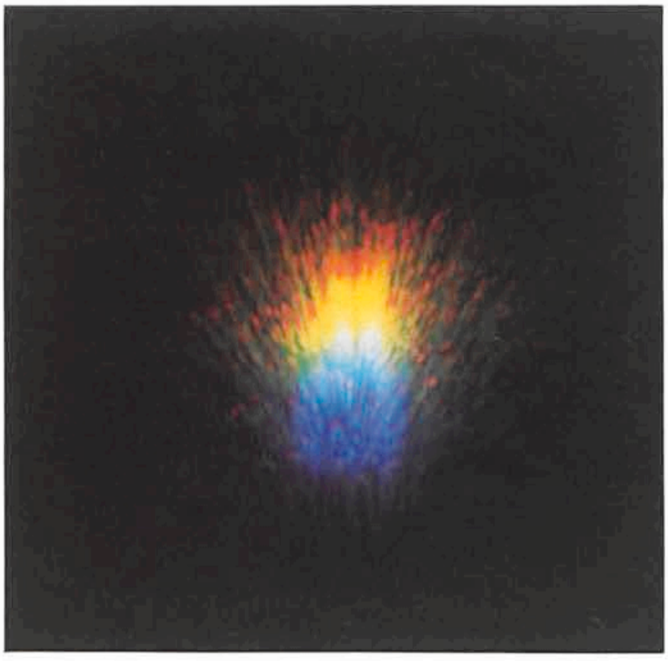


Fig. 4: *Colour photographs of a laboratory spectrum speckle interferogram (see text). The laboratory speckles are produced by special phase distortion plates and the dispersion by a prism.*

The CCD on La Silla

H. Pedersen and M. Cullum, ESO

Introduction

Throughout the history of observational astronomy, there has been a continual demand for detectors of higher sensitivity and lower noise. The ultimate goal, of course, is for an imaging detector that will record every photon reaching it with a noise level limited only by the random fluctuations of the photons themselves. Although we may not yet have the ideal detector, there has been a quiet revolution taking place in astronomy over the last year or so which has caused the world's major observatories to replace many of their older detectors, such as image intensifiers, by Charge-Coupled Devices (or CCDs as they are universally known).

The CCD

About as big as a fingernail, a CCD does not look particularly impressive: a rectangular piece of black silicon somewhat like a small solar cell. But, unlike the power-generating device, the surface of the CCD is divided into a vast number of small, discrete, light-sensitive elements or pixels. The size of these pixels is between 15 and 30 microns across, and the largest CCDs currently made have 640,000 such pixels. Even larger ones are on the drawing board. The CCD chips in use at La Silla at the present time have some 160,000 pixels covering a total field of about 10×15 mm^2. CCDs were originally developed by the micro-electronic industry for television applications, but it did not take long for astronomers to discover them and fall in love with them. Their cherished characteristics include a very high sensitivity (responsive quantum efficiency exceeding 80 % has been reported in the 600–700 nm range), linearity, low noise and excellent stability.

The entire surface of the CCD is traversed by rows of transparent electrodes of polycrystalline silicon. By applying a pattern of voltages to these electrodes, a series of potential wells is formed in the underlying silicon. Charge is prevented from spreading laterally along these wells by orthogonal potential barriers diffused into the silicon thus forming a matrix of individual charge-collecting centres. During an integration, electrons liberated by absorbed photons collect at these centres as indicated in Fig. 1a. This shows the potential well structure along the column of a three-phase CCD such as currently used at La Silla. The charge can be moved along the columns by varying the potential of the electrodes cyclically (Figs. 1b and 1c) so that the potential wells, and therefore the packets of accumulated charge, move along like a file of marching soldiers. At the end of an integration, the image is read out, first by shifting the entire charge-image down by one row, so that the bottom row is emptied into a "horizontal" output register, and then reading this register out serially to an output amplifier in the same way. This process is repeated, row by row, until the entire charge-image is cleared from the CCD. The output signals, after being processed and digitized, are transferred to computer mass-storage ready for display, reduction and analysis.

To minimize the accumulation of thermally generated charges during an integration, the CCD is cooled to a temperature of around 150 K. At this temperature, the dark current is negligible for most applications, and integration times of several hours are possible when the sky brightness permits. For reasons of cooling, as well as to avoid the risk of ice forming on the chip and to insulate it thermally from the surroundings, the CCD is mounted inside a vacuum cryostat.

The CCD on the Danish 1.5 m Telescope

The first CCD system to be permanently installed at La Silla was put into operation in June 1981 on the Danish 1.5 m telescope for direct imaging. The initial observations turned out to be so successful that several observers who had originally been scheduled for other instruments had second thoughts

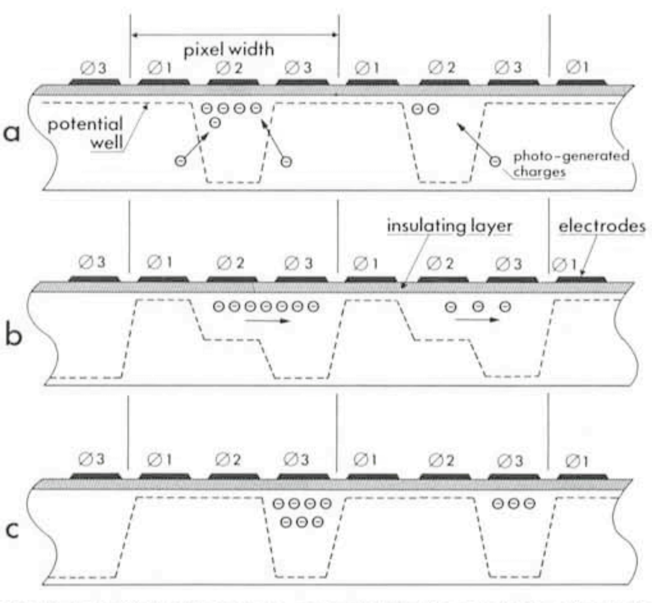


Fig. 1: *Potential well structure generated by the overlaying electrodes along a column of a 3-phase CCD.*
(a) Static potential wells during integration; (b) and (c) charge transfer process during image read-out.

and asked for the CCD instead. It is now the most requested instrument on this telescope. What has the CCD seen in the meantime? Comets, asteroids, lots of stars, identified and unidentified radio, X-ray and gamma-ray sources, nebulae, clusters, galaxies, quasars . . ., in short, any object for which high sensitivity and good photometric accuracy are important and for which a large field is unnecessary.

Apart from scheduled observing, the CCD has also shown great potential in a follow-up mode, for example, for objects discovered with the Schmidt telescope.

An example of a direct CCD image is shown in Fig. 2. This shows the central part of the beautiful barred galaxy NGC 1365. This picture is a 3-colour composite formed from three separate CCD frames taken through B, V and R filters. These were superimposed on a colour TV monitor by using the three frames, appropriately scaled, to modulate the blue, green and red channels of the monitor respectively. This picture can be compared to photographs of the same object taken with the 3.6 m telescope that were published in *Sky & Telescope* **53,** 97 (1977) and *Astronomy & Astrophysics* **87,** 245 (1980).

The CCD at the 3.6 m Telescope

The first tests of ESO's CCD camera at the 3.6 m telescope were recently carried out in spectroscopic mode with the low-dispersion spectrograph. This spectrograph is usually used with either an Image Dissector Scanner (IDS) or a Reticon as detector. In both cases the astronomer is limited to the observation of a single point in the sky at a time, together with a small area of neighbouring sky. In many cases, however, it is desired to obtain spectra of extended objects, for example, to observe the rotation patterns of galaxies or the differences in the metal content over the surface of supernova remnants. With the CCD these pose no problem. In one direction one gets the spectral information and the orthogonal direction, from a three-arc-minute line on the sky, the spatial information.

Fig. 3: *Spectrum of NGC 7009 along an E-W line through the central star. The wavelength range is approx. 350 – 475 nm. The night-sky spectrum has been subtracted. The data below 370 nm are contaminated by red light from the 1st-order of the spectrum. (3.6 m telescope, 244 Å/mm, 5 min. integration time, 2" slit.)*

Fig. 4: *Spectrum of NGC 7009. Wavelength range 693–950 nm. 10 min. integration. Other data as Fig. 3.*

Fig. 2: *Three-colour composite CCD picture of the central part of NGC 1365. Notice the intense red source near the centre of the galaxy (the nucleus is slightly saturated on the red image) and the much hotter patches nearby. The field is 1.25′ × 1.25′; S is up and E to the left.*

Figs. 3 and 4 show two examples of test spectra obtained with the CCD in this way. These spectra, taken during the full moon period, are of the Planetary Nebula NGC 7009, also known as the Saturn Nebula. The grating position for both exposures was the same, the red and blue parts of the spectrum being selected by order separation filters. The vertical line in the middle is the hot central star. To the left and right of it are a number of emission lines originating from elements present in the nebula itself. Close inspection shows that some lines are strongest close to the central star while others (most notably the O II 372.7 blend) are strongest further out. Detailed calculations can tell us about the physical conditions that exist in different parts of the nebula. This task is aided by a pleasant characteristic of the CCD: the narrowness of the instrumental profile. Even very strong emission lines have a shape which is practically only determined by the width of the entrance slit. This can be appreciated in Figs. 5 and 6 which are tracings made from the data contained in Figs. 3 and 4 respectively, and obtained by co-adding the data in the nebula each side of the central star.

As the 3.6 m telescope collects several times more light than the 1.5 m, there are obviously many direct imaging programmes which would benefit from the shorter exposure times possible from the prime focus of the larger telescope. Also, in conditions of exceptional seeing, other programmes could exploit the higher spatial resolution at the Cassegrain focus. All these possibilities should be available to visitors to La Silla during the first half of 1983.

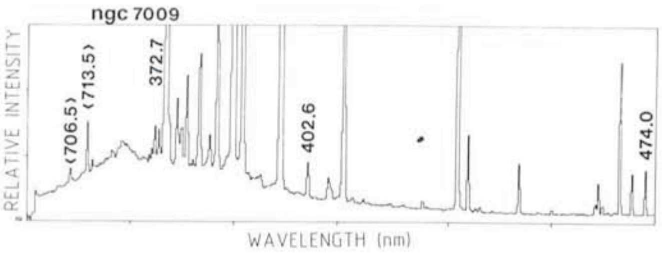


Fig. 5: *Spectrum of the nebulous parts of NGC 7009 in the range 350–475 nm. Other data as Fig. 3.*

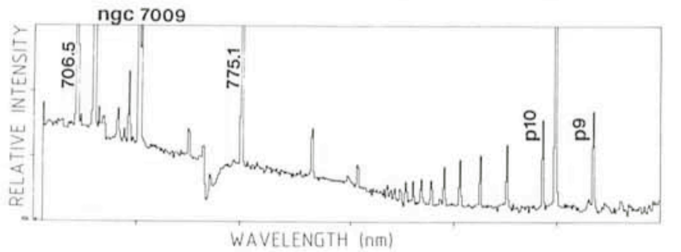


Fig. 6: *Spectrum of the nebulous parts of NGC 7009 in the range 693–950 nm. Other data as Fig. 4.*

Observing with the CCD

Although visiting astronomers are usually shown the telescope and how the CCD is mounted on it, there is no need for the observer ever to enter the dome. All acquisition and operation controls are carried out remotely from the control room. Faced with a couple of computer terminals and a colour monitor, the observer makes the decisions necessary for his or her programme. Almost all parameters are entered interactively on a terminal using a "form-filling" technique in which the observer is presented with a form showing the default parameters which can be left or modified at will. This permits newcommers to familiarize themselves with the equipment very quickly and to minimize mistakes without being too time-consuming or inconvenient for old-hands. The long waiting hours during integrations can be used to examine previous exposures, reduce and make prints of data. It has even been known for observers to sneak down to the midnight kitchen during such periods. This has been made easier of late by the provision of an automatic sequencing system that can be pre-programmed to execute a series of integrations with different exposure times and filters without observer intervention.

Data Reduction

It might appear from the preceding paragraphs that the CCD is completely without problems. This is certainly not so. As with any detector, a lot of care and patience is needed both during the observations, including the many calibration exposures necessary, and afterwards during the data reduction and interpretation. The main problems faced, that are intrinsic to the CCD, include interference effects, dead and "hot" pixels, non-linear columns at very low signal levels, charge transfer problems, and cosmic ray events. Some of these problems can be minimized by correct choice of operational and observational parameters. Others need to be corrected during data reduction. To assist with this there is a large and growing library of software routines available. We hope to return to these problems, and to give some more quantitative performance data in a later issue of the *Messenger*.

The Distance of the Magellanic Clouds

L. Divan, Institut d'Astrophysique, Paris

Introduction

The Magellanic Clouds are very important for many problems of Astrophysics. At a distance of about one tenth of that of the Andromeda Nebula, they are the nearest extragalactic objets, and in many cases the individual stars can be studied in detail. On the other hand, the distance to each Cloud is quite large when compared to the linear dimensions. No distance effect greater than ± 0.15 mag is to be expected on the apparent magnitudes and, practically, all objects can be considered to be at the same distance. A great advantage of the Magellanic Clouds over other groups of stars is that their population, with radial velocities around + 275 km/s for the Large Cloud and + 160 km/s for the Small Cloud, can easily be separated from the Galactic foreground stars. In addition, very little interstellar absorption occurs along the line of sight, either in the Galaxy or in the Clouds. For all these reasons the Magellanic Clouds are a very efficient tool (c.f. the discovery of the period-luminosity relation in the SMC as early as 1904) and considerable efforts have been made to determine their distances.

The Distances to the Clouds During the Last Fifty Years

The distance to the Small Cloud could be estimated for the first time when the "period-luminosity" variables discovered in 1904 by Miss Leavitt were identified as Cepheids by E. Hertzsprung (1913). Cepheid variables are found in the solar vicinity and from their known proper motions and radial velocities, Shapley could determine their absolute magnitudes, the zero point of the "period-luminosity" relation and the distance to the Small Cloud. The first published data, around 1918, placed the Small Cloud definitely outside the Galaxy at a distance d = 19 kpc, changed six years later into 31 kpc after a revision of the apparent magnitude system (Fig. 1). The slow decrease with time of the distance between 1924 and 1951 is mainly due to the fact that interstellar absorption corrections were introduced. It is interesting to note that during the long period extending from 1918 to 1951 the zero point of the "period-luminosity" relation has been revised by several authors who all confirmed the first determinations of Shapley. Much more observational data on proper motions and radial velocities were at hand. The effects of galactic rotation on the motions as well as the effect of interstellar absorption on the magnitudes were included in the discussion. With the exception of an important increase in the absolute luminosity of the Cepheids proposed by H. Mineur in 1945, all the efforts which were made resulted only in insignificant changes of the zero point of the "period-luminosity" relation: the absolute magnitudes of the galactic Cepheids were apparently well established by the converging results obtained by different authors. However, at the same time more and more doubts arose upon the validity of these results, especially because no RR Lyr star could be observed at m = 17 or m = 18 as might be expected from their mean absolute magnitudes. When early in 1953 Thackeray and Wesselink found RR Lyr stars at $m_{pg} = 18.7$ in the Small Magellanic Cloud their result implied a correction factor of about 2 for the extragalactic distance scale. The old Cepheid zero point was abandoned and a set of several new and, as far as possible, independent distance indicators were used (novae, RR Lyr stars, integrated magnitudes of globular clusters, Cepheids in galactic clusters of known distance . . .).

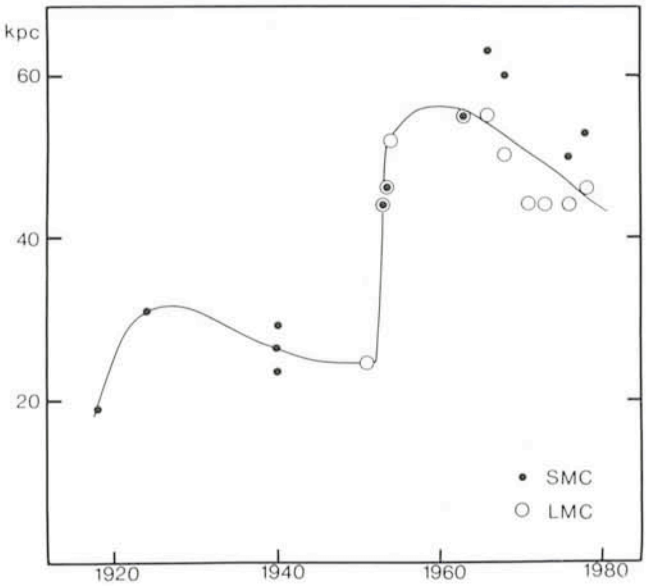


Fig. 1: *The distance to the Magellanic Clouds as a function of time. Note the great discontinuity around 1952, when it was finally recognized that the zero point of the period-luminosity relation for the Cepheids was unreliable. The new distances were derived from a set of several independent indicators.*

This is a very sound situation because if one of the indicators is viciated by an unrecognized parameter, there is a priori no reason why all the indicators should be viciated exactly in the same way. After the "great jump" of 1952–1953, the distance to the Magellanic Clouds did not undergo major changes and Fig. 1 shows only a slow decrease. However, this relatively stable distance is sometimes due to effects which cancel each other. For instance, we have seen that in 1953 Thackeray and Wesselink discovered the first RR Lyr variables in the Small Magellanic Cloud at the mean absolute magnitude $m_{pg} = 18.7$. At that time the adopted mean absolute magnitude was $M_{pg} = 0$ and the derived apparent modulus $\mu = 18.7$. Ten years later, Tifft (*MNRAS*, **125,** 199) found the RR Lyr variables at the mean magnitude B = 19.7; fortunately the mean absolute magnitude adopted for the RR Lyr stars had also changed, from $M_{pg} = 0$ to $M_B = 1{,}0$ and the apparent distance modulus remained unchanged. . . . The magnitude scales are now well established but the reliability of the modulus still depends on the answers to the two questions:

(i) Given a certain type of stars in the Galaxy, are their counterparts in the Magellanic Clouds really identical?

(ii) Is it possible to determine accurately a mean absolute magnitude for this type of stars in the Galaxy?

None of these two questions can be answered favourably for any group of stars and the only chance of having some confidence in the distance moduli is to derive them from as many "good indicators" as possible. The population of the Clouds is very rich in groups of stars which have counterparts in the Galaxy and many distance indicators were used since the revision of 1952. Unfortunately most of them were difficult to handle and we are left with only three indicators, novae, Cepheids and RR Lyr stars, which have been re-examined many times. In 1970, considering the uncertainties still present in the distances to the Magellanic Clouds (and very happy at the idea of a first visit to La Silla) we initiated a series of observations at the ESO 150 cm telescope in order to derive the distance moduli of the Magellanic Clouds from a new indicator: the BCD parameters of moderately bright B and A supergiants.

The Large Magellanic Cloud Distance in the BCD System

In the BCD system, the first two parameters D and λ_1 are independent of the interstellar reddening. They are schematically described in Fig. 2. A third parameter is the energy distribution in the continuum, generally in the wavelength range 6200–3150 Å. The comparison between this observed energy distribution and the intrinsic energy distribution which can be deduced rom D and λ_1 gives the amount of interstellar reddening A_v for each star, and individual reddening corrections are made.

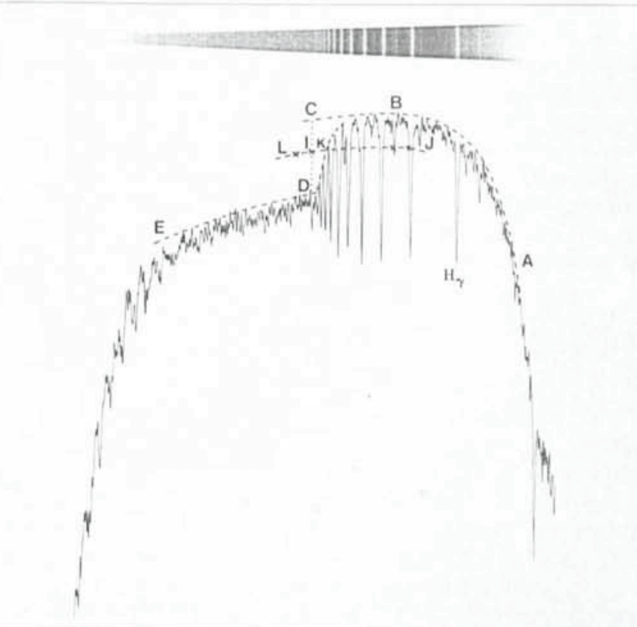


Fig. 2: *The parameters D and λ_1 of the BCD system represented on a microphotometer tracing.*
ABC: blue continuum; DE: ultraviolet continuum; CD: Balmer Jump (D, in dex); IJ: blue continuum − D/2; IL: ultraviolet continuum + D/2; K: intersection of IJ with a smooth curve joining the points of highest intensity between the Balmer lines. λ_1 is the wavelength corresponding to the point K. Let us note that the real determination of D has a sounder base than the "eye extrapolation" shown in the figure.

Twenty-three A and B supergiants have been measured in the Large Magellanic Cloud and ten of them are in regions of the λ_1D plane well calibrated in absolute magnitudes by a sufficiently dense population of measured galactic stars (Fig. 3). For these ten stars, M_v is obtained by interpolation between the curves of equal absolute magnitude. The mean value of the distance modulus ($V-A_v-M_v$) for these ten stars is found to be 18.1 which becomes 18.3 if we take into account the change of 0.2 mag in the distance modulus of the Hyades recommended by de Vaucouleurs (*Ap.J.* **223,** 351–363 and 730–733) in a very careful re-discussion of the galactic and extragalactic distance scales.

The same result (but based on quite a small number of spectra) was announced a few months after the first observing run at the IAU Symposium No. 50 and later, in 1972 (IAU Symposium No. 54) with some more results and a discussion of the underlying hypothesis.

Though derived from stars in a wide range of spectral types (B5–A3), the distance moduli are in very good agreement, with a dispersion $\sigma = 0.25$ and even only 0.17 if two deviating stars are not considered. No dependence of the modulus on the spectral type can be observed and the galactic calibration of the λ_1D plane in absolute magnitudes seems to fit quite well the LMC supergiants.

The two stars that deviate are probably interesting. The uncertainties in the BCD parameters (deduced from the results for stars that have two or more measurements) are too small to explain the difference between their distance moduli which are 18.6 for G233 (B6Ia) and 17.7 for G305 (B6Ia). As the two stars have the same spectral type, no change in the λ_1D plane calibration can help. The difference between their distance moduli must be due to the stars themselves: real difference in the distances, multiplicity, spectral anomalies. . . . However, these phenomena are marginal in the Large Cloud and would have been neglected if they did not occur at a much higher degree in the Small Cloud. In most cases the correlation between the position of a star in the λ_1D diagram and its apparent magnitude is very good even for the brightest supergiants and the calibration in absolute magnitudes can be extended to $M_v = -9$ or -9.5 with the results already at hand. It could easily be improved by observing some more stars and we would like to do it, especially in view of unexplained phenomena in the Small Cloud.

The Small Magellanic Cloud

Twelve stars have been measured in the Small Cloud. Only four of them are in the region of the λ_1D plane calibrated by galactic stars. The distance moduli have been derived and their mean is 18.4. This value is a little larger than for the Large Cloud in conformity with what is generally admitted, but the dispersion is abnormally high and the four moduli are spread over an interval of more than one magnitude. The eight other stars are in the region of the λ_1D plane which is calibrated only by LMC supergiants. As we have already said, this calibration is still provisional and should be improved. However, we used it to derive distance moduli for the eight brighter SMC stars. The mean modulus is 18.6, not very different from the first one and the dispersion is exactly the same, with a difference of 1.1 mag between the smallest and the largest modulus. If this dispersion reflected real differences in distance, the Small Cloud would have a depth about ten times larger than the linear dimensions projected on the sky. This result is for many reasons difficult to accept and we have verified that the individual interstellar absorptions A_v are all relatively small and have no correlation with the apparent distance.

The problem of the apparent depth of the Small Cloud has been investigated many times by different methods. All authors agree upon the existence of this apparent depth, but curiously,

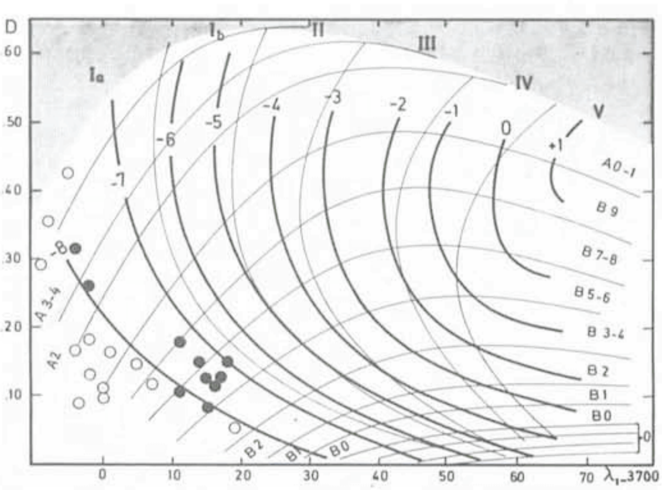


Fig. 3: *Position of 23 LMC supergiants in the λ_1D plane. The λ_1D plane has been calibrated in absolute magnitudes (thick continuous lines, M_v from +1 to −8) using stars situated in galactic clusters of known distances. All the LMC stars in this figure are brighter than $M_v = -7$. Ten of them (filled circles are in regions of the λ_1D plane well populated by galactic stars and for which the calibration in absolute magnitudes is reliable. For each of these stars a distance modulus can then be derived. The remaining stars (open circles) are brighter in apparent magnitudes and their higher luminosities (M_v between −8 and −9.5) are in very good agreement with their positions in the λ_1D plane.*

they completely desagree on which star is far and which star is near. The question is still open.

The Problem of Chemical Composition

It is now a general belief that our difficulties with the Magellanic Clouds are due to differences between the Galactic and Magellanic chemical compositions. These differences were first recognized in the interstellar medium. However, to detect eventual anomalies in their luminosities, stars themselves had to be analysed. This is a very difficult task because high-dispersion spectra and good model atmospheres are necessary. Both conditions cannot be fulfilled with the same star as only very intrinsically bright supergiants for which no good model exists have apparent magnitudes bright enough for a high-dispersion analysis. However, it is believed that the Large Cloud stars have a small metal deficiency and that a significantly larger one is present in the Small Cloud stars. These results could be in agreement with the fact that intrinsic luminosities seem to fit the galactic luminosities in the Large Cloud and not in the Small Cloud. They could also explain that the consistency between the MK and λ_1D spectral types is much better in the LMC than in the SMC.

The conclusion is that the distance to the Large Cloud is probably reasonably well determined. But in the case of the Small Cloud, even the mean distance modulus is questionable if the relation between the observed properties of the stars and their absolute luminosities is sensitive to relatively small changes in the chemical composition as suggested by J.W. Pel (*The Messenger* No. 29, Sept. 1982) in the case of Cepheids. For these stars J.W. Pel and collaborators claim that a decrease in luminosity as large as 0.5 mag occurs with a metal underabundance of a factor 4.

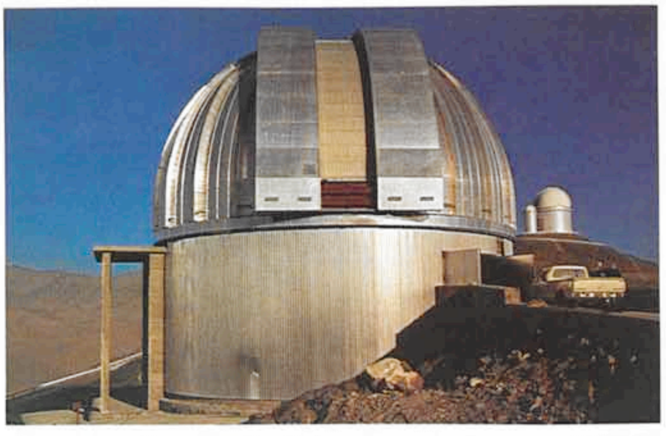
The effects of chemical composition on the other distance indicators are still to be investigated, but in the Small Cloud, unless very large differences in chemical composition from one star to another occur, the dispersion observed in the distance moduli for stars having the same BCD parametes, if confirmed, will remain unexplained.

Dome for the 2.2 m Telescope Commissioned

It took the American crew of Observa Dome Lab. (Jackson, Mississippi) six weeks to install the dome at the 2.2 m telescope site on La Silla. In spite of heavy winds and unfriendly weather during the first weeks, the work was completed ahead of schedule on November 20, 1982.

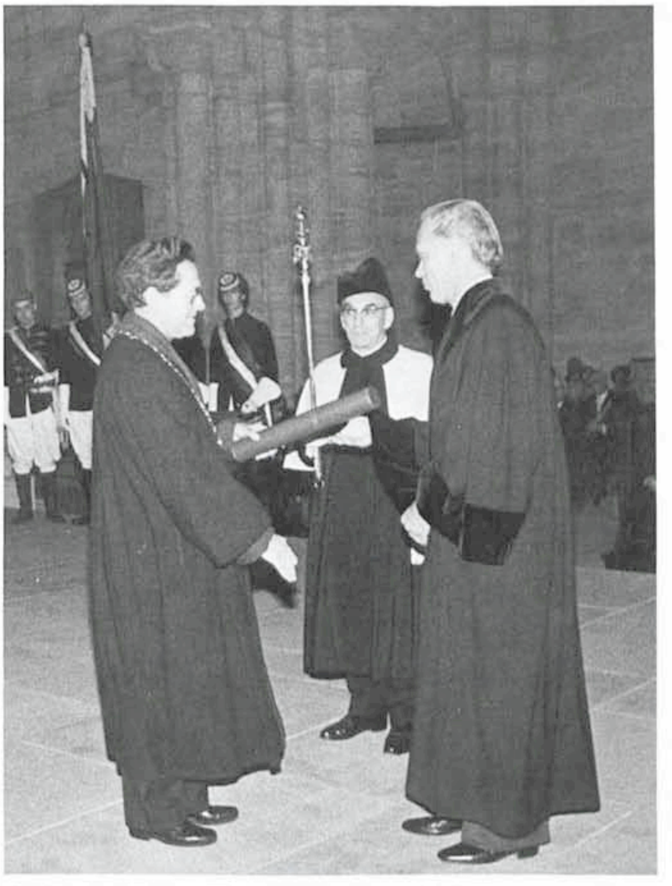
The dome was manufactured and preassembled at the Jackson works and all mechanical and electrical functions were tested there in June 1982. Disassembly and packing into five 12 m sea containers lasted until the end of August. Finally the consignment arrived at La Silla one month later.

Now, the roof being closed, the installations in the building can start with full power in order to have everything ready before the arrival of the telescope. *W. Bauersachs*



Instalación de la cúpula para el telescopio de 2.2 m terminada. *El grupo americano del Observa Dome Lab (Jackson, Mississippi) necesitó solo seis semanas para instalar la cúpula en el edificio en que quedará ubicado el telescopio de 2.2 m en La Silla. A pesar de fuertes vientos y un tiempo hostil durante las primeras semanas, el trabajo fue terminado el día 20 de Noviembre de 1982, antes del límite que había sido fijado.*

Y ahora, estando cerrado el techo, podrán comenzar las instalaciones en el edificio para tener todo preparado antes de la llegada del telescopio.



On Friday 26 November 1982, Prof. L. Woltjer was named Dr. honoris causa of the Sciences Faculty of the University of Basel. This honour was bestowed on him in recognition of his scientific work, his accomplishment as Director General of ESO and his successful negotiation to bring Switzerland into ESO.

☆ ☆ ☆

At the last IAU General Assembly in Patras in August, Dr. R. M. West, ESO staff member, was elected as General Secretary. At the same time, Dr. J. P. Swings, ESO associate, was elected Assistant General Secretary.

ALGUNOS RESUMENES

20 AÑOS ESO

El día 5 de octubre de 1962 fue firmada en Paris la Convención de ESO por los representantes de Bélgica, Francia, la República Federal de Alemania, los Países Bajos y Suecia. Más de un año después, el día 17 de enero de 1964, la Convención entró en vigor, luego de su ratificación parlamentaria requerida en la mayoría de los países. En 1967, también se unió Dinamarca. En el primer tiempo (en parte aun antes de que se completaran las formalidades) se hicieron investigaciones de terreno que llevaron a la elección de La Silla como ubicación para el observatorio, y se comenzó con los trabajos de infraestructura de La Silla y de los telescopios Schmidt y de 3,6 m. Algunos otros telescopios fueron pedidos a la industria. Una vez verificado de que ESO no disponía de la capacidad técnica necesaria para finalizar con éxito todos sus proyectos, se sostuvieron conversaciones con CERN, las que en el año 1970 llevaron a la fundación de la División de Proyecto de Telescopio en Ginebra, compuesta parcialmente por personal de CERN. Como resultado, en 1976 se finalizó el telescopio de 3,6 m.

A fines de 1975 se tomaron decisiones fundamentales para el futuro de ESO: Se decidió continuar la Division TP en aproximadamente su misma dimensión y con la tarea de desarrollar la instrumentación. Y adicionalmente se creó la División Científica, la que daría su identidad científica a la organización. En 1980 la ESO se trasladó a Garching, donde el gobierno alemán puso a disposición un nuevo edificio.

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where twelve 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 are located in Garching, near Munich.
ESO has about 120 international staff members in Europe and Chile and about 120 local staff members in Santiago and on La Silla. In addition, there are a number of fellows and scientific associates.

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También en Chile se produjeron cambios importantes. Mientras que originalmente se había fundado un centro en Santiago, a 600 km del observatorio, aumentaba la evidencia de que era difícil dotar a La Silla con la necesaria prioridad desde tal distancia. Como resultado, en 1975 se determinó trasladar todas las facilidades técnico-científicas a la montaña.

En los últimos años ESO recibió un nuevo fuerte impulso. Dos nuevos países, Italia y Suiza, decidieron formar parte de la organización y los procedimientos de ratificación finalizaron a comienzos del presente año. En parte relacionado a ésto, fue decidido agregar al parque de telescopios de La Silla el telescopio de 2,2 m de la Sociedad Max Planck y construir un Telescopio de Nueva Tecnología de 3,5 m. Además, la Agencia Espacial Europea decidió ubicar en la ESO los Servicios de Coordinación Europea para el Telescopio Espacial. Estos desarrollos indican de que ESO ha sido capaz de obtener la confianza de la comunidad europea como una efectiva organización cooperativa.

Es importante que ESO haya demostrado de que es capaz de desarrollar telescopios e instrumentación y estimular la investigación científica a un nivel comparable con el mejor existente en cualquier otro lugar. Quizás, sin embargo, su aporte más significativo es aquel hacia la integración europea. Naturalmente, el hecho de que personas de distintas nacionalidades trabajen en conjunto en relativa paz es un factor positivo. Pero la tarea de ESO va mucho más allá: ESO debe aportar su parte para crear la confianza de que Europa es capaz de ponerse sus propias metas científicas y tecnológicas y llevarlas a cabo con éxito. Solo en base a esta confianza en si misma será posible construir una Europa progresiva e independiente.

L. Woltjer, Director General

Impresiones astronómicas a color en ESO

Cuando se planificaron los laboratorios fotográficos en la nueva Sede en Garching, fue prevista también la instalación de un laboratorio a color. El equipo fue suministrado durante el año 1981 y siguiendo algunas pruebas fue encargada la máquina de procesamiento a fines de aquel año.

Luego de un período en que se produjeron impresiones a color tomadas de originales a color, ha comenzado ahora la producción de fotografías astronómicas a color. Las motivaciones para la fotografía astronómica a color no son tan sólo de orden estético sino también científico. Una fotografía a color de una vasta parte del cielo, de una compleja nebulosa, o de una galaxia activa, da informaciones inmediatas sobre la distribución de los diferentes tipos de estrellas, o sobre la diferente estructura de un objeto en particular.

El método elegido para la fotografía a color es el llamado método tricolor, el cual requiere del mismo objeto tres diferentes exposiciones en blanco y negro tomadas con diferentes filtros. Dos resultados de este método se muestran en las páginas 16 y 17 en la presente edición del *Mensajero*.

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