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The Southern Crab

H. SCHWARZ, ESO

Heavenly Crabs

The object under scrutiny in this article – a suspected symbiotic star with the prosaic name of He2-104 – looks far more like a crab than the Crab nebula. A quick look at Figure 1 will convince you that the name Southern Crab is most suitable and fully deserved! Our search for such objects was started by selection of special cases in the adapted emission line ratio diagram used by Schwarz (1988). Four possible protoplanetary nebulae were found of which He2-104 is by far the most spectacular example.

A recent literature search on He2-104 yielded 36 references. The object was classified by 17 authors as a planetary nebula (PN), by 14 as a symbiotic star, and 5 simply referred to it as an emission-line star. The spatial extent was in all cases recorded as less than 5″. Recent distance determinations based on the Cudworth method gave 6 to 7 kpc.

Near IR photometry was used to classify the object as a possible symbiotic star containing dust (Allen, 1984) and a recent IR photometric period of 400 days has been found by Whitelock (1988), indicating a Mira-like star.

No emission-line variability has been observed in the spectrum which shows lines up to [FeVII], [ArV] and HeII but also low-excitation lines like [SII], [NII] and [OI]. Generally, the spectrum is that of a dusty symbiotic star and is quite similar to that of H1-36 (Allen, 1983).

He2-104 is in the IRAS point source catalogue as 14085-5112 and has fluxes on the order of 10 Jy up to 100 micron.

New Observations

Inspection of Figure 1 shows that the object extends over about 75″ or is 15 times larger than previously thought. The three images in the light of the Hα 6563, the [NII] 6584 and the [SII] 6731 lines clearly show that the structure is different in each of the emission lines. Excitation and therefore density and

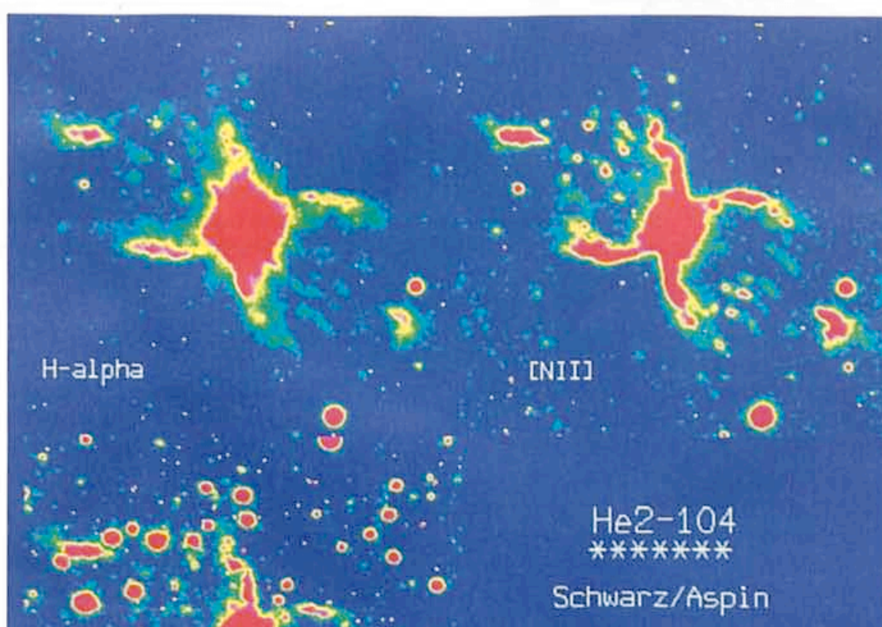

Figure 1: *False-colour images of He2-104 in the light of Hα 6563, [NII] 6584 and [SII] 6731. They have been taken with the adapter/CCD at the 2.2-m telescope at La Silla in March 1988. The exposure times are 30 minutes for the Hα and [NII] images and 1 hour for the [SII] frame. Data reduction was done at ESO, La Silla, and at the JAC, Hawaii.*

temperature vary throughout the nebula.

We interpret the object as follows. The "legs of the Crab" are bubbles formed by the red giant primary stellar wind which due to the presence of a dust torus cannot escape in the equatorial direction. The Herbig-Haro type blobs at either end are moving shocks due to a highly collimated wind from the hot secondary which is surrounded by a thick accretion disk. For more details on this kind of scenario, see Morris (1987).

High resolution spectra taken at the 2.2-m telescope at La Silla show that the radial velocity of the central object is −139 km per second. The blobs have velocities of −36 and −235 km per sec. indicating that they are moving away from the central star with at least 100 km per second. Since the object looks like being near the plane of the sky, the space velocities could be as high as 400 to 600 km per second.

Photometry in the visual and IR combined with the IRAS data have allowed us to determine the energy distribution of He2-104. From this curve the bolometric magnitude has been derived and when the fluxes are de-reddened with a measured A_V of 1.5 magnitude and assuming that the central star has a bolometric magnitude of −2 we arrive at a distance of 1 kpc. This places the object much nearer than previously thought and this is also borne out by using arguments on the size and mass limits of the ejected nebula by comparing with typical values for PNe.

Other independent estimates of the distance of He2-104 can be obtained by comparing the absorption with the 21-cm hydrogen flux in the same direction. A distance of more than about 1-2 kpc is also made unlikely by considering that with a galactic latitude of 10 degrees, the object would be out of the plane by about 1.2 kpc, assuming a distance of 7 kpc.

With our derived distance of 1 kpc the Herbig-Haro objects are at a distance from the central object of 0.2 pc giving, with the measured expansion velocity of 100 km per second, a dynamical age of the nebula of 2,000 years. Since we have ignored any projection effects on the radial velocity, this represents an upper limit to the age which could actually be as low as 300–500 years.

The Future

Clearly, more work needs to be done on this fascinating object: we have planned SEST observations to look for the presence of an SiO maser, high resolution spectroscopy to determine the velocity structure in detail and photometric imaging to find the temperature and density structure of the nebula.

IR spectrophotometry could tell us something more about the central star(s) since nothing is detected in the visual. Finally, IR imaging with the new ESO IR camera, IRAC, could provide information about the dust distribution and temperature in the object.

In the near future we hope to spend a lot more time with our southern Crab!

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Key Programmes on La Silla: First Allocations

H. VAN DER LAAN, Director General, ESO

Introduction

With the Observing Programmes Committee's recommendations in hand, early December last year, all information was available to allocate and plan the observations for Period 43 (normal programmes) and Periods 43 and 44 (Key Programmes). The scenario of preparations and decisions has precisely followed the intentions outlined in my original article in the *Messenger* of March 1988 (No. 51). Here the community is briefly informed about the procedures, the proposals and the allocations. Investigators of Key Programme Proposals successful in this first round will themselves describe their research plans in brief *Messenger* articles, starting with three such contributions in this issue and to be continued. Later in this article there is an overview of Key Programme time committed and time expected to be available for subsequent rounds, with the 15th of October 1989 as the next deadline.

Proposal Evaluation

There were 42 proposals submitted for the 15 October deadline last year. These were grouped according to the normal OPC classification (see Table 1).

The column "Comparison" in the table gives the relative numbers of proposals per class, normalized to the same total, received for periods 38 to 42 incl., more than 1,750 proposals in total. The difference, where significant, is interesting and is probably attributable to at least two factors. First, the Key Programmes concern primarily the use of the bigger telescopes (1.5-m and larger); secondly it has been emphasized, in written and verbal presentations and in discussions, that Key Programmes afford an opportunity to gently re-orient European astronomy towards fields now relatively underdeveloped in our community but obviously crucial for the VLT era. This emphasis appears to provide an appropriate stimulus, resulting in more proposals of class 1 + 2 and fewer of class 4 through 7.

For each class of programmes two referees external to the OPC, mostly but not exclusively from ESO member states, and one OPC member were asked to evaluate and grade the programmes as well as to rank them within their class. A special form designed for the purpose asked the referees to justify their grade and rank in prose. Without exception everyone approached to contribute their expertise and time towards

TABLE 1.

Class	Number of proposals	Comparison
1. Galaxies and clusters	14	8.8
2. Quasars, Seyferts, radio galaxies	8	6.2
3. Magellanic Clouds	3	3.4
4. Interstellar matter	3	5.9
5. Star clusters and galactic structure	4	3.8
6. X-ray sources	1	1.3
7. Stars	7	10.4
8. Solar system	1	1.8
9. Miscellaneous	1	0.4

TABLE 2.

Class 1: Allocation: Investigators:	**"A redshift survey of galaxies with z $\lesssim$ 0.6"** 60 nights at the 3.6 m plus NTT **De Lapparent** (Inst. d'Astrophysique, Paris)/Mazure (Univ. du Languedoc)/Mathez, Mellier (Obs. du Pic du Midi et de Toulouse)
Class 1: Allocation: Investigators:	**"Towards a physical classification of early-type galaxies"** 28 nights at the 3.6 m and 34 nights at the 2.2 m or 1.5 m Danish **Bender** (Landessternwarte Heidelberg)/Capaccioli (Oss. Astronom. Padova)/Nieto (Obs. de Toulouse)/Macchetto (STScI Baltimore)
Class 1: Allocation: Investigators:	**"A search for dark matter in elliptical galaxies"** 9 nights at the 3.6 m 16 nights at the 2.2 m **Bertola** (Ist. di Astronomia, Padova)/Bertin (Scuola Normale Superiore, Pisa)/Buson (Oss. Astronom. Padova)/Danziger (ESO-HQ)/Dejonghe (Koninklijke Sterrenwacht Brussels)/Sadler (Anglo-Australian Obs.)/Saglia (Scuola Normale Superiore Pisa)/Vietri (Oss. Astrofisico Firenze)/de Zeeuw (Inst. for Advanced Studies Princeton)/Zeilinger (Ist. di Astronomia, Padova)
Class 1: Allocation: Investigators:	**"Identification of high redshift galaxies with very large gaseous halos"** 25 nights at the 3.6 m **Bergeron** (Inst. d'Astrophysique, Paris)/Cristiani (Asiago Obs.)/Pierre, Shaver (ESO-HQ)
Class 1: Investigators:	**"Structure and dynamical state of nearby clusters of galaxies"** **Mazure** (Lab. d'Astronomie, Montpellier)/Katgert (Sterrewacht Leiden)/Dubath (Obs. de Genève)/Focardi (Dpto. Astron. Bologna)/Gerbal (Obs. de Meudon)/Giuicin (Dpto. Astron. Trieste)/Jones (NORDITA, Copenhagen)/Lefèvre (Canada-France-Hawaii Tel. Corp.)/Molès (Obs. Grenada)
Class 1: Investigators: Allocation: for the combination of the above mentioned two Key Programmes.	**"Peculiar motions of rich clusters of galaxies"** **Rhee,** Katgert (Sterrewacht Leiden) 35 nights at the 3.6 m and 5 nights at the 1.5 m Danish
Class 2: Allocation: Investigators:	**"A study of the most distant radio galaxies"** 43 nights at the 3.6 m or the NTT and 34 nights at the 2.2 m **Miley** (Sterrewacht Leiden)/Chambers (STScI, Baltimore), Hunstead (Univ. Sydney)/N.N. (La Silla Postdoc, beginning period 45)/Roland (Inst. d'Astrophysique, Paris)/Röttgering (Univ. Leiden)/Schilizzi (Radiosterrenwacht, Dwingeloo)/Macchetto (STScI Baltimore)/N.N. (Leiden Postdoc beginning Sept. 1, 1989)
Class 2: Allocation: Investigators:	**"Gravitational lensing: Quasars and radio galaxies"** 54 nights at the 3.6 m or the NTT and 48 nights at the 2.2 m and 9 nights at the 1.5 m Danish **Surdej** (Inst. d'Astrophysique, Cointe-Ougrée)/Arnaud (Canada-France Hawaii Tel. Corp.)/Borgeest (Hamburger Sternwarte)/Djorgovski (CALTECH)/Fleischmann (Phys. Inst. der Univ. Erlangen-Nürnberg, Erlangen)/Hammer (Obs. de Meudon)/Hutsemékers (ESO-La Silla)/Kayser (CITA, Univ. of Toronto)/Lefèvre (Canada-France Hawaii Tel. Corp.)/Nottale (Obs. de Meudon)/Magain (Inst. d'Astrophysique, Cointe-Ougrée)/Meylan (ESO-HQ)/Refsdal (Hamburger Sternwarte)/Remy (ESO-La Silla)/Shaver (ESO-HQ)/Swings (Inst. d'Astrophysique, Cointe-Ougrée)/Vanderriest (Obs. de Meudon)/Van Drom (ESO-La Silla)/Véron-Cetty, Véron (Obs. de Haute-Provence)/Weigelt (MPI für Radioastronomie, Bonn)
Class 2: Allocation: Investigators:	**"A homogeneous bright quasar survey"** 40 nights at the 2.2 m 50 nights at the 1.5 m 40 nights at the 1.0 m and 40 nights at the Schmidt telescope **Barbieri** (Oss. Astronomico, Padova)/Andreani (Physics Dept. Roma)/Clowes (ROE Edinburgh)/Cremonese (Oss. Astronomico, Padova)/Cristiani, Gemmo (Asiago Obs., Padova)/Gouiffes (ESO-La Silla)/Iovino (Obs. Merate)/La Franca (Asiago Obs., Padova)
Class 3: Allocation: Investigators:	**"Coordinated Investigation of selected regions in the Magellanic Clouds: Population, Structure, Evolution"** 36 nights at the 3.6 m 8 nights a the NTT and 37 nights at the 2.2 m **De Boer** (Sternwarte Univ. Bonn)/Azzopardi (Marseille)/Baschek (Landessternwarte Heidelberg)/Dennefeld (Inst. d'Astrophysique, Paris)/Israel (Sterrewacht Leiden)/Molaro (Trieste)/Seggewiss (Sternwarte Hoher List, Daun)/Spite (Obs. de Meudon)/Westerlund (Uppsala)
Class 5: Allocation: Investigators:	**"Radial velocities of southern late type HIPPARCOS stars"** 150 nights at the 1.5 m Danish **Mayor,** Duquennoy, Burki, Grenon (Obs. de Genève)/Imbert, Maurice, Prévot (Marseille Obs.)/Andersen, Nordstrøm (Copenhagen Obs.)/Lindgren (ESO-La Silla)/Turon (Obs. de Meudon)
Class 5: Allocation: Investigators:	**"Astrophysical fundamental parameters of early-type stars of the HIPPARCOS survey"** 160 nights at the 1.5 m Danish **Gerbaldi** (Inst. d'Astrophys.)/Gomez, Grenier (Obs. de Meudon)/Faraggiama (Univ. di Trieste)/Turon (Obs. de Meudon)

the refereeing effort responded positively. All reports were received in time for the OPC meeting. This participation is gratifying and ESO is pleased to acknowledge the referees' very substantial contribution to the quality of the programme evaluation.

The OPC spent one half day to discuss the Key Programmes and to complete its recommendations for the allocation of telescope time. As is well known, allocation of time on the 3.6-m, the 2.2-m and the Danish 1.5-m has long been a process of choosing between good and very good, with the cutoff line falling among the good. This was true for these proposals too. Reference to the special criteria I sketched in previous articles in this journal (Nos. 51 and 52), the prospects of some space-based telescopes and the distribution among the several programme classes all played their part in the final allocation.

TABLE 3. *Key Programme Commitments – January 1989*

	Period	43 + 44	45 + 46	47 + 48	49 + 50	51 + 52	53 + 54
Telescope	Number of nights						
3.6	K.P. Total	40 + 40	60 + 60	60 + 60	60 + 60	60 + 60	60 + 60
	Committed	15 + 31	39 + 44	14 + 22	4 + 4	0 0	0 0
	Available	–	21 + 16	46 + 38	56 + 56	60 + 60	60 + 60
NTT	K.P. Total	15 + 30	60 + 60	60 + 60	60 + 60	60 + 60	60 + 60
	Committed	14 + 19	20 + 13	16 + 13	10 + 0	10 + 0	10 + 0
	Available	–	40 + 47	44 + 47	50 + 60	50 + 60	50 + 60
2.2	K.P. Total	20 + 20	40 + 40	40 + 40	40 + 40	40 + 40	40 + 40
	Committed	21 + 43	30 + 40	17 + 28	4 + 4	4 + 4	0 0
	Available	–	10 + 0	23 + 12	36 + 36	36 + 36	40 + 40
1.5 E	K.P. Total	25 + 25	50 + 50	50 + 50	50 + 50	50 + 50	50 + 50
	Committed	16 + 24	21 + 24	21 + 24	21 + 22	21 + 22	0 0
	Available	–	29 + 26	29 + 26	29 + 28	29 + 28	50 + 50
1.5 D	K.P. Total	15 + 15	30 + 30	30 + 30	30 + 30	30 + 30	30 + 30
	Committed	19 + 25	19 + 20	16 + 18	15 + 16	15 + 15	0 0
	Available	–	11 + 10	14 + 12	15 + 14	15 + 15	30 + 30
CAT/1 m/Schmidt: Available as pressure requires.							

The First Key Programme Allocations

Table 2 gives the names and the institutional affiliation of all investigators for each successful proposal. The first name is that of the Principal Investigator/Coordinator. The class and the programme title are then given, followed by the allocation, specified according to telescope to which ESO is provisionally committed. Provisionally, because only for Periods 43 and 44 are the allocations definitive; the affirmation of the further allocations depends on the evaluation of progress reports to be submitted to the OPC each year in October.

Each one of these programmes will be introduced by one or more of the proposers in a brief *Messenger* article in the course of 1989. The authors have been asked to clearly sketch their strategy, goals and their programme's potential for opening new dimensions in European astronomy. I hope that these articles, together with the information in Table 2, will further extend existing collaborations as well as serve to inform new proposers as they prepare to compete in subsequent rounds.

The Scope of the Next Round

In late November this year the OPC will again assess Key Programme initiatives. The proposal deadline is the same as for the normal proposals that pertain to Period 45, viz. 15 October 1989. In Table 3 an overview is given of total time to be provided, time already committed, and the difference, that is the time available. The next round should fill the time for periods 45 and 46, leaving a wedge for later periods.

I have not included the CAT, the Schmidt and the 1.0-m telescope in the table. It has become clear that these instruments must also play a role in Key Programmes, often in conjunction with the use of bigger telescopes. Since the pressure on these smaller telescopes is relatively lower, they will be made available for Key Programmes as warranted by proposal pressure.

The first round was a heavy one and the allocations have been very substantial, in order to provide a flying start of the new service. Both the ESO 1.5-m and the Danish 1.5-m telescopes are heavily committed to programmes enriching the HIPPARCOS mission and new commitments in the next round that go beyond periods 45 and 46 will have to be light if there are to be opportunities in 1990 through '93. The 2.2-m MPG telescope proved very much in demand and is largely committed already for next year. For the 3.6-m and the NTT there are 124 nights available for Key Programmes initiatives in periods 45 and 46. Allocations beyond these periods have to be modest if the accumulation is not to pre-empt subsequent rounds.

In 1990 a steady state of sorts will have to be attained for the resources available each double period. Subsequent versions of Table 3 will monitor this development. They provide some guidance for users to weigh their ambitions against realistic expectations.

Some Fringe Benefits

It is obvious that the process of writing the rather extensive, often complex proposals by multinational teams, was a big chore and one that could hardly have been achieved without electronic mail networks. Even for the 70% of proposals that did not receive time in this round, that effort is not wasted and may well serve to guide collaborative research of a more modest scope in the near future. In any case, one disappointment need not deter another try. A conversation with the national representative in the OPC may also improve the next version as will a very critical look at the transparency of presentation and the balance between time requested and results hoped for.

Several successful Key Programmes have led to small workshops among the proposers, as they get their act together for the heavy observing schedules and reduction labour ahead. In one case I organized a two day get-together at ESO Headquarters to induce the teams of half a dozen responses to the preliminary enquiry one year ago, to work together. The major initiative for Magellanic Cloud research, coordinated by K.S. de Boer in Bonn and combining these teams' intentions, was the result. I hope this coordination will have a seminal effect upon investigations of the Clouds that will spill over even beyond the scope of this far ranging specific programme. Another example of a fringe benefit is the renewed interest in the ESO Schmidt telescope as a research tool, discussed in a Garching workshop in early February. The outcome will be reported in one of the next issues of the *Messenger*. One year after the Key Programme initiative it may be concluded that at least one goal: more European and more ambitious interaction, is being achieved.

A Redshift Survey of Galaxies with $z \lesssim 0.6$ Using Multi-Object Spectroscopy

V. DE LAPPARENT, Institut d'Astrophysique de Paris, France
A. MAZURE, Laboratoire d'Astronomie de Montpellier, France
G. MATHEZ and Y. MELLIER, Observatoire de Toulouse, France

Through the steady acquisition of redshifts of galaxies, our understanding of the large-scale galaxy distribution has evolved drastically during the past decade. Most recently, the Centre for Astrophysics (CfA) redshift survey ($B \leq 15.5$) has suggested a new picture of the galaxy distribution: galaxies appear to be distributed on thin shells surrounding vast regions with diameters between 20 and 50 h^{-1} Mpc (H_0 = 100 h km s^{-1} Mpc^{-1}) devoid of bright galaxies (de Lapparent, Geller, and Huchra 1986). This new interpretation of the galaxy distribution is consistent with the detection of a 60 h^{-1} Mpc void in Boötes (Kirshner et al. 1981) and with the alternation of peaks and ~ 100 h^{-1} Mpc wide valleys in deep pencil-beam probes (Koo, Kron, and Szalay 1987). Shell-like structures are also detected in redshift surveys of H I galaxies (Haynes and Giovanelli 1986).

Although the CfA redshift survey is unique in its combination of large angular coverage and depth, it does not represent a fair sample of the universe: the size of the largest coherent structures (~ 50 h^{-1} Mpc) is comparable to the spatial extent of the survey (~ 100 h^{-1} Mpc). Deeper redshift surveys are therefore necessary for measuring the mean statistical properties of the large-scale clustering. Deep surveys can constrain the size and frequency of the shells, and thus complement nearby wide-angle surveys which provide information about the details of the galaxy distribution within the shells. In an attempt to satisfy the need for deep surveys, we have designed a redshift survey programme ~ 15 times deeper in velocity than the CfA redshift survey.

Our programme aims at the acquisition of a complete galaxy catalogue to $R \sim 20.5$, with BVR photometry and low-resolution spectroscopy ($\Delta\lambda \sim 10$ Å). We will start the observations on the 3.6-m using the ESO Faint Object Spectrograph and Camera (EFOSC; Buzzoni et al. 1984) for both imaging and spectroscopy. We will take full advantage of the multi-object spectroscopy capability of EFOSC provided by the Punching Machine (PUMA), which allows real time drilling of multiple slits into aperture plates (Fort et al. 1986). At $R \leq 20.5$, there are on the average ~8 galaxies per ~3.5 × 5′ field of EFOSC, and the slit spectra of ≲ 10 galaxies can be obtained simultaneously (as demonstrated during two previous observing runs). When the ESO Multi-Mode Instrument (EMMI; D'Odorico et al. 1986) becomes available on the NTT with the multi-slit mode (1990), we will switch to the NTT. The larger field of view planned for EMMI (7′ × 10′ with a new-generation CCD) will result in a time gain of a factor ~3 for the photometry and a factor ~2 for the spectroscopy. The total observing time (60 nights) will be spent in the proportion of ~ ⅛ for imaging and ~⅞ for spectroscopy.

We will survey a strip with a total area of 0.4 deg^2, in a region near $\alpha \simeq 22^h$ and $\delta \simeq -30°$, located at high galactic latitude ($b^{II} \sim -50°$). Measurement of the redshifts of the ~700 galaxies in the survey region will provide a unique data base for studying the clustering on very large scales. With its effective depth of $z \sim 0.6$ (~1400 h^{-1} Mpc with q_0 = 0.1), our survey could intercept along the line of sight ~45 shells with mean diameter 30 h^{-1} Mpc. The size of the projected area surveyed by the strip at 1400 h^{-1} Mpc, ~6 × 45 h^{-2} Mpc^2, can be compared to the characteristic scales for the structures in the CfA redshift survey (mean separation of galaxies in the shells – a few h^{-1} Mpc –, and diameter of the shells). This comparison suggests that the deep survey will sample the structures with a sufficient spatial coverage for delineation of the individual shells.

The deep redshift survey will indicate whether the nearby voids are typical in size, and whether larger inhomogeneities exist. The contribution of large voids dominates the uncertainty in the mean number density of galaxies. This uncertainty in turn introduces a large scatter in the determination of the two-point correlation function (de Lapparent, Geller, and Huchra 1988), an important tool for constraining the power spectrum of primordial fluctuations at large-scale (Peebles 1980). In addition, the survey will provide information on the spectrum of shell diameter, and therefore, will tightly constrain the N-body models for the formation of large-scale structure (Melott 1987; White et al. 1987; see also Ostriker and Vishniac 1986). The large number of individual structures sampled by the survey will also allow to put direct limits on evolution in the large-scale clustering with redshift.

The other major goal of the programme is to examine the spectrophotometric evolution of field galaxies. Catalogues of distant clusters of galaxies (Butcher and Oemler 1978; Butcher and Oemler 1984; Dressler, Gunnn, and Schneider 1985; Lavery and Henry 1986) suggest a significant evolution at $z \sim 0.5$ in the "blue" population of clusters. Deep galaxy counts suggest a similar effect in the field at $B \gtrsim 24$ (Koo 1986; Tyson 1988), suggesting UV excess from massive star formation in galaxies at $z \sim 1–3$. The availability of redshifts for the galaxies in our survey will allow to recover their intrinsic colours and thus distinguish evolution from cosmology. We will then be able to estimate the fraction of intrinsically "blue" galaxies [$(B-V)_{intr} \lesssim 0.7$] per redshift interval. Examination of the spectral features will yield information on the nature of these "blue" galaxies (see Dressler and Gunn 1983), and thus will provide a test for the interpretation of the "blueing" trend as originating from extensive star formation. A study of the variations in the fraction of "blue" galaxies with the local galaxy density might also provide some insight into the influence of the environment on the process for galaxy formation.

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PROFILE OF A KEY PROGRAMME

Towards a Physical Classification of Early-type Galaxies

R. BENDER, Landessternwarte, Heidelberg, F.R. Germany
M. CAPACCIOLI, Osservatorio Astronomico, Padova, Italy
F. MACCHETTO, Space Telescope Science Institute, Baltimore, USA
J.-L. NIETO, Observatoire de Toulouse, France

Hubble was the first who succeeded in classifying galaxies within a scheme of some physical meaning. Although it soon became clear that Hubble's *tuning fork* does not represent an evolutionary sequence, this essential diagram has proven to be a powerful tool especially for the understanding of late-type galaxies. On the other hand, the "early-type" sequence of elliptical (E) and S0 galaxies is less satisfying, because it does not seem to reflect a unique sequence of physical properties. The S0 class, although conceived to bridge the gap between disk- and disk-less galaxies, has often been abused to host ellipticals exhibiting peculiarities incompatible with their definition as structureless objects. For the elliptical galaxies themselves, "ellipticity" has been found to be essentially meaningless with regard to their angular momentum properties, and shows little, if any, correlation with other global parameters. This fact became apparent after the first stellar kinematical measurements of luminous ellipticals (Bertola and Capaccioli 1975, Illingworth 1977): E galaxies are not necessarily flattened by rotation and may have anisotropic velocity dispersions (Binney 1978).

A first step towards a physical classification of early-type galaxies was the investigation of the correlations between the classical global parameters (luminosity, scale length, projected central velocity dispersion, central density, and metallicity/colour). These parameters were found to form a plane in the parameter space ("the fundamental plane"). More specifically, each of these global parameters can be given as a function of two independent parameters, namely in general the central velocity dispersion and the mean surface brightness. The fundamental plane corresponds to the cooling diagram plane of modern theories of galaxy formation, which are based on the self-regulation of the dissipative collapse of protogalaxies (Silk 1983, Blumenthal et al. 1984).

In contrast to the "global" parameters, those describing the detailed shape and kinematics of early-type galaxies (ellipticity gradients, isophotal twists, trends of radial light profiles, velocity anisotropies, etc.) do not correlate with the fundamental plane. This lack of correlations has instilled further suspicion that even the Hubble E class alone is not physically homogeneous (Capaccioli 1987). Indeed, while all ellipticals share roughly the same morphological appearance, they may nonetheless belong to genetically distinct families (see Bender et al. 1988, Nieto 1988, Prugniel et al., 1989). The consequences of this hypothesis are more dramatic than having the E galaxies populate a "2 + N" parameter space (e.g. Djorgovski and Davis 1987, Dressler et al. 1987) since a physical segregation of E types would bear directly on our understanding of the formation/evolution of the different species of galaxies.

An effective tool for separating E galaxies into at least two physically distinct classes has been recently identified with a simple and direct observational parameter which measures the lowest-order axisymmetric deviation (a_4) of the galaxy isophotes from perfect ellipses (Bender 1987). This parameter, easily extracted from good S/N images by Fourier analysis, discriminates between "boxy" ($a_4 < 0$) and "pointed" ($a_4 > 0$) isophotes (e.g. Lauer 1985, Bender and Möllenhoff 1987, and Jedrzejewski 1987).

Bender et al. (1988, 1989) and Nieto (1988) found that these two "shape-classes":
(a) contain ≈80% of all Es, and
(b) isolate objects with distinct physical properties.
More specifically, boxy ellipticals are frequently radio-loud (the power being a function of the mass) and permeated by gaseous "halos" (as inferred from their X-ray emission), while ellipticals with pointed isophotes are usually undetected in the radio and X-ray bands (Fig. 1). There is also a clear segregation of the kinematical properties between these two classes: in most cases boxy ellipticals are flattened by anisotropic velocity dispersion while "pointed" E's are rotationally supported (Bender 1988a, Nieto et al. 1988; see Fig. 2).

The nature of "pointed" E's is easily understood if one assumes (Nieto et al. 1988) that they are internally structured

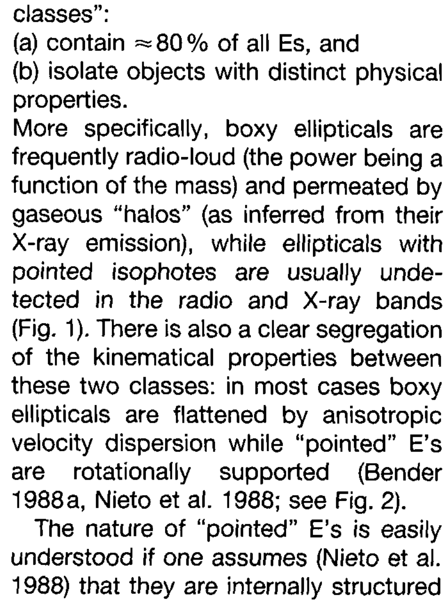

Figure 1: *Logarithm of radio luminosity at 1.4 GHz against isophotal shape parametrized by a(4)/a(a(4)/a < 0 indicates boxy isophotes, a(4)/a > 0 disky isophotes). Below the dashed line most symbols indicate upper limits (Bender et al. 1989).*

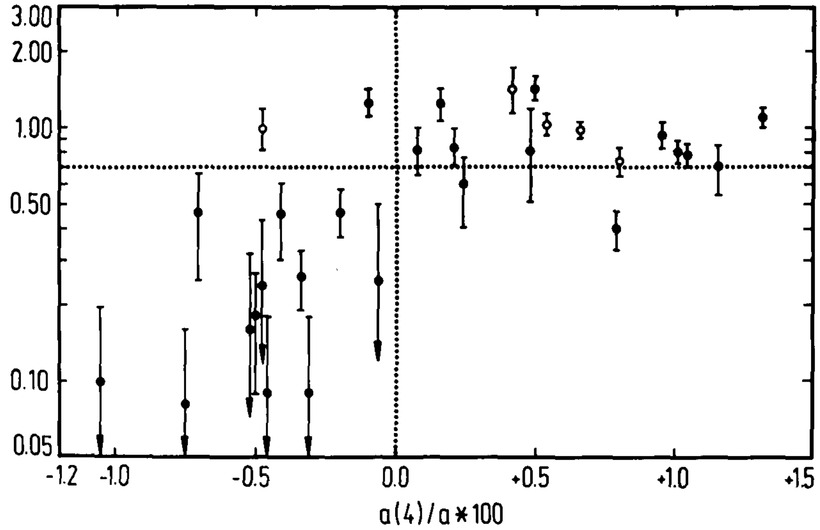

Figure 2: *Anisotropy parameter $(V_m/\sigma)^*$ against isophotal shape parameter* a(4)/a. *Boxy ellipticals are in most cases supported by anisotropic velocity dispersions (i.e. $(V_m/\sigma)^* < 1$), while nearly all disk-ellipticals are rotationally flattened objects showing $(V_m/\sigma)^* \approx 1$. Open circles indicate ellipticals less luminous than* $M_T = -20.5$ *(H_o = 50 km/s/Mpc), while filled dots indicate objects above* $M_T = -20.5$ *(Bender 1988a).*

like classical S0's (the pointed isophotes being reasonably interpreted as caused by the superposition of an edge-on stellar disk and an ellipsoidal bulge). Actually, a strong morphological similarity has already been firmly established for those few "disk"-E's where the faint edge-on disk has been disentangled from the bright bulge (Carter 1987, Capaccioli 1987, Capaccioli et al. 1988). Although faint disks harboured in disk-E's obviously have no direct dynamical consequence on host-galaxy evolution, they are nevertheless symptomatic of strong physical differences in intrinsic shape and internal kinematics as compared to boxy E's.

The physical nature of boxy E's is not so clear. Boxy ellipticals are not only anisotropic objects, but also present peculiarities such as, e.g., kinematically misaligned or even counter-rotating cores (Franx and Illingworth 1988, Bender 1988b, Jedrzejewski and Schechter 1988) and other features generally recognized as signatures of *recent* accretion or merging processes (Nieto, 1988). This strongly suggests that boxiness (at least in these objects, see Nieto and Bender, 1989) is related to these violent phenomena. The distinct kinematical differences between boxy and disky E's shed light in particular on the large scatter in velocity anisotropies of luminous ellipticals (the (M_T, $(V_m/\sigma)^*$) diagram, Davies et al. 1983).

What fraction of elliptical galaxies belong to each class? A rough estimate can be obtained from the investigation of a sample of 47 elliptical galaxies of the *Revised Shapley-Ames Catalogue of Bright Galaxies* (Sandage and Tammann 1981) performed by Bender et al. (1988): ~1/4 of bright elliptical galaxies exhibit nearly edge-on stellar disks. From the statistics of inclination angles, one therefore expects that up to 50% of luminous elliptical galaxies could in fact be disk-galaxies with very low D/B ratios ($D/B < 0.05$).

Although the segregation of elliptical galaxies into at least two distinct physical classes seems to be well established now, the cosmological interpretation of this finding is still open. The two classes certainly reflect different historical pasts in terms of interaction with the environment, notably at early stages of galaxy formation.

In particular, it seems that disk-E's, together with S0's and spirals, belong to a continuous sequence in disk-to-bulge ratio ("D/B"), which in turn appears to be related to the *specific* angular momentum (Fig. 3). Therefore, since the frequency of morphological types depends on the density of the environment (Dressler 1980), the discovery of two classes of E's is expected to give new insights in the relation between D/B ratios, the environment and the process of acquiring angular momentum during the primordial collapse phase (see e.g. Barnes and Efstathiou 1987). In addition, comparing the disk properties along the D/B sequence is certainly important in order to understand the mechanisms driving the formation of these flat components; this is not a trivial aspect since disk properties (exponential decline and same central surface brightness μ_o for all objects) are suspected to be independent of the D/B values (van der Kruit 1987, Capaccioli and Vietri 1988).

Unlike disk-E's, whose structure seems to result from initial conditions, boxy E's are probably produced by *recent* violent mergings. However, we

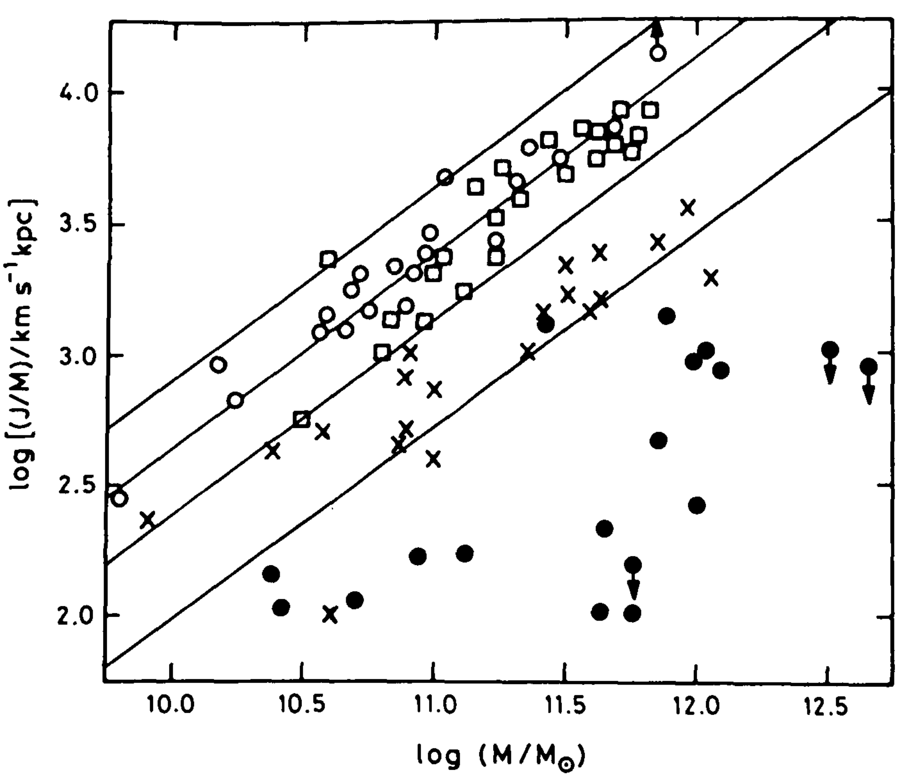

Figure 3: *Specific angular momentum* J/M *(calculated from half-light radius and maximum rotation velocity) against mass in solar units for different types of objects. Sc and Sb galaxies are represented by open circles and squares (adapted from Fall 1983), disk-E's by crosses, and boxy E's by filled circles (Bender et al. 1989, in preparation).*

cannot exclude that boxy E's just represent extreme examples of enivronmental evolution at early phases of galaxy formation. The physical state of the hot interstellar medium, which is present in many of these objects, is certainly of importance for the understanding of formation and present-day evolution of boxy ellipticals.

In summary, the isophotal shape analysis offers a new methodology/tool for a complete revision of the classification of early-type galaxies and our understanding of the underlying formation mechanisms/conditions, provided it is applied to a significant and statistically meaningful sample of objects (in the same way the Hubble classification scheme was applied before). This revision obviously requires a huge research project.

Our key-programme is an attempt to collect all the observational and theoretical expertise to coordinate the efforts toward an effective solution of the problem outlined above. As a first step of the project, we aim to investigate the occurrence of faint stellar disks in E galaxies, their properties, origin, significance, and relation to their analogues in S0's. Surface photometry will be supplemented by kinematical analyses in order to investigate the kinematical behaviour of the spheroids and the distribution of their specific angular momentum. Narrow-band images will be used to study the properties of the interstellar medium and relate the gas properties to the other galaxian parameters (shape of potential, X-ray emission, etc.).

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PROFILE OF A KEY PROGRAMME

Gravitational Lensing

J. SURDEJ[1], J. ARNAUD[2], U. BORGEEST[3], S. DJORGOVSKI[4], F. FLEISCHMANN[5], F. HAMMER[6], D. HUTSEMEKERS[7], R. KAYSER[8], O. LE FEVRE[2], L. NOTTALE[6], P. MAGAIN[1], G. MEYLAN[9], S. REFSDAL[3], M. REMY[7], P. SHAVER[9], A. SMETTE[9], J.P. SWINGS[1], C. VANDERRIEST[6], E. VAN DROM[7], M. VÉRON-CETTY[10], P. VÉRON[10] and G. WEIGELT[5]

[1] Institute of Astrophysics, University of Liege, Belgium; [2] Canada-France-Hawaii Telescope Corporation, Hawaii; [3] Hamburg Observatory, F.R. Germany; [4] Astronomy Department, California Institute of Technology, Pasadena, USA; [5] Physics Institute of the Erlangen-Nürnberg University, F.R. Germany; [6] Meudon Observatory, France; [7] European Southern Observatory, La Silla, Chile; [8] CITA, University of Toronto, Canada; [9] ESO, Garching, F.R. Germany; [10] Haute-Provence Observatory, France

Prior to Professor van der Laan's enquiry, in the March 1988 issue of the *Messenger,* on the general interest among astronomers from the European community to possibly participate in Key Programmes (KPs) at the European Southern Observatory, at least three distinct groups (including more than half of the above authors) were already involved in the study of "gravitational lensing" effects (see box on pages 10–11). Observations were being performed with the help of various telescopes on La Silla as well as at other observatories (VLA, CFHT, Palomar, Kitt Peak, etc.).

A general feeling existed that our individual work was progressing very slowly, the number of effective nights that were allocated to our programmes being modest, also very much dependent on unknown weather and/or seeing conditions, on possible instrument failures as well as on the sometimes unpredictable decisions of the programme committees. We all knew that there was a total absence of coordination between our independent programmes and that, of course, we could not avoid duplicating observations of similar objects. Furthermore, each or our teams was hoping very much to broaden its observational interests: those studying "highly luminous quasars" wished to look also at distant "radio galaxies", and vice-versa, but this would remain a mere dream until . . . it became really possible for our present team to submit an ESO Key Programme entitled "Gravitational lensing: quasars and radio galaxies". We do feel very fortunate to-day since our programme has been generously allocated 54 nights with the ESO 3.6-m and/or NTT telescopes, 48 with the ESO/MPI 2.2-m telescope and 9 effective nights with the 1.5-m Danish telescope during the next three years, starting effectively during period 43 (April 1–October 1, 1989). We should like to describe briefly hereafter the main goals of our programme and say a few words about the different instruments and techniques that we intend to use.

The Importance of Gravitational Lensing Effects

Following the discovery of the first example of a multiply lensed quasar (Walsh et al., 1979), there has been increasing evidence that gravitational lensing perturbs, to a significant extent, our view of the distant Universe (see Nottale, 1988 for a review on the subject). Gravitational mirages are indeed being identified among QSOs, especially among highly luminous quasars (Surdej et al., 1987, 1988a–c; Magain et al., 1988; Meylan and Djorgovski, 1989), among distant 3C and 4C radio galaxies (Le Fevre et al., 1987, 1988a–b; Hammer et al., 1987; etc.) and as giant luminous arcs lensed by individual foreground galaxies and/or their associated cluster(s) (Soucail et al., 1987a–b, 1988; Lynds and Petrosian, 1986, 1988; Hammer et al., 1988).

Highly significant statistical effects of "gravitational amplification" have also been reported for various samples of extragalactic objects. For instance, the case of anomalous quintets – as well as other tight groups – of galaxies has been accounted for by the lensing of quartet haloes on background galaxies (Hammer and Nottale, 1986a). Good evidence for gravitational amplification by intervening matter (stars, galaxies, clusters, etc.) has been set forward for the Brightest Cluster Galaxies (Hammer and Nottale, 1986b), for quasars with the richest absorption line spectra (Nottale, 1987) and for a selected sample of flat-radio spectrum quasars (Fugmann, 1988). Furthermore, it has been suggested that the variability of some eruptive quasars such as 0846+513, 3C446, etc., is a direct consequence of gravitational lensing by stars or compact objects located in galaxy haloes (Nottale, 1986). These so-called "microlensing" effects had been predicted by Chang and Refsdal (1979, 1984). Finally, speculations have been made that the second observed rise in the comoving density of quasars from $z \approx 2.45$ up to at least $z = 3.8$ (Véron, 1986) could be due to statistical gravitational lensing effects by foreground objects near the lines-of-sight.

A Quest for New Observations

The answer to the question "what fraction of extragalactic objects are gravitationally lensed?" is very closely related to that of "how do the visible and dark matter distributions look at different scales in the Universe?". It turns out that any prediction made for the expected number of gravitationally lensed quasars, radio galaxies, etc. is bound to be very model dependent. We conclude that it is essential to carry out a systematic observational search and study of gravitational lensing effects in order to better understand the luminosity function of quasars, distant radio galaxies, etc., their observed number counts, their apparent cosmic evolution and the basic physical mechanism(s) powering these energetic objects. The proposed observations will also allow us to determine the Hubble parameter (Refsdal, 1964, 1966; Borgeest and Refsdal, 1984; Gorenstein et al., 1988) as well as galaxy masses (Borgeest, 1986) on account of the expected time delay between the brightness variations of multiply lensed QSO images. More generally, we shall obtain information on the distribution of luminous and dark matter at various scales in the Universe. Furthermore, information on the size and structure of quasars should be derived from the observation of micro-lensing effects (Grieger et al., 1986, 1988).

Our Choice of Gravitational Lens Candidates

We do consider that the apparently ($m_v < 18.5$) and intrinsically ($M_v < -29$) highly luminous quasars (hereafter HLQs) as well as the distant ($z > 1$) powerful ($P(178\,\mathrm{MHz}) > 10^{28}$ W/Hz) radio sources (hereafter DPRSs) constitute the best extragalactic candidates to search for the presence of gravitationally lensed images at arcsec./sub-arcsec. angular scale resolutions and/or for a brightness amplification due to an excess of foreground objects (galaxies, clusters) in the vicinity of the relevant targets. The technical arguments leading to this assumption may be found in Surdej et al. (1988c). High angular resolution imaging of selected HLQs and DPRSs with the ESO/MPI 2.2-m telescope (plus direct CCD camera/DISCO or digital speckle camera) under optimal seeing conditions (FWHM < 1.″2) is likely to give important clues on our understanding of lensing effects by galaxies, clusters and/or any other class of unknown massive objects. Recent systematic searches for lensed QSO images with the 2.2-m telescope have already led to the discovery of three new cases of multiply lensed HLQs: ESO GL1 = UM 673 (Fig. 2a), ESO GL2 = H1413+117 (Fig. 2b) and ESO GL3 = UM425 (Fig. 2c). Similarly, several multiple DPRSs have been identified among the distant 3C radio sources at Mauna Kea using the CFH telescope; strong arguments supporting the mirage hypothesis have been obtained for one of them: 3C324 (Le Fevre et al., 1987). Of special interest is that a detailed comparison between CCD frames obtained for a sample of 30 distant 3C radio sources with $z > 1$ and randomly selected fields indicates a significant excess of bright foreground galaxies and Abell/Zwicky clusters near the 3C sources (Le Fevre and Hammer, 1989). It seems that gravitational amplification by foreground galaxies and rich clusters is at least partly responsible for the observed radio and optical luminosities of the bright 3C sources.

Further Proposed Observations

We intend to monitor under very good seeing conditions (FWHM < 1.″2) the three ESO gravitational lens systems mentioned above plus the Einstein cross 2237+031 (Huchra et al., 1985). UM 673 (cf. Fig. 2a) constitutes our best candidate to attempt an independent determination of the Hubble constant H_o, and hence to set an upper limit to the age of the Universe, while 2237+031 appears to be the most ideal object for detection of micro-lensing effects. It will be imperative to monitor each of the four proposed targets about once a week with the ESO 3.5-m NTT and/or ESO/MPI 2.2-m and/or 1.5-m Danish telescopes through a B filter. We wish to thank in advance, for their comprehension, all observers at La Silla with whom we shall routinely share observing nights during some 90 minutes.

Furthermore, because one expects most of the multiply lensed QSO images to have angular separations of less than 0.″5 (e.g. Turner et al., 1984), we wish to image approximately 50 HLQs with speckle masking. We recall that speckle masking is an interferometric imaging method that yields diffraction limited images with 0.″05 resolution in spite of image degradation by the atmosphere

Figure 1a: *Sunset from La Silla (16 November 1988).*

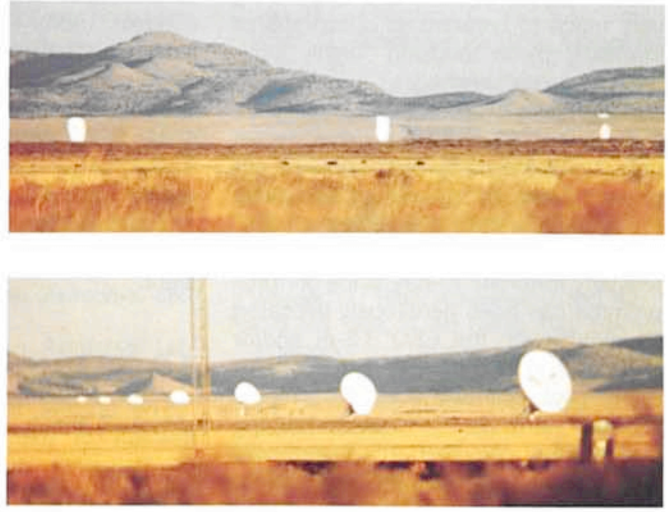

Figure 1b: *Two different views of the VLA as seen in the early morning of 17 January 1989 (Socorro, New Mexico).*

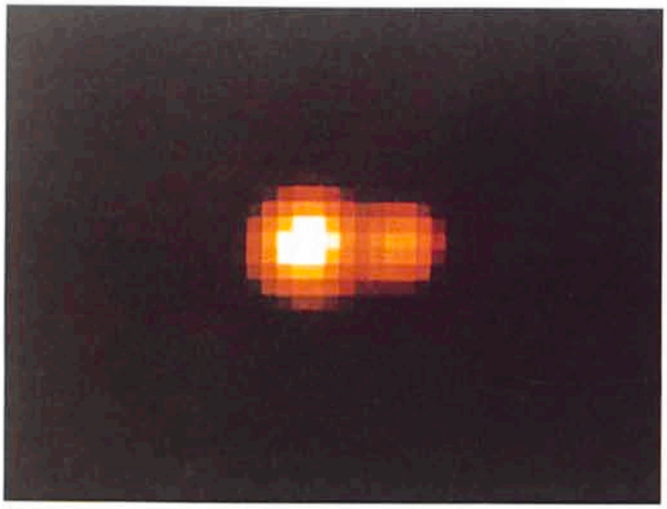

Figure 2a: *The double quasar ESO GL 1 = UM 673* (Nature **329** *695).*

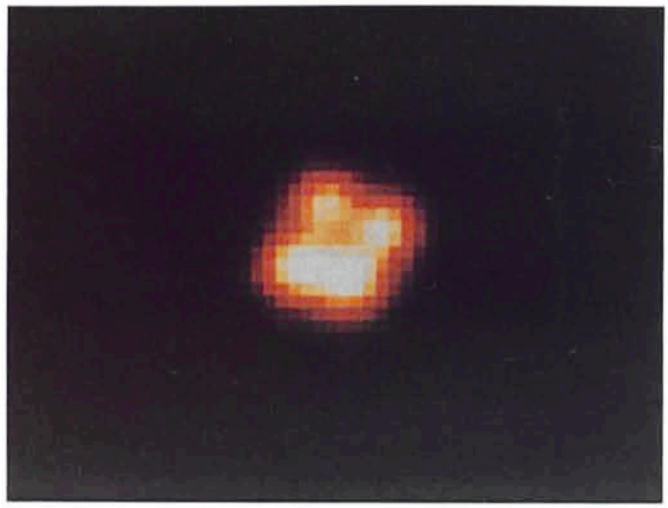

Figure 2b: *The Clover-leaf ESO GL 2 = H1413+117* (Nature, **334,** *325).*

Gravitational fields in the Universe may act on light rays emitted by distant sources in a way very similar to the refraction properties of our atmosphere, or to the way lower air layers act on objects located near the horizon (cf. the Sun in Fig. 1a or the Very Large Array or car lights at night in Figs. 1b–c).

Fig. 1d gives a schematic representation of the light ray paths when the ground turns out to be somewhat hotter than the ambient air (cf. around noon on a sunny day). Because the refraction always bends light rays towards regions of colder air, a second lower, inverted and somewhat deformed–image of the source (a palm-tree in this case) may result. Such a multiplication, deformation and also amplification of different source images are readily seen in Figs. 1a–c.

Since the total solar eclipse of 1919, when astronomers observed for the first time an apparent displacement in the positions of stars near the limb of the Sun, it was recognized that light beams can be bent, not only in air layers having different densities or in optical systems, but also in gravitational fields. As a matter of fact, this effect was predicted by Einstein within his General Theory of Relativity. Bending of light is also observed when the light from a distant quasar,

and by telescope aberrations (Weigelt and Wirnitzer, 1983).

In addition, since gravitational amplification of a compact or extended source by large-scale foreground inhomogeneities (cf. rich galaxy clusters, etc.) may very well occur without multiplication of images, a detailed comparison of the count number of field objects (galaxies, clusters) will be made between the R CCD frames taken for the HLQs, the DPRSs and randomly selected fields. This unprecedented statistical study combined with the observed frequency of detecting multiply lensed images versus their angular separation should enable us to quantify the importance of lensing effects as a whole.

We also plan of course to perform detailed photometric and spectroscopic studies of the immediate surroundings and projected intergalactic medium near known, suspected and expected new ESO gravitational lens systems.

Acknowledgements

Our recognition naturally goes to Prof. van der Laan for having promoted so convincingly the idea of the ESO Key Programmes in the European community. Our thanks are also due to the Observing Programmes Committee and to the external referees for their patient (and somewhat hidden) work. We specially thank Jacques Breysacher and Christa Euler, for gently orchestrating the non trivial task of scheduling all our

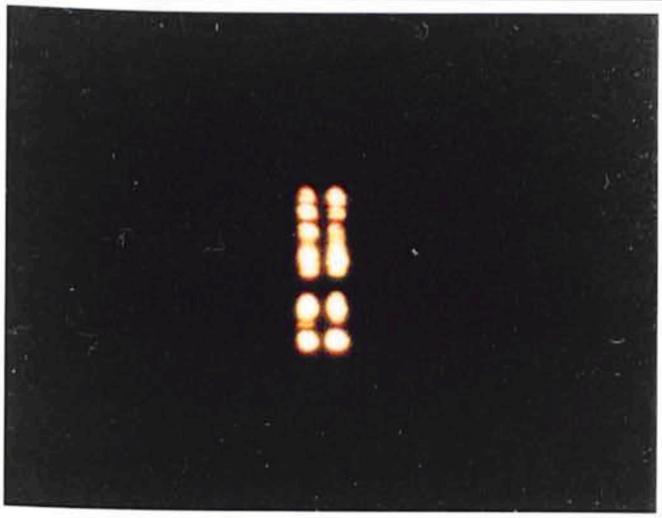

Figure 1c: *Lights from a distant car on the national road between Magdalena and Datil (New Mexico, 16 January 1989).*

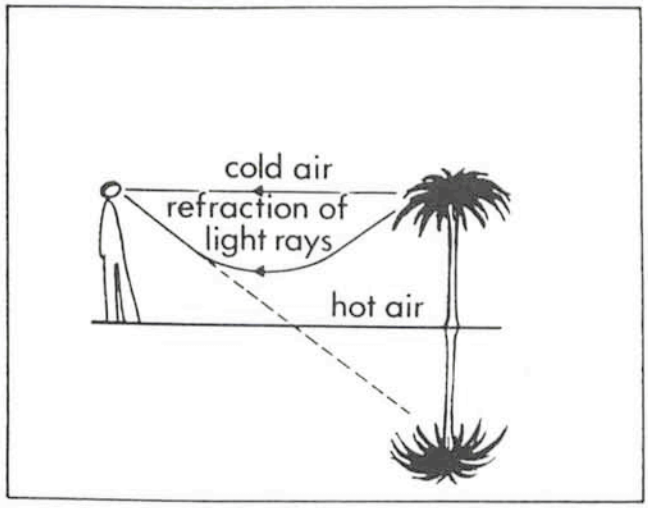

Figure 1d: *Explanatory diagram: formation of terrestrial mirages.*

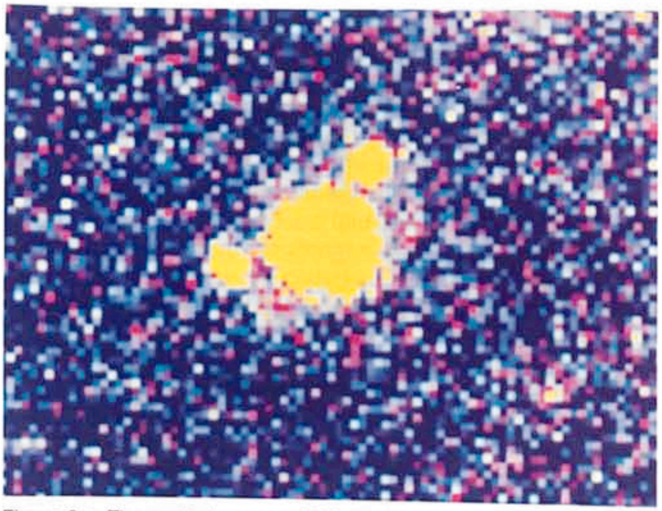

Figure 2c: *The multiple quasar ESO GL 3 = UM 425* (Ap. J. *Letters, in press).*

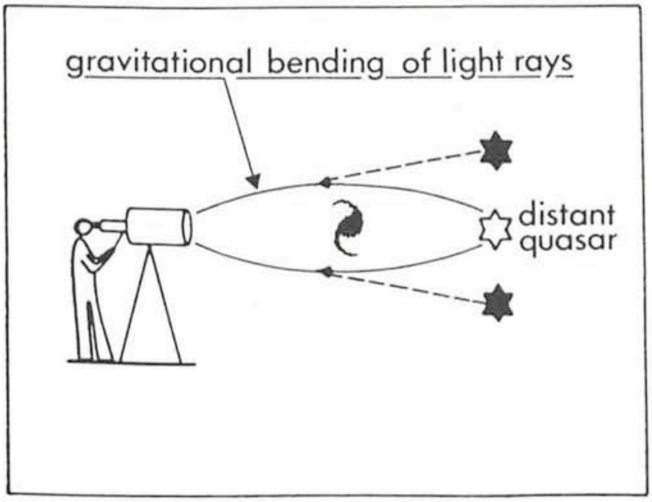

Figure 2d: *Explanatory diagram: formation of gravitational mirages.*

galaxy or any other astronomical source passes close by one or more massive objects on its way to us. Such objects may be individual galaxies (cf. Fig. 2d), clusters of galaxies or even larger structures in the Universe. This effect is referred to as the so-called "gravitational lensing". Depending on the intensity and form of the gravitational field, the light from the quasar may not only be bent into multiple images, but some of these images may become brighter than the quasar itself would have appeared in the absence of the gravitational lens (cf. Figs. 2a–c). This is referred to as "light amplification". Due to the amplification effect, we may be able to observe gravitationally lensed images of very distant quasars, galaxies, etc. which would otherwise have been too faint to be detected with present telescopes. Gravitational lenses may therefore act as giant telescopes, allowing us to investigate otherwise inaccessible, very remote regions of the Universe. It is partly in order to evaluate the extent to which our view of the distant Universe corresponds to a still unveiled mirage, and not to the real Universe, that we have proposed to perform the studies summarized in the present article.

requested observations.

Finally, we apologize for not having quoted in this short note the works of all scientists having contributed to the progress of our knowledge in the field of gravitational lensing; they are simply just too numerous!

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The New Research Student Programme of the European Southern Observatory

H. VAN DER LAAN, Director General, ESO

For many years ESO has appointed young astronomers as Fellows to work one to two years at Headquarters or on La Silla. The HQ Fellows spend the greater part of their efforts on personal research, the Fellows on La Silla split their time roughly 50/50 between their research and support astronomy duties. The ESO Fellowship programme has successfully contributed to the development of young scientists from member states into mature research astronomers. It has also promoted the interaction among investigators from many places and traditions, interactions that continue long after the collaborators have left their ESO posts. This postdoctoral Fellowship programme continues undiminished.

Henceforth ESO is also offering Studentships, about 8 appointments per year, equally shared between Garching and La Silla. This article introduces this new predoctoral Studentship Programme.

Selection and Studentship Conditions

ESO aims at having sixteen such graduate students in the Organization's establishments at any time. The programme will be semi-annually announced in the *Messenger* and by the circulation of announcements in member states' institutes. Applicants have to make use of a form designed for the purpose and available upon request from Personnel and General Services at Headquarters. Deadlines for application will be May 1st and December 1st. Appointments can commence throughout the year.

Students whose duty station is the Garching Headquarters, will be required to spend at most 25% of their official working time on duties in support of Visiting Astronomers (users of measuring machines, of computers with the IHAP and MIDAS data reduction systems, and astronomers using the Remote Control Observing Facilities). Students on La Silla will normally be part of the team in the La Silla astronomy department that provides introductions and observational support to Visiting Astronomers. Typically, half their official working time will be occupied by these duties.

Students are appointed for one year, normally renewable by a second, final year. During their studentship term, they may have diverse forms of support from their home institution. ESO will supplement these to a maximum, total stipend of DM 2200/month during the first year.

For many years young astronomers and engineers from France, called coopérants, have worked on La Silla in national service, which is an alternative to military duty. More recently Belgium and Italy also offer such "coopérant" programmes. Henceforth ESO will require coopérants, whether at HQ or on La Silla, to meet at least the same requirements as candidates for studentships. Coopérants are normally preselected by national selection committees and then proposed to ESO. Some coopérants already have a doctor's degree and are then regarded as Fellows. Where they are selected by studentship criteria the coopérants will henceforth be counted as part of the contingent of 16 students.

Selection Criteria – Necessary Conditions

- Candidates must be registered postgraduate students at a recognized university in an ESO member state.
- Candidates must have at least an outline of their Ph.D. dissertation programme and a professor who accepts responsibility for that programme and the student's supervision.
- The candidate must have fulfilled the normal course- and examination requirements for the Ph.D., except the dissertation research.
- The candidate's programme must be such that it can be successfully pursued at ESO HQ or on La Silla, because of its affinity with work going on there and facilities available for the student.
- The candidate's university must guarantee the conditions necessary for the student to complete her/his dissertation after the tenure of the ESO Studentship.
- An ESO staff member must be prepared to be the student's local supervisor and mentor, notwithstanding the continuing responsibility of the student's university supervisor.

From this list it should be obvious that ESO in no way seeks to play the role of a degree-granting institution. The programme means to provide opportunities, circumstances and facilities which enhance the participating universities' postgraduate programmes and enrich selected students' early research experience. The conditions listed above are necessary. From among applicants potentially capable of meeting them, ESO will select those whose talents and circumstances are best attuned to the programme's goals.

Groups Where Research Students May Work

There is a brochure in preparation, available in a few months, which will describe the programme in some detail.

For the moment the following brief indications suffice. It is expected that most of the studentships will be offered in the Astronomy Group of the Science Division at Headquarters in Garching and in the Astronomy Department at the La Silla Observatory. In addition, more instrumentally oriented students may work in one of three groups in the Project Division at Headquarters, viz. Optical Instrumentation, Infrared Instrumentation and High Resolution Imaging and Interferometry. Computer science students may find possibilities in the Image Processing Group of the Science Division, and occasionally physics or engineering students can be engaged in one of the three discipline groups of the Technology Division, viz. Electronics, Optics and Mechanics.

On La Silla, the latter interests may also be served in the department called Technical Research Support. The just mentioned technology disciplines are also practised in the TRS. Finally the SEST group, running the Swedish-ESO submillimetre telescope on La Silla, and the group known as VLT Site Services provide a good context for a variety of astronomical, technical and atmospheric research interests.

ESO Motives for the Studentship Programme

There are many, most quite obvious, and I mention but a few. ESO is firstly a service organization for European astronomy. To fulfil this mission there is a heavy operational, technological emphasis in what we do: the reliability of the service is paramount. All this activity aims at enabling the best astronomical research attainable. The quality of this work requires an acute awareness of astronomy's requirements. Having research students in our teams in addition to fellows, to visitors and to staff serves this purpose: research students, bright, ambitious, naïvely demanding, contribute to the **research mindedness** of an institution. This needs to be maintained both in Garching and on the mountain.

Secondly, the studentship programme serves to extend the **linkage** of ESO to Europe's universities, of ESO staff to the academic staff of the astronomy institutes in its users community. Such linkage is indispensible for the continuous information flow that keeps our priorities and services attuned to the research requirements of the users.

A third aspect concerns the long-term quality and ambitions of European astronomy embodied in the next generation. The fellows and students who spend a year or two within ESO are better equipped to use its facilities for their personal research in future. In addition, and just as important, they will enable the institutes that employ them to use ESO telescopes and services to best advantage. They are the **vanguard of VLT observers,** training now and set to work for decades in the next century.

Finally, and related to the preceding point, these youthful scientists establish patterns of professional and personal relations among themselves, relations that will guide their collaborations and projects of the future. The result will be a lowering of national boundaries, the growth of **European excellence** in astronomy. And that too is ESO's *raison d'être.*

The Users Committee (UC)

B. MARANO, UC Chairman, Osservatorio Astronomico, Bologna, Italy

The Users Committee meets as a rule once a year, in May. Besides the national representatives, the meeting is attended by the Director General and by the Heads of La Silla, of the Image Processing and Measuring Machines, and of the Visiting Astronomers Office. Other members of the ESO staff may attend, especially if they are directly involved in some item in the agenda.

The meeting is opened by a report of the Director General on the present ESO state and future perspectives. The Head of La Silla then reports on more technical subjects, as, for instance, statistics of failures at the telescopes and recent or foreseen improvements in the instrumentation. A similar report on image processing and measuring machines often follows.

National representatives are then called to speak. They have collected from their colleagues complaints, impressions, suggestions. Their reports can span from the description of problems pointed out by a single observer or group to very general matters. A few examples of general issues raised in the last two meetings can better give the spice of the discussion: introduction of service observing, future of small telescopes on La Silla, deterioration of the dome seeing at the 3.6-m telescope, flight safety.

The agenda is often closed by some specific items, related to current or foreseen projects. In the last meeting, for instance, the Users Committee heard two reports on key programmes and ESO policy on data archiving.

The atmosphere is always sound and collaborative, and plenty of time is devoted to the discussion of each item. The effectiveness of the Users Committee must also be evaluated on

THE USERS COMMITTEE

Membership

The members (one from each member country) are appointed by the Director General from among the recent Visiting Astronomers for four year terms (not immediately renewable). The terms are staggered, so that each year two persons are replaced. The Committee annually selects its Chairman. National Committees are invited to submit nominations for membership to the Director General.

Present Composition of the UC

M. Azzopardi, France, 1988–1991
L. Hansen, Denmark, 1987–1990
F.P. Israel, Netherlands, 1986–1989
J. Krautter, F.R. Germany, 1989–1992
B. Marano (Chairman), Italy, 1986–1989
B. Stenholm, Sweden, 1989–1992
J. Surdej, Belgium, 1987–1990
Chr. Trefzger, Switzerland, 1986–1989

Functions

The Committee advises the Director General on matters pertaining to the functioning of the La Silla Observatory from the point of view of the Visiting Astronomers. It should consider the possibility to arrange a Users Conference.

Functioning

The Committee meets at least once a year. It is convoked by the Director General.

another ground: does action follow the discussion? My experience is that, when specific technical problems are identified, they are solved by ESO in relatively short time. When a long-term action or a change in ESO policy are required, or when budget problems are involved, the Users Committee represents only one of a number of steps in the process, and things are obviously not so simple. In my opinion it is widely felt that the role of the U.C. in these circumstances could be better clarified.

In the past, some efforts have been made to improve the work of the U.C. and its effectiveness. It has become customary to have an informal gathering of the national representatives the day before the annual meeting. The issues raised by various members can be compared, and common and general problems can be more easily extracted and presented in the meeting after deeper consideration. Furthermore, it has been realized that pointing out a general problem in a wide, multinational community is often a slow process. Solving the problem can take a long time as well. The overall process can barely be followed if its typical timescale is longer than the turnover time of the members of the Committee. For this reason it was proposed, and approved by the Director General and by the Council, to extend to four years, that is to four meetings, the term of the members of the U.C.

Looking to the near future, one can foresee several changes in our way of working at the telescopes: key programmes imply a different way of scheduling and using them; the availability of both the 3.6-m and the NTT will permit more flexibility in the instrumentation; remote observing is becoming a real possibility; flexible scheduling is currently proposed, in various observatories, as a way of better exploiting optimum sky conditions. These examples, only a few from a longer list, show a strongly evolving situation. The users can play a critical role in it, providing essential inputs and acting as a feedback. The Users Committee could be an important link in this process. Or, in absence of a continuous pressure from the community of users, it could slip back to a not-very-interesting "safety valve for disgruntled astronomers". The choice is mostly up to us.

Tentative Time-table of Council Sessions and Committee Meetings in 1989

May 2	Users Committee
May 10–11	Finance Committee
May 18–19	Scientific Technical Committee
May 30–31	Observing Programmes Committee
June 5	Committee of Council
June 6	Council
Nov. 13–14	Scientific Technical Committee
Nov. 16–17	Finance Committee
Nov. 30–Dec. 1	Observing Programmes Committee
Dec. 4	Committee of Council
Dec. 5	Council

All meetings will take place at ESO in Garching.

ESO'S EARLY HISTORY, 1953–1975

II. SEARCHING FOR A SITE IN SOUTH AFRICA*

A. BLAAUW, Kapteyn Laboratory, Groningen, the Netherlands

"– – – observers are on duty from sunset till sunrise – – –."
From André Muller's instructions for the site tests, December 1960.

Introduction

Over a time span of more than seven years, with several interruptions from late 1955 to the middle of 1963, young European astronomers and their assistants have been engaged in the search for a site in South Africa. By the end of that time, it became clear that the observatory would not be built on this continent; the South American Andes Mountains offered superior observing conditions.

Does it make sense, then, to devote a full chapter to the South African explorations? It does – not only because we want to do justice to the large effort made by many young astronomers and their assistants, but also because the South African venture was ESO's first exercise in European collaboration.

First Impressions

Already in January 1954, at the second meeting of the ESO Committee (henceforth to be denoted by EC), the question of the best site for the observatory was taken up. As I explained in the previous article, the southern part of Africa seemed a natural choice. However, the major observatories in South Africa were all located in, or near, major cities or communities: the Cape Observatory, the Union Observatory – originally only at Johannesburg but later having its field station at nearby Hartebeespoortdam –, the Boyden Observatory near Bloemfontein, and the Radcliffe Observatory near Pretoria. This latter observatory had been created rather recently, in the early 1930's, as a result of the transfer of facilities from Oxford; yet also in this case proximity to a major city had been chosen, even for the planned 74-inch telescope [1].

For ESO, vicinity of a major centre of civilization was not an important criterion, and so, the EC decided to start from scratch. Needed was, of course, a place with a minimum of cloudiness and as free as possible from smoke and sky illumination. Moreover, astronomers want good "seeing". By this they mean, that the image of a star as observed in a telescope should show minimum distortion due to turbulence in the earth's atmosphere. This question of "seeing" is explained in some more detail in the box accompanying this article.

Apart from the experience collected over the years by the existing observatories, there was little the EC could go by. There was an interesting report by B.J. Bok of August 1953, dealing with a comparison of conditions at Harvard Observatory's Boyden Station in South Africa and its Agassiz Station in Massachusetts [2], in which Bok drew attention to what seemed to be a general characteristic: *"All over the High Veld of South-Africa, with its remarkably clear and pure skies, the seeing deteriorates often about midnight or shortly after, with no recovery before dawn – – –. The after-midnight deterioration of seeing happens as well at the Union Observatory in Johannesburg, at the Radcliffe Observatory near Pretoria*

* Article No. I appeared in the *Messenger* of December 1988.

and at the Lamont-Hussey Observatory on Naval Hill in Bloemfontein. – – –."

Also of historical interest is an extensive letter by Walter Baade to Oort of 1 November 1954 [3]. That Baade's opinion would carry much weight is obvious: his fundamental discovery of the different stellar populations had been possible by a combination of two special circumstances at Mt Wilson Observatory some time during World War II: a sky free of illumination by the neighbouring city of Pasadena, and exceptional seeing conditions at the 100-inch during the photographic exposures of the Andromeda Nebula and its satellites.

Baade's letter stressed the importance of local conditions: *"– – – I have no experience with the conditions on high plateaus such as that in South Africa but I am strongly inclined to believe that there, just as in Southern California, the seeing during the best observing season is largely determined by the air layers close to the ground – – –. Local topological conditions therefore must play a role – – –."* Baade also stressed the importance of correlating the rating of the seeing as judged in the test instrument with that observed in a large reflector, and suggested that the Haute-Provence Observatory, favoured with good seeing, might be a suitable place for such comparison.

Astronomical "Seeing"

Under ideal atmospheric conditions, the image of a star as seen in a telescope consists of a bright central spot surrounded by a weak circle, the diffraction ring. This is due to the wave character of the light in combination with the fact that the telescope objective or mirror cannot but be of limited size. If the atmosphere is disturbed by turbulence, then (a) the ring is broken up and both it and the central spot loose their sharpness, and (b) the whole image of the star moves rapidly, in an erratic manner. The combination of these two effects determines the quality of the image, called *seeing* by the observer. The less turbulent the atmosphere, the better is the seeing. Hence, astronomers can judge seeing by the quality of the appearance of the diffraction ring, and by the degree of violence of the motion of the bright central spot, called the "image motion".

Estimates by the appearance of the diffraction ring are not easy to put on a quantitative basis; observers use a scale of ratings mutually agreed upon and to be checked regularly. The Danjon telescopes, equipped with mirrors of 25 cm, produced a suitable size of the diffraction ring and gathered sufficient light to make it well visible for bright stars. Normally, the estimates were not seriously hampered by the image motion.

Judging the seeing by the image motion has the advantage of allowing a quantitative measurement, for instance the average deviation of the central spot from its mean position. It has the disadvantage of requiring very stable mounting of the telescope. There is, however, a way around this: one fixes two telescopes on one sturdy mounting and by means of an optical device arranges for the two fields of view to be seen superposed on each other. Measurement of the relative displacement of the two central spots is then a measure of only the atmospheric effect because the shaking of the mounting affects the two in the same manner.

There is still a third method that helps measuring the seeing. In a turbulent atmosphere, we can distinguish turbulence cells, somewhat vaguely defined units which move with respect to the surrounding medium. Such cells differ slightly in temperature with respect to this medium. As a consequence, if one measures the temperature at a fixed point above ground level – for instance at the top of a fixed pole – then one will find rapid fluctuations as a consequence of the successive passages of the cells and the surrounding medium. The more turbulent the atmosphere, the more violent the temperature fluctuations. Experiments have shown that the degree of violence is closely correlated to the rating of the seeing by the diffraction ring method or by the image motion. Conversely, measures of the temperature fluctuations can tell us whether we may expect to observe with good, or with bad seeing.

At the request of the EC, meteorological data on South Africa were collected and discussed by Siedentopf of Tübingen [4]. He concluded that the High Veld, the semi-desert plateau stretching from Johannesburg to Bloemfontein and southward, should offer the most favourable over-all conditions. The EC meeting of November 1954 therefore decided to first explore the Pretoria-Johannesburg and Bloemfontein-Kimberley areas, with limited tests in the Beaufort West region located further south. In each of the first two a fixed observing post was to be chosen near the existing observatory, to serve as a reference point, and the surroundings were to be explored with a moving telescope.

At a meeting in March 1955 in Uccle, details of the project were discussed by Bourgeois, Danjon, Heckmann, Spencer Jones and Oort [5]. A classical method was chosen for the evaluation of the quality of stellar images: the appearance of the diffraction rings as observed in a small reflector. In the accompanying box we explain some of the ways in which the astronomer can evaluate the quality of the stellar images. The method selected had been described by Danjon and Couder in their textbook *Lunettes et Télescopes* of 1935 [6]. Four azimuthally mounted reflectors of 25 cm aperture were built for the project at the Paris Observatory. For the measurement of the atmospheric extinction, photo-electric observations were to be made at wavelengths about 4500 and 5300 Å, with small refractors. Moreover, of course, cloudiness, wind velocity and wind direction would have to be recorded.

The first observers left in October 1955 by boat: G. Courtès from France, J. Dommanget from Belgium, H. Elsässer from the German Federal Republic, and Ch. E. Heynekamp from the Netherlands. They arrived in Capetown on November 6. An extensive letter by Elsässer and Heynekamp to the spiritual father of the project, J.H. Oort, of 17 January 1956, reports on the beginning of their activities [7]. Elsässer described this early work in *Die Sterne* **33,** p. 3, 1957. First observations for intercomparison of all observers were made in the Bloemfontein area in December 1955. Subsequently, the work was divided over the northern (Johannesburg-Pretoria) area and the southern one (Bloemfontein).

On the basis of this first reconnaissance, the EC meeting of April 1956 decided to drop the Johannesburg-Pretoria area and concentrate further work on the region of Bloemfontein and farther southward down to the surroundings of the village Oudshoorn. This is located close to the Swartberg mountain range at the southern border of the Karroo semi-desert. J. Boulon from France replaced G. Courtès for this second phase, which was reported at the October 1956 meeting of the EC by Danjon and Siedentopf. The Karroo emerged more and more as the most promising region, so that the EC decided to extend testing there, in particular near the settlements Zeekoegat and De Aar-Koffiefontein. A new team of observers replaced those mentioned before: F. Bertiau from Belgium, and K. Rohlfs and J.W. Tripp from the FRG. They embarked upon a years' programme to be completed by September 1957. A joint interim report of March 23, 1957 submitted to the chairman of the EC [8] gives first observational results, but also reflects some concern about the problem of systematic differences between the results of different observers, the relevance of tests made with small telescopes for work done with large telescopes, the possible influence of local seeing-disturbing elements, etc. Nevertheless, the Zeekoegat area began to seem superior to the other ones investigated.

After the completion of this mission in September 1957, the work done over the years 1955–1957 was reviewed in a meeting on 9–11 January 1958 at the Paris Observatory by a group consisting of Danjon, Heckmann, Fehrenbach, Couder, Dommanget, Guinot and Tripp [9], which led to a re-analysis of the data by Tripp [10]. This was first prepared for the July 1958 meeting of the EC and, in more complete form, for its October/November meeting. It confirmed the favourable impression of the Zeekoegat site, with Tafelkopje, a hill near Bloemfontein, as a close second. However, as the report pointed out, the analysis suffered from systematic differences between the evaluations obtained by different observers at different places and between observations made with different telescopes, notwithstanding the careful measures taken to eliminate these effects. An independent analysis was published by Dommanget [11].

Adding Some "Real" Astronomy

A new phase of more rigorous investigation in the Karroo developed in the second half of 1958. It envisaged, apart from continuation of work with the Danjon and photo-electric telescopes, some real research programmes. A suggestion for such broadening had been made by Danjon at the July 1958 meeting of the EC. Doing "real" astronomy would help testing the site and make it more attractive for young astronomers to become involved in the work. Two projects presented themselves for this purpose.

The Marseilles Observatory, directed by Fehrenbach, had developed plans for the erection in South Africa of a duplicate of the objective-prism refractor of 40 cm aperture of the HPO, the so-called GPO (Grand Prism Objective) for determining radial velocities [12]. Initially, a location near the village Prince Albert had been considered, but now an alternative was contemplated: one of the possible sites for the ESO project. The operation would become more expensive for logistic reasons; the additional costs might then be absorbed by the site testing project [13]. The solution also would strengthen the effort for integration of France in the ESO project. At this time the French participation in ESO was still quite uncertain.

A second suggestion had been made by myself on behalf of the Kapteyn Laboratory: it proposed photo-electric

Map of South Africa. The ESO site tests over the years 1955–1963 covered the area from around Pretoria-Johannesburg to the Great Karroo near the south coast, and during the last years concentrated on the region marked with the rectangle. This region is shown in blow-up in the upper left corner, adapted from the report by Ursula Mayer mentioned in the text. The site testing station near Zeekoegat and the three on Klavervlei Farm: Table Mt., Rockdale Mt. and Flathill are marked by crosses. The blow-up of Table Mt. on Klavervlei Site shows the three locations investigated by the Quick-Look expedition in early 1961.

The Zeekoegat Site.
Above: *In spring 1959: members of the "Technical Group" with the owner of Sunny Side Farm; from left to right, Fehrenbach, Haffner, Miss Oosthuizen, Hooghoudt. Photograph by the author.*
Below: *ESO's "Zeekoegat Station" in 1962, in the background ESO buildings and houses. Photograph by D. Beintema.*

The Klavervlei Site.
Above: *Table Mountain (middle, background) and in front of it the Klavervlei Farm Settlement. Photograph by the author, 1959.*
Below: *Klavervlei Farm Settlement seen from the air; the large dark-roofed house in the lower left housed the ESO observers. Photograph by D. Beintema, 1962.*

photometry of moderately faint stars, providing information on the photometric quality of the site as a by-product. As it turned out later, this project could not be realized, but a similar one was done by the Tübingen programme of Siedentopf described below.

These suggestions were submitted to the October/November 1958 meeting of the EC [14], at which also another step was taken up: an evaluation of building costs, technical expertise, acquisition of water and power supply, etc. in South Africa. These were to be investigated by a "technical" group consisting of the engineer B.G. Hooghoudt (responsible for technical developments of radio astronomy in the Netherlands), Fehrenbach and myself, together with the German astronomer H. Haffner who at that time resided at the Boyden Observatory. The group arrived in South Africa on 16 March 1959 and stayed for about five weeks, after which it reported to the EC meeting of May 1959 [15].

The report led to a somewhat modified approach. Further testing of the Zeekoegat area was recommended, but attention was also to be given to sites at considerably higher elevation than those explored so far. Such sites were to be found on the Nieuwveld Plateau northwest of the village Beaufort West. On the other hand, no further testing of the region around Bloemfontein was to be done. Reasons for its exclusion were the fear for growing disturbance by city lights, and seasonal effects in the climate which are unfavourable for observing the Magellanic Clouds.

Henceforth, interest focussed mainly on two possible locations: the vast territory of Klavervlei Farm on the Nieuwveld Plateau, where contacts with the owner, R. Köster, had been established by the "technical" group; and Zeekoegat, where the same had been done with the owner Miss M.E.Z. Oosthuizen of the Farm Sunnyside. Klavervlei Farm was located about 35 km northwest of Beaufort West, and Zeekoegat about 80 km south of this town. Ultimately, three montain spots on Klavervlei Farm became the subject of intensive tests: Table Mountain at elevation about 1,970 m, Rockdale Mt. at 1,860 m, and Flathill at 1,490 m. They are indicated on the accompanying map.

The Zeekoegat site was located at elevation about 1,000 m, only slightly above the surrounding plane. In a way, the two kinds of sites represented two different philosophies: in the Klavervlei area, the mountain-top concept embodied by the Californian observatories; at Zeekoegat the concept of the French Haute-Provence Observatory – only slightly elevated above its surroundings – which reminds us of the description at the end of the chapter on image quality in Danjon and Couder's *Lunettes et Télescopes* referred to before: *"D'une manière générale, il convient de rechercher de préférence les plateaux secs d'altitude moyenne, loin de la mer ou des grandes vallées, couloirs de vent. Il est superflu d'avoir un horizon dégagé, car un observatoire astronomique n'est pas un point de vue. – – –".*

The Quick-Look Expedition

In order to get a first impression of the Nieuwveld Plateau, one of the Klavervlei sites, Table Mt. was explored by a three-month "Quick-Look" expedition. However, whereas the earlier tests had been limited to well accessible locations, for the Klavervlei sites road construction was a first requirement. It was achieved through the intermediary of the owner of the farm, so that in September 1959 access to Table Mt. was possible. 11 km of roads suitable for four-wheel-drive vehicles were constructed, leading to the three observing locations numbered I, II, and III on Table Mt., marked on the accompanying map.

The Quick-Look expedition was carried out by André Muller in collaboration with the Swedish geodesist C. Ulff. André Muller was one of my associates at the Kapteyn Laboratory and had previously conducted observations at the Leiden Observatory Station on the premises of the Union Observatory at Johannesburg. He was, therefore, well acquainted with South Africa. In November 1959, on the way to South Africa, Muller and Ulff spent a week at the Haute-Provence Observatory in order to gain experience with the use of a Danjon telescope in consultation with the staff of the HPO. They completed the Quick Look per 1 April 1960 after three months of seeing tests and climate monitoring, and Muller reported at the July 1960 meeting of the EC [16].

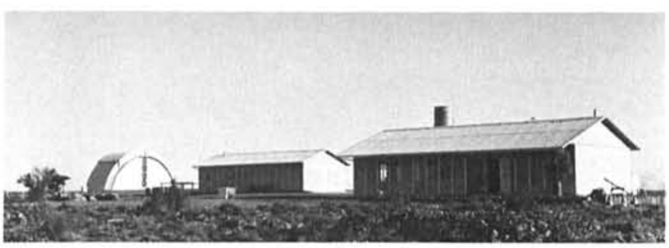
Letters of Muller to myself in the period December 1959 to March 1960 [17] describe delays in the transport of the telescopes and the rather primitive living conditions under which the Quick Look had to be executed (for shelter during the night a tent was borrowed from the Dutch organization ZWO), and troubles with the instruments, among which a lack of stability of the mounting of the Danjon telescopes under the sometimes very strong (and cold!) winds on Table Mt. For the follow-up of the Quick Look, therefore, new mountings were made at the Kapteyn Laboratory. The first impression of the site on Klavervlei Farm was sufficiently encouraging to make the EC decide on a more thorough comparison with the Zeekoegat area. Besides Table Mt., some other sites on Klavervlei Farm with somewhat different local characteristics were to be investigated: Rockdale Mt. and Flathill mentioned before. Of the three sites on Table Mt. only the most southern one was to be kept. For the new programme, the Danjon telescopes were returned to Paris for thorough overhaul. By the beginning of 1961 they were available again on the sites.

Meanwhile, in the course of 1960, plans for Fehrenbach's GPO project had advanced so far that a search for a suitable location became desirable. As we shall see in article IV, it also was at about this time that the EC agreed in principle to incorporate the GPO into the "initial programme" of telescopes mentioned in the Convention. For the preparation of the many logistic measures connected with it as well as with the Klavervlei testing (erection of GPO housing, satisfactory living quarters for the observers, water and power supply, etc), Fehrenbach, Couder and Blaauw visited South Africa from mid-November to mid-December 1960. They reported on their visit at the January 1961 meeting of the EC [18]. As one of the results of the mission, the choice for the location of the GPO fell on the site near Zeekoegat.

The Comprehensive Programme, 1961–1963

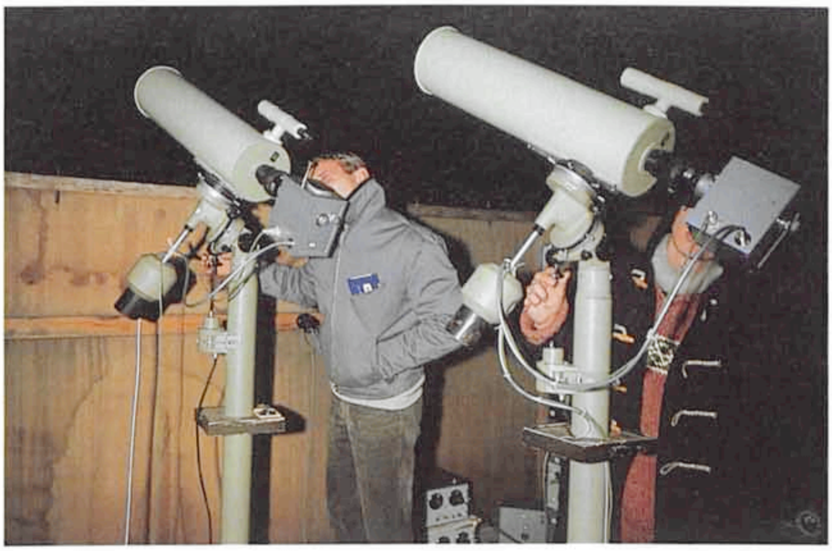
The final, comprehensive programme was planned to run for at least a full year but would, in fact, be concluded only in the course of 1963. It was supervised by a succession of astronomers, the first one being again André Muller. The simultaneous monitoring of the four sites required a larger staff than had been engaged before, but we realized that it would by no means be necessary for all of these to be astronomers. What we rather needed was: willingness to spend long periods at isolated spots in the desert in primitive housing; handiness in technical matters; a gift of improvisation and elementary cooking; and, last but not least, readiness to perform over extended periods the routine work of the testing . . .

How to find such people? It occurred to me that all this sounded like the interests of an ambitious boy-scout, so we advertized our wishes in a Dutch journal of boy-scout leaders. The result was rewarding: among the applicants were Albert Bosker and Jan Doornenbal, both of whom later became employees of ESO. Among the team that started the work in March 1961 we also encounter the two young German astronomers D. Messerschmidt and W. Schlosser, and



At the Zeekoegat Station, January 1962.
***Above:** André Muller with Bert Bosker, adjusting the mounting of a Danjon telescope, in front of the rondavel that housed the instrumentation.*
***Below:** at left, the "Abri" housing the Marseilles GPO; middle and right, houses of the observers. Photographs by the author.*

At Rockdale Station on Klavervlei Farm, January 1962.
***Above:** B. van Geelen of ZWO, at left, talking to observers of the Tübingen photometric project J. Pfleiderer, U. Haug and Kopp in Rockdale farmhouse.*
***Below:** Rockdale farmhouse on Klavervlei Farm. Photographs by the author.*



Site testing in the "Comprehensive Program" in 1962. *Left: with the Danjon telescope for image quality. Right: with photometric telescopes for extinction measures; here: intercomparison check of two telescopes. Photographs by D. Beintema, 1962.*

G. Bilius, a geodesist from Sweden who took over the local supervision in May 1961. He was succeeded in this capacity by H. Lindén from Sweden over the period from August 1961 to April 1962, and by L. Petterson from Sweden from May to October 1962, after which André Muller took over again. Others who over certain periods collaborated in the site tests were P. McSharry, a geodesist from South Africa, and the young astronomers K. Kopp, W. Seufert, W. Weber and M. Grewing from the GFR, and D. Beintema from the Netherlands.

A working scheme for the operations had been drawn up by Muller in December 1960 [19]. From it we quote:

"– – – Irrespective of weather conditions, the observers and their assistants are on duty from sunset till sunrise to do meteorological and astronomical observations at regular times.

– – – Observers and assistants have to work during 25 consecutive nights and after this period have to take leave of 5 consecutive nights. These 5 nights, covering a period of nearly 6 days, can be spent anywhere in the Union of South Africa and special provisions are made to meet extra expenses. With the exception of these 5 nights, there will be no opportunity for outings, whatsoever.

The groups of observers and assistants will be shifted from one station to the other at regular times, to ensure a good comparison between the different stations.

– – – The observers and assistants do organize their own housekeeping [which] includes foraging in Beaufort West, Zeekoegat or Prince Albert – – –."

An interim report on the new tests was submitted by Muller and Blaauw to the March 1962 meeting of the EC [20]. They had just returned from a visit to the activities in South Africa in December and January made jointly with B. van Geelen who, as an associate of J.H. Bannier of the Dutch organization ZWO, took care of the many financial, administrative and personnel matters connected with the site testing. Their report [21] describes in detail the structure of the site tests at that epoch. The routine monitoring of image quality and climatic conditions proceeded satisfactorily at the four sites. Of the three on Klavervlei Farm, Flathill seemed to emerge as the most favourable one; of the other two, about equal in quality, it was decided to lower the priority for Rockdale Mt. The meeting decided that regular observations should continue till about March 1963, so that the period on which final judgement was to be based should contain two complete runs of the normally most favourable season from November through March.

Muller reported again at the June and October 1962 meetings of the EC, after returning from visits to South Africa. By October the image quality tests on Rockdale Mt. had been stopped (as was the photometric project of Tübingen on that site, described below). With the termination of all tests in sight, the EC appointed a small group to study the results in preparation for the decision on the site, to be chaired by Siedentopf and further consisting of Dommanget, Fehrenbach, Muller and E. Holmberg from Sweden, thus having representatives of the five participating countries.

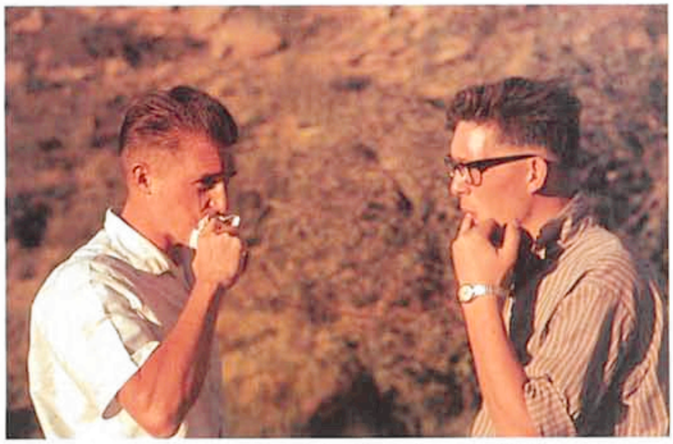
By the time of this EC meeting of October 19 and 20, 1962 the ESO Convention had just been signed (October 5) and the EC took two important measures. One was the appointment of Otto Heckmann as acting Director of ESO, per 1 November 1962 (to be confirmed after the ratification). Heckmann had visited the ESO activities in South Africa together with Fehrenbach in August and September, 1962. Furthermore, by this time the interest of ESO in the site tests in South America had led to a mission of Muller and McSharry to Chile, to join the American group under J. Stock; McSharry was already on his way at the time of the October 1962 meeting and Muller was to follow him shortly thereafter. Their findings will be reported in the next article.

The routine observations of image quality and of climatic conditions terminated, as had been planned, around March 1963. At its February 1963 meeting the EC decided to continue the work in South Africa only for the purpose of an intercomparison of the Danjon telescope tests with telemeter observations as they had been used by Stock's group in the Andes; for this purpose one of their telemeters was shipped to South Africa. This final programme was carried out by McSharry under supervision of Muller.

Last Tests in South Africa: the Siedentopf Experiment

Towards the end of the activities in South Africa, a new kind of test was introduced that had been developed over the past years by Siedentopf and Mayer at Tübingen. It used measurements of the rapid temperature fluctuations which accompany the turbulence in the atmosphere and which, in turn,

One of the Danjon telescopes, provided in the last stage of the tests with a mask for experiments by A. B. Muller simulating a double beam telescope for measuring image motion. Photograph by D. Beintema, 1962.



From boy-scout leaders to ESO site testers to ESO employees: Jan Doornenbal, left, and Bert Bosker. Photograph by D. Beintema, 1962.

are correlated to the image quality; see also the description in the accompanying box. For the measurement of these temperature fluctuations, thermocouples and resistance thermometers of small time constant were used. By mounting the instruments on masts at different heights, the dependence of temperature fluctuation on elevation above ground level could be measured and, hence, the dependence of turbulence on height. These experiments have played an important role in the decisions taken later with respect to the level at which the telescopes on La Silla were to be mounted.

Applications of the method in ESO context were made by F. Unz in the period July 17 to September 1, 1963 at Zeekoegat and Flathill. After verbal provisional accounts by Siedentopf this work was reported in an ESO publication in 1964 by (the late) Siedentopf and Unz [22]. Simultaneously with these measurements, wind velocity was monitored, and the quality of the seeing was estimated by the measures of image motion with the double-beam telemeters. Two important results were found: the amplitude of the temperature fluctuations decreased rapidly with increasing height within the range of 3.5 to 24 meters, and the difference between the amplitudes at low and high levels was strongly correlated with the amplitude of the image motion. These results immediately led to the conclusion that mounting the telescopes at high level above the ground should eliminate most of the image motion, and hence improve the seeing. A more extensive report was published by Unz in 1970 [23].

The Tübingen Photometric Project

The Tübingen photometric project on Rockdale Mt. ran from August 1961 to November 1962. It was carried out with a 3-colour photometer on a 40-cm telescope by members of the staff of Siedentopf: J. Pfleiderer, Miss U. Mayer, J. Pesch, U. Haug, and J. Dachs. Also, surface photometry was done of the Milky Way and of the Zodiacal Light in blue and red. Siedentopf reported at the October 1962 meeting of the EC on provisional results. The Rockdale Mt. observations would become part of the data later used by the Site-Selection Committee. Full reports on the Tübingen project were published in 1966 by Dachs, Haug and Pfleiderer [24] and by Pfleiderer, Dachs and Haug [25].

The Marseilles GPO Project

Fehrenbach's objective-prism radial velocity project at Zeekoegat became fully operational about the middle of 1961, after delays in the construction phase. It extended in time considerably beyond the termination of the monitoring of image-quality and climatic conditions, until well in the year 1966, after which the GPO was moved to La Silla.

In the first issue of the *ESO Bulletin*, of November 1966 (the Bulletins were a series of ESO publications terminated in 1975), Fehrenbach describes the history of the GPO work at Zeekoegat. Over the years, altogether some thirteen collaborators of which several with their families, most of them from the Marseilles staff, had worked on the project. It produced a large number of GPO plates, most of them on the Magellanic Clouds. However, the observational conditions, although not unsatisfactory, proved to be inferior to those encountered soon afterward on La Silla.

One of the disturbing factors were the strong daily temperature variations at the Zeekoegat site. Moreover, the GPO had been mounted at Zeekoegat at ground level, and one of the measures taken to obtain better image quality at La Silla was placing the telescope at high level. For an early progress report on the project, see, for instance, the *Information Bulletin of the Southern Hemisphere,* No. 2, Sept. 1962, p. 22.

The Comprehensive Reports on the South African Tests

We finally arrive at the reports which sum up the total of the ESO efforts in South Africa. A final report has been published as an ESO publication in 1967, long after the decision on the choice of the site had been taken. It was compiled at the request of the Director of ESO by Ursula Mayer of Tübingen who had participated in some of the activities in South Africa, and under the auspices of ESO's Site Evaluation Committee. It carries the title Astronomical Site Testing in South Africa and contains contributions by many of the people who had participated or had been actively involved in the tests.

The report systematically surveys studies of the meteorological conditions, matters of organization, and the seeing tests and their results in chronological order. Although the report, in this form, has not played a role in the decision on the site, it remains an interesting document, not just for historical reasons, but also because in its concise, yet sufficiently detailed presentation it may serve for other purposes of meteorological and astronomical nature. The booklet is in the ESO Library (and probably in many institute libraries) and also forms part of the ESO Historical Archives [26].

The decisive comparison between conditions in Chile and South Africa was based on provisional reports, but on virtually the same data as those used for the final document just mentioned. This comparison was prepared by Siedentopf for the EC Meeting of 15 November 1963; it was published in 1966, in the first issue of the *ESO Bulletin.* Siedentopf used the data collected at Zeekoegat, Flathill and Rockdale Mt., and those collected in Chile by Stock and by Muller and McSharry. We shall return to it in the next article and mention here only that the report confirmed what had been strongly suspected: that the sites in the Andes Mountains around La Serena were to be preferred on several grounds: the number of clear nights, the image quality, and the surprisingly low temperature drop during the night. It was at this meeting, 15 November 1963, that the EC decided in favour of South America.

In the beginning of this article I referred to the deterioration of seeing in the course of the night in the northern part of South Africa, mentioned by Bok. Such systematic change is not explicitly discussed in the reports on the ESO tests. However, while preparing this article, I am informed by André Muller that also on the Klavervlei and Zeekoegat sites this phenomenon was definitely noted and the deterioration was closely related to the decrease of temperature in the course of the night. In fact, according to Muller, this relation provides a strong first indication of the quality of a potential site: the smaller the drop in temperature, the better the site.

Finally, we note that in the course of the tests, the rating of image quality by means of the diffraction rings only was felt more and more as an unfortunate limitation. Nights with "good" rings but appreciable image motion did occur and were of little use for practical work like stellar spectroscopy, as was in fact experienced by observers at the GPO. This was pointed out, for instance, in the report of February 1962 referred to under footnote [21] but it did not lead to drastic modifications of the techniques of observation.

At the End, Bewilderment and Consent

The rather sudden switch from South Africa to Chile did not pass without bewilderment to the young astronomers and their collaborators still at work in South Africa. Had years of effort been waisted? Some disappointment was undeniable. Heckmann was aware of this and expressed it in a letter to me which, unfortunately, I have not been able to recover but of which I do remember the first words: "Mich drückt das Bewußtsein . . .". Disappointment would soon make room for the conviction that the decision had been right.

The Benevolent Environment

In the description of ESO's earliest history we encountered first of all the astronomers and their immediate collaborators. But their work would not have been possible without strong administrative support in Europe and the logistic services and hospitality of South African institutes.

Throughout the pre-ratification phase, the efforts toward ESO relied heavily on the moral support from the part of individuals in government departments or in science funding organizations. For France, the authorities concerned were in the Ministry of Science and Education and, ultimately, in the Ministry of Foreign Affairs; for the German Federal Republic and Belgium, in those dealing with science and education or technical development. For the Netherlands and Sweden they belonged to the science supporting organization ZWO and the Swedish Natural Science Research Council, respectively. These structural differences also determined the nature of the sources for the provisional funding of the site tests.

Particularly meritorious for ESO's early development was the Director of the Dutch organization ZWO, J.H. Bannier. From the moment of his appointment as Treasurer of the ESO Committee (at its October 1957 meeting) Bannier firmly took in hand the financial management. His task was not only budgeting and bookkeeping, but also the continuous effort to persuade the authorities in the partner countries to provide, on the necessarily *ad hoc* basis, the required funds. Bannier's authority allowed him, when necessary, to take initiatives in funding measures which made it easier for the partner countries to cross the financial bridge. From early 1959, Bannier made his associate Dr. B. van Geelen, a young chemist, available for services including personnel matters, preparation of travel, insurance, etc. – without frowning upon the bill of a water diviner in South Africa [27].

On the South African side, throughout the site testing there was strong interest and support from the part of the President of the Council for Scientific and Industrial Research, Dr. S.M. Naudé. CSIR provided know-how on technical matters required for setting up the testing stations and made vehicles and measuring instruments available for ESO's rather demanding use. Responsible for these services was from 1956 CSIR's Director for International Scientific Relations, Dr. C.G. Hide.

Essential was, of course, the collaboration and support experienced throughout the work from the part of the owner of Klavervlei Farm, the Köster family, and of Mrs. Oosthuizen of Sunnyside Farm at Zeekoegat.

Last but not least, there was the generous hospitality extended to the ESO teams by the South African observatories. With the testing activities gradually shifting to the Karroo, ESO relied more and more on the counsel and support provided by the staff of the Cape Observatory. The outstanding hospitality offered by its Director, R.H. Stoy and Mrs. Stoy, and by his associate David Evans and Mrs. Evans is warmly remembered by all those who participated in ESO's South African venture.

References and Notes

Abbreviations used:
EHA = ESO Historical Archives (see the description in the previous issue of the *Messenger*).
FHA = Files belonging to the Office of the Head of Administration at ESO Headquarters.
EC = ESO Committee (the committee that preceded the Council); for a list of the meetings of the EC, see the previous article.
Heckmann Sterne = O. Heckmann, *Sterne, Kosmos, Weltmodelle,* Verlag Piper & Co., München, Zürich, 1976.

[1] See the report on the site selection by W.H. Stevenson and H. Knox-Shaw in *Monthly Notices R.A.S.*, Vol. 95, p. 447, 1935.
[2] In EHA-I.A.1.3. A paper presented at the Flagstaff Conference on Photo-electric Problems, Techniques, and Instrumentation, Aug.-Sept. 1952.
[3] In EHA-I.A.1.3.
[4] H. Siedentopf: *Climate of the Union of South Africa,* Astron. Inst. of the Univ. of Tübingen, 1955, in EHA-I.A.1.3.
[5] Memo of this meeting in EHA-I.A.1.3.
[6] A. Danjon and A. Couder, *Lunettes et Télescopes,* Paris 1935, Chapitre V. See also *Comptes Rendus* No. 183, 1032, 1926 for the calibrations.
[7] EHA-I.A.1.3. A long report by Elsässer to Heckmann, Siedentopf and Unsöld accompanies this letter.
[8] See I.A.1.5. and I.B.3.
[9] See I.C.2.3.a.
[10] EHA-I.C.2.3.d.
[11] *Comm. Obs. de Belgique* (Uccle), No. 141, 1958.
[12] See minutes of a discussion on 25 July 1958 following the 8th EC Meeting in EHA-I.A.1.7.
[13] See minutes EC Meeting of July 1958, item 13 in EHA-I.A.1.7.
[14] See letter of J.H. Oort to the EC of Oct. 21, 1958 in EHA-I.C.2.3.
[15] This report in EHA-I.B.11. and I.C.2.5.b.
[16] See the minutes of this (12th) meeting of the EC. The report by Muller seems to be missing from the EHA.
[17] In EHA-I.C.2.5.d.
[18] The report is contained in the minutes of the meeting.
[19] In EHA-I.C.2.2.a.
[20] In EHA-I.B.11.
[21] See map EHA-I.A.1.16.
[22] EHA-I.C.2.7.b., H. Siedentopf and F. Unz, Temperature Fluctuations in the Atmospheric Ground Layer observed at Zeekoegat and Flathill (South Africa), March 1964.
[23] F. Unz, Mitteilungen Tübingen No. 116 = *Meteorol. Rundschau* 23, p. 87, 1970.
[24] J. Dachs, U. Haug and J. Pfleiderer, *Mitt. Tübingen* No. 87 = *J. Atm. Terr. Phys.* **28,** p. 637, 1966.
[25] J. Pfleiderer, J. Dachs and U. Haug, *Mitt. Tübingen* No. 88 = *Zeitschr. für Astroph.* **64,** p. 116, 1966.
[26] In EHA-I.C.2.7.b.
[27] See letter van Geelen to Blaauw of 11 November 1960 in EHA-I.C.2.8.d.

Wind Turbulence in the Dome of the 3.6-m Telescope

L. ZAGO and F. RIGAUT, ESO

Introduction

It is a common experience that telescope tracking may be affected by strong winds, as in some cases the air flow and its associated turbulence penetrate the dome with an amplitude sufficient to perturbate the smooth operation of the telescope. Reports of this phenomenon are, however, only qualitative as no measured data were available (to the authors' knowledge) on quantities such as mean flow penetration, turbulence intensity and vortex scale in a dome with an open slit. Only some recent wind tunnel tests [1] have addressed this question, although the reliability of the results may be somewhat questioned because of the scale similarity problems of wind tunnel simulations with round buildings.

Here the results of a preliminary investigation in the 3.6-m dome are presented. The purpose of this first series of measurements was to get a quantitative evaluation of the most critical (worst case) wind effects in the dome, rather than a systematic survey representative of all observing conditions.

The Parameters of Wind Turbulence

Air flow turbulence may be characterized by several parameters. The most immediate is the velocity rms σ_u measured along the mean flow direction. Also one often refers to the turbulence intensity, which is defined as $I = \sigma_u/\bar{U}$, with $\bar{U}$ being the mean velocity.

Actually the turbulent movement within the mean flow consists of multiple vortices of different size. A measure of the mean dimension of these vortices is given by the so-called turbulence scales. The main (longitudinal) scale L_u^x is computed from the autocorrelation coefficient R (x, x, Δt) of velocity as:

$$L_u^x = \bar{U}\int_0^\infty R(x, x, \Delta t)\, d\Delta t$$

Each size of vortices generates velocity fluctuations at a given frequency. The distribution of kinetic energy along the frequency is given by the spectral power density function $S_u(n)$, computed as the Fourier transform of the autocorrelation function. This is often called the gust (velocity) spectrum and from its definition it is also:

$$\sigma_u^2 = \int_0^\infty S_u(n)\, dn$$

The tracking performance of a telescope is actually affected by the *pressure* power spectrum $S_p(n)$ which is obtained from a time series of dynamic pressure values $P(t) = \frac{1}{2}\varrho U(t)^2$, similarly as $S_u(n)$ from $U(t)$. The pressure fluctuations, represented by $S_p(n)$ (which are seen by the telescope as forces and moments) should be compensated by the tracking control loop. Therefore particularly important is the amplitude of $S_p(n)$ in the range beyond the bandwidth of the control system, typically 1 Hz, which represents fluctuations which the tracking loop will often not be able to correct and, in a worst case, which may even excite resonance modes in the telescope.

Measuring Equipment and Procedure

The measurements were taken in the upper part of the 3.6-m dome, taking advantage for access of the bridge crane there located, during the evening of a windy day when the dome anemometer indicated almost constantly a mean velocity of 18 m/s from North. The dome slit was opened as shown in Figure 2.

A vortex type anemometer (Fig. 1) was utilized, which is particularly suited for fast response measurements, having a $\Delta t \cdot U$ resolution of 6 mm. The measurements consisted of wind velocity sequences of 137 seconds each with 4096 records, therefore at the frequency of nearly 30 Hz. Several such sequences were recorded at different positions along the path of the bridge crane as shown in Figure 2. Before each sequence, the dome was rotated forth and back in order to find, rather empirically, the azimuth angle at which one would have the stronger feeling of wind flow and turbulence. Not surprisingly, this was found to be approximately facing the mean wind direction. Therefore the values measured are properly worst case quantities, as one may expect that during observation the slit would be facing the wind only a fraction of the observing time. The recordings were subsequently processed with the MIDAS system in order to get statistical parameters.

Results and Conclusions

The main results from the measurements are given in Figures 3 to 7, in function of the distance from the edge of the slit. The data of each figure are commented with reference to the corresponding parameters of the free wind flow incident to the dome. Note also that some data sequences were taken along the centre of the slit, others along the left side: this simply because we remarked that flow and turbulence were

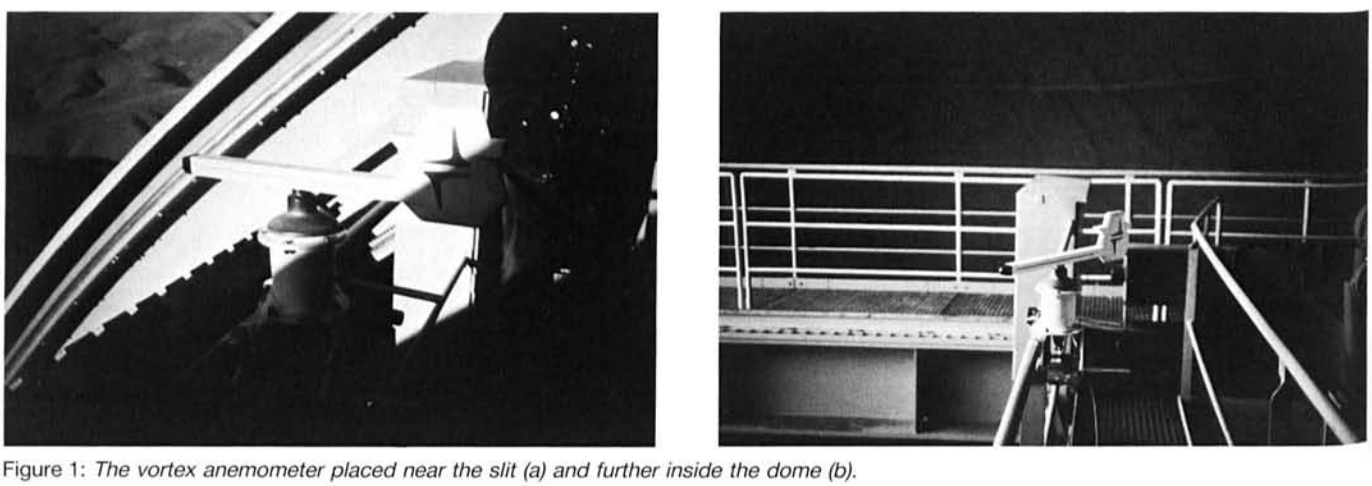


Figure 1: *The vortex anemometer placed near the slit (a) and further inside the dome (b).*

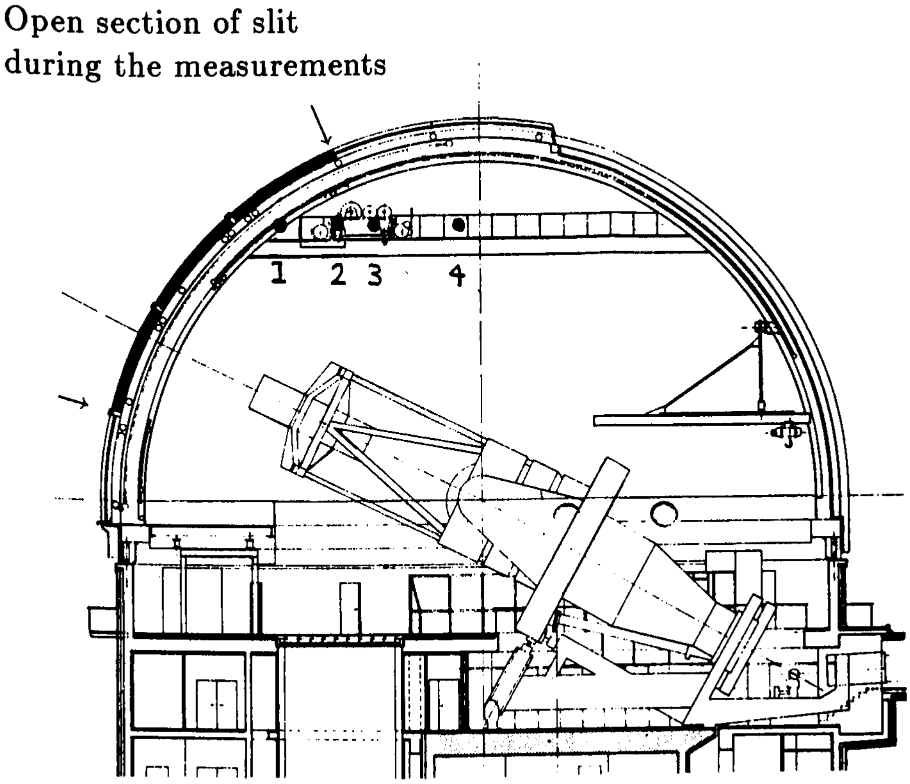


Figure 2: *Measurement locations in the 3.6-m dome.*

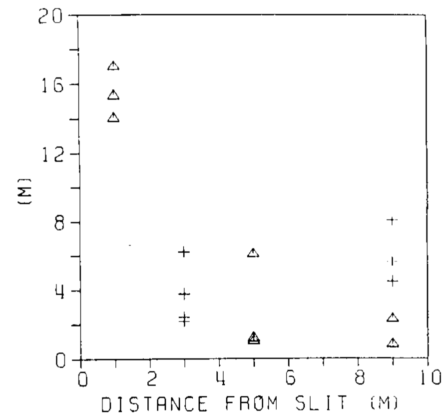


Figure 5: *Turbulence scale L_u^x. The turbulence scale in the free atmosphere at the level of the 3.6-m dome is likely to be in the range 50 to 200 metres. This free flow turbulence is still a contributing factor near the edge of the dome (L_u^x = 14–17 m); further inside we have purely slit made turbulence, with an average scale of the order of slit width.*

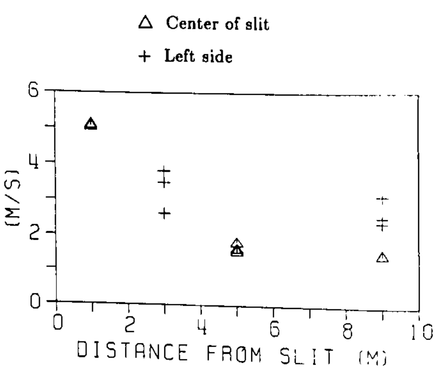


Figure 3: *Mean flow velocity $\overline{U}$. The mean wind velocity outside the dome was about 18 m/s. Already just inside the slit, this is reduced to about 5 m/s. However even further inside the dome centre, one still records up to 3 m/s.*

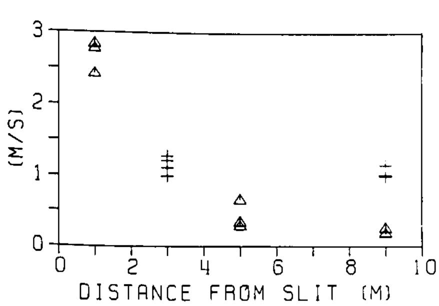


Figure 4: *Turbulent velocity σ_u. In the free flow this quantity is practically independent of height. Therefore the values measured at the same time at the meteo tower located down the ridge, 0.7–0.8 m/s, may correctly be taken as reference. Note that the values in the dome are almost everywhere higher.*

often stronger along the sides than along the slit midline.

We have verified that the 3.6-m dome, even with the slit facing the wind, acts as an efficient wind shield in terms of mean flow velocity. Nevertheless, the slit is the cause of velocity fluctuations inside the dome, which are definitely larger than in the original atmospheric turbulence. This dome induced turbulence has a mean scale of the order of the slit width and a peak frequency in the range 0.3 to 1 Hz. In proximity of the slit this effect causes also pressure variations which are larger than in the free atmosphere, particularly in the frequency range above 1 Hz where they might directly affect the tracking behaviour of an hypothetic telescope whose top structure would come closer to the slit than the present 3.6-m one. Further inside the dome, because of the large decrease of mean velocity (note that, from the definition of dynamic pressure, $\sigma_p \propto \overline{U}\sigma_u + \frac{1}{2}\sigma_u^2$) the amplitude of pressure oscillations is largely below the situation in the free flow.

When dealing with flow turbulence around or inside telescope domes, a question which is often raised is whether this is linked to the thermal microturbulence causing dome seeing. Although the measurements described here meant to address only the problem of wind disturbance on tracking, the evidence found of important and large flow

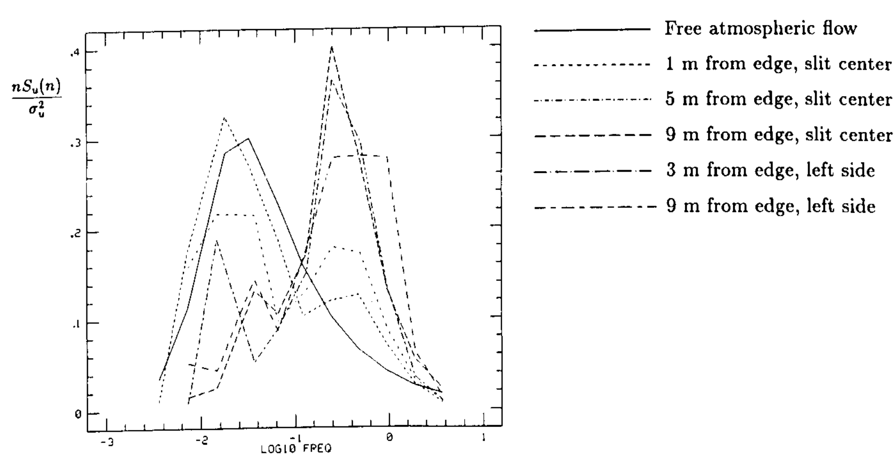


Figure 6: *Normalized gust spectra at different locations inside the dome and, for reference, in the free flow. In the free atmosphere most of the wind turbulence energy is found in the range 0.01 to 0.05 Hz. In the dome a peak in the range 0.3 to 1 Hz appears, which takes more of the turbulent energy the further away one is from the slit. Note that the spectra are here normalized with the respective σ_u^2 values.*

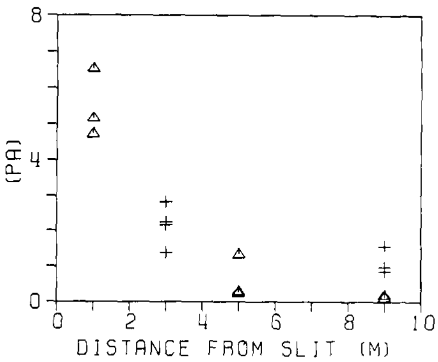


Figure 7: *Turbulent pressure high-pass filtered at 1 Hz:*

$$\sigma_{p>1Hz} = \sqrt{\int_{1Hz}^{\infty} S_p(n)dn}$$

This quantity is an approximate indicator of the dynamic wind loading which, if acting on an hypothetic telescope, cannot be compensated by the tracking control loop, assumed here to have a bandwidth of 1 Hz. The reference free flow value is 3.2 Pa: one may note that inside the dome this value is exceeded only in proximity of the slit. Further inside, the amplitude of pressure fluctuations is largely below the level in the free atmosphere.

vortices quite deep inside the dome may have relevance also to dome seeing, in particular to the energy balance of the phenomenon.

Particularly in large domes, it is unavoidable that temperature gradients exist between different sections and structures. Then any flow turbulence will increase the heat transfer between dome and air, therefore feeding energy to the microthermic turbulence which causes dome seeing. In this respect the dome mechanical turbulence may act as an intensifier of the known seeing effect created by temperature differences between air and surfaces or between inside and outside conditions.

Acknowledgements

The authors wish to thank J.-L. Sauvageot and C. Santini of ESO La Silla for helping to carry out the measurements. They are also grateful to the dome maintenance staff for their cooperation and apologize for some inconveniences involuntarily caused during the tests.

References

[1] Kiceniuk T. and Potter K., Internal Air Flow Patterns for the Keck 10-m Telescope Observatory Dome, GALCIT Report 10' GWT-DR 1104.

Visiting Astronomers

(April 1 – October 1, 1989)

Observing time has now been allocated for Period 43 (April 1–October 1, 1989). The demand for telescope time was again much greater than the time actually available.

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

3.6-m Telescope

April: Oosterloo/van der Kruit, Danziger/Cappellaro/Turatto, di Serego Alighieri/Tadhunter/Fosbury, Ruiz/Maza, Renzini/D'Odorico/Greggio/Bragaglia, Danziger/Moorwood/Oliva, Moorwood/Oliva, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Krautter/Starrfield/Ögelman, Bertola/Buson/Zeilinger.

May: Bertola/Buson/Zeilinger, Krautter/Starrfield/Ögelman, Scaramella/Chincarini/Vettolani/Zamorani, Ilovaisky/Chevalier/Pedersen, Surdej et al. (2-003-43 K), Schmider/Fossat/Grec/Gelly, Butcher, Molaro/Spite F./Vladilo, Butcher/Pottasch/Slingerland/Baade/Christensen-D./Frandsen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Seggewiss/Moffat/Robert.

June: Seggewiss/Moffat/Robert, Cacciari/Clementini/Prévot/Lindgren, Piotto/Capaccioli, Pasquini, Cacciari/Clementini/Prévot/Lindgren, Perrier/Mariotti/Mayor/Duquennoy, Pottasch/Pecker/Karoji/Sahu K.C., Häfner/Barwig/Schoembs.

July: Häfner/Barwig/Schoembs, Augusteijn/van Paradijs/Schwarz, Meylan/Mayor/Dubath, Weidemann/Koester/Jordan, Ardeberg/Lindgren H./Lundström, v.d. Veen/Habing/Geballe, Krabbe/Sternberg, Véron/Hawkins, de Lapparent et al. (1-003-43K).

August: de Lapparent et al. (1-003-43K), Dubath, Bergvall/Rönnback, Guzzo/Collins/Heydon-Dumbleton, Neri/Grewing/Bässgen M., Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Wagner, Leibundgut/Tammann, Iovino/Shaver/Cristiani/Clowes/Pierre.

September: Iovino/Shaver/Cristiani/Clowes/Pierre, Rhee et al. (1-005-43K), Mazure et al. (1-014-43K), Ögelman/Gouiffes/Hasinger/Pietsch/Pedersen, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Webb/Carswell/Shaver, Bergeron/D'Odorico/Petitjean, Marano/Cappi/Held, Soucail/Cailloux/Fort/Mathez/Mellier/Pello, Schwope/Beuermann, Miley et al. (2-001-43K), Bender et al. (1-004-43K), Bergeron et al. (1-012-43K).

2.2-m Telescope

April: Oosterloo/van der Kruit, Galletta/Bettoni, Katgert/van Haarlem, Giraud, Srinivasan/Danziger, Reinsch/Beuermann/Festou/Pakull, Meisenheimer/Röser, Moneti/Zinnecker/Reipurth, Moorwood/Oliva, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Tadhunter/Pollacco, Reinsch/Beuermann/Festou/Pakull, Cetty-Véron/Woltjer.

May: Cetty-Véron/Woltjer, Bertola et al. (1-008-43K), Surdej et al. (2-003-43K), Srinivasan/Danziger, Bertola et al. (1-008-43K), MPI TIME.

June: MPI TIME, Chini/Wargau, Glass/Moorwood/Moneti, Ortolani/Piotto, Piotto/Djorgovski.

July: Brahic/Sicardy/Roques/Barucci, Habing/Le Poole/Schwarz/van der Veen, Brahic/Sicardy/Roques/Barucci, v.d. Veen/Habing/Blommaert, v.d. Veen/Habing/Geballe, Tosi/Focardi/Greggio.

August: Richtler/Kaluzny, Wiklind/Bergvall/Aalto, Bergvall/Rönnback, Tanzi/Bersanelli/Bouchet/Maraschi/Falomo/Treves, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Jörsäter/Bergvall, Appenzeller/Wagner, Miley et al. (2-001-43K), Christensen/Sommer-Larsen/Hawkins.

September: Barbieri et al. (2-007-43K), Bender et al. (1-004-43K), MPI TIME.

1.5-m Spectrographic Telescope

April: Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Chincarini/De Souza/di Stefano/Sperandio/Molinari, Courvoisier/Bouchet, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Buzzoni/Mantegazza/Malagnini/Castelli/Morossi, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Thé/Westerlund/Vardya/de Winter, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Andreae/Drechsel.

May: Tadhunter/Pollacco, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Lanz/Artru, Gehren/Steenbock/Reile/Axer/Burkert/Fuhrmann, Spite F./Spite M., Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Acker/Stenholm/Lundström.

June: Acker/Stenholm/Lundström, Baade/Stahl, Gerbaldi et al. (5-004-43K), Waelkens/Lamers/Trans/Waters, Pottasch/Pecker/Karoji/Sahu.

July: Courvoisier/Bouchet, Bica/Alloin, v. Genderen/v.d. Hucht/Schwarz/de Loore, Baribaud/Alloin/Pelat/Phillips, Boffin/Jorissen/Arnould, Hron, Baribaud/Alloin/Pelat/Phillips, Wiklind/Bergvall/Aalto.

August: Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Baribaud/Alloin/Pelat/Phillips, Tanzi/Bersanelli/Bouchet/Maraschi/Falomo/Treves, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Eriksson/Gustafsson/Olofsson, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Baribaud/Alloin/Pelat/Phillips, Katgert/Rhee, Baribaud/Alloin/Pelat/Phillips.

September: Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Cappi/Chincarini/Vettolani, Baribaud/Alloin/Pelat/Phillips, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Jugaku/Tekada-Hidai/Holweger, Gerbaldi et al. (5-004-43K), Baribaud/Alloin/Pelat/Phillips, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Calvani/Marziani, Baribaud/Alloin/Pelat/Phillips.

1.4-m CAT

April: Franco, Baade/v. Kerkwijk/Waters/Henrichs/van Paradijs, Gratton/Gustafsson/Eriksson, Westerlund/Krelowski, Mathys, Lemmer/Dachs.

May: Gillet/Crowe, Baade/v. Kerkwijk/Waters/Henrichs/van Paradijs, Stalio/Franchini/Porri/Chavarria/Terranegra/Covino/Neri, Spite F./Spite M., Crane/Palazzi/Mandolesi/Blades.
June: Crane/Palazzi/Blades/Kutner, Hubert-Delplace/Floquet/Chatzichristou/Hubert, Danks/Crane/Massa, Pasquini, Houdebine/Panagi/Foing/Butler/Rodono, Gredel/v. Dishoeck/Black.
July: Pottasch/Sahu, Diesch/Bässgen M./Grewing, Didelon.
August: de Vries/van Dishoeck/Habing, Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov.
September: Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov, Prein/van Genderen/Zwaan, Gustafsson/Eriksson/Olofsson/Lambert/Paresce, Thimm/Hanuschik/Schmidt-Kaler.

1-m Photometric Telescope

April: Lorenzetti/Berrilli/Ceccarelli/Nisini/Saraceno, Lorenzetti/Ceccarelli/Liseau/Nisini/Saraceno, Scaltriti/Busso/Origlia/De Francesco/Robberto/Persi/Ferrari-Toniolo/Silvestro, Schultz, Courvoisier/Bouchet, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Catalano F.A./Kroll, Madejsky/Appl.
May: Madejsky/Appl, Gouiffes/Cristiani, Reinsch/Pakull/Festou/Beuermann, Courvoisier/Bouchet, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Kreysing/Kaelble/Grewing, v.d. Hucht/Thé/Williams, Prévot/Lindgren H.
June: Hahn/Lagerkvist/Magnusson/Lindgren M., Cacciari/Clementini/Prévot/Lindgren H., Terzan, Wink/Greve, Courvoisier/Bouchet, Manfroid/Vreux/Gosset.
July: Brahic/Sicardy/Roques/Barucci, Manfroid/Vreux/Gosset, Brahic/Sicardy/Roques/Barucci, Gouiffes/Cristiani, Schneider/Weiss/Kuschnig.
August: Poulain/Davoust/Nieto, Eriksson/Gustafsson/Olofsson, Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Di Martino/Zappala/Cellino/Farinella/Davis, Alcaíno/Liller/Alvarado/Wenderoth.
September: Alcaíno/Liller/Alvarado/Wenderoth, Barbieri et al. (2-007-43K), Danziger/Bouchet/Gouiffes/Lucy/Wampler/Fosbury/Fransson, Zickgraf/Wolf, Gouiffes/Cristiani.

50-cm Photometric Telescope

April: Scaltriti/Busso/Origlia/De Francesco/Robberto/Persi/Ferrari-Toniolo/Silvestro, Schultz, Poretti/Antonello, Thé/Westerlund/de Winter.
May: Thé/Westerlund/de Winter, Stalio/Franchini/Porri/Chavarria/Terranegra/Covino/Neri, Seggewiss/Moffat/Robert.
June: Seggewiss/Moffat/Robert, Kohoutek/Wenskat, Houdebine/Panagi/Foing/Butler/Rodono, Carrasco/Loyola.
July: Group for Long Term Photometry of Variables.
August: Sinachopoulos, Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov, Carrasco/Loyola, Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov.
September: Foing/Crivellari/Vladilo/Castelli/Beckman/Char/Jankov, Group for Long Term Photometry of Variables.

GPO 40-cm Astrograph

April: Elst, Scardia.
May: Scardia, Landgraf.
June: Landgraf, Aniol/Seitter/Duerbeck/Tsvetkov.
July: Aniol/Seitter/Duerbeck/Tsvetkov.
August: Debehogne/Machado/Mourao/Caldeira/Vieira/Netto/Zappala/De Sanctis/Lagerkvist/Protitch-B./Javanshir/Woszczyk.
September: Debehogne/Machado/Mourao/Caldeira/Vieira/Netto/Zappala/De Sanctis/ Lagerkvist/Protitch-B./Javanshir/Woszczyk.

1.5-m Danish Telescope

April: DANISH TIME, Olsen, Della Valle/Rosino/Barbon/Cappellaro/Ortolani/Turatto, Ortolani/Fusi Pecci/Buonanno/Renzini/Ferraro.
May: Ortolani/Fusi Pecci/Buonanno/Renzini/Ferraro, de Jong/Slijkhuis/Hu/van der Bliek, Gregorini/Messina/Vettolani, Ilovaisky/Chevalier/Pedersen, DANISH TIME.
June: DANISH TIME, Calvani/D'Odorico/Zwitter, Reinsch/Pakull/Festou/Beuermann, Calvani/D'Odorico/Zwitter, Mayor et al. (5-001-43K), Duerbeck/Vogt/Leibowitz, Bandiera/van den Bergh.
July: Bandiera/van den Bergh, Reinsch/Pakull/Festou/Beuermann, Azzopardi/Lequeux/Rebeirot, Gratton/Ortolani, DANISH TIME.
August: DANISH TIME, Mayor et al. (5-001-43K), Ardeberg/Lindgren H./Lundström, Meylan/Mayor, Bender et al. (1-004-43K).
September: Bender et al. (1-004-43K), de Jong/Jørgensen/Nørgaard-Nielsen/Hansen/Goudfrooij, Vettolani/Cappi/Garilli/Gregorini/Maccagni, Ardeberg/Lindgren H./Lundström, DANISH TIME.

50-cm Danish Telescope

April: DANISH TIME.
May: DANISH TIME.
June: Ardeberg/Lindgren H./Lundström, DANISH TIME.
July: DANISH TIME.
August: Group for Long Term Photometry of Variables.
September: Ardeberg/Lindgren H./Lundström.

90-cm Dutch Telescope

April: DUTCH TIME, van Genderen.
May: van Genderen/v.d. Hucht/van Genderen, DUTCH TIME.
June: v. Amerongen/v. Paradijs.
July: v. Amerongen/v. Paradijs, van Paradijs/Strom/van der Klis/Spijkstra, v. Genderen/v.d. Hucht/Schwarz/de Loore, DUTCH TIME.
August: DUTCH TIME, Prein/van Genderen/Zwaan.
September: van Genderen, v.d. Hucht/van Genderen, DUTCH TIME.

61-cm Bochum Telescope

April: Lemmer/Dachs, Schneider/Jenkner/Maitzen.
May: Schneider/Jenkner/Maitzen.

SEST

May: SWEDISH TIME, Israel, de Graauw, Danziger, Reipurth, van der Veen, Schwarz.
June: SWEDISH TIME.
July: Henkel, Wielebinski, Israel, Eckart, Becker, Zinnecker, Israel, Henkel, Zinnecker, Omont, Pottasch, Chini.
August: SWEDISH TIME.
September: Harnett, Combes, Dupraz, Dennefeld, Bujarrabel, te Lintel, Hekkert, Le Bourlot, Haikala, Brand, Wilson, Roland.

IRC + 10216: a Peanut Nebula!

T. LE BERTRE, P. MAGAIN and M. REMY, ESO

1. Carbon Stars with Shells

Carbon stars with low effective temperature (2,000–3,000 K) are thought to be long-period variables evolving on the Asymptotic Giant Branch (AGB). These objects are burning alternately hydrogen and helium in different shells around a degenerate core of carbon and oxygen [1]. Material processed during the helium burning phase is dredged-up by convection to the surface and enriches it in carbon relative to oxygen.

Objects on the AGB are loosing mass due to a combination of two processes: pulsation of the central star and radiation pressure on grains. Consequently, carbon stars are surrounded by shells which also have a carbon-rich composition. The dust which is formed in these shells is expected to be mainly carbon-rich. Its composition is still a matter of controversy: graphite or amorphous carbon are generally proposed, but also silicon carbide (SiC) and magnesium sulfide (MgS). Depending on the optical depth of the circumstellar dust shell (CDS), the central star may or may not be observable. In the first case, one speaks of a *carbon mira* and, in the second case, of an *extreme carbon star* (ECS). In fact, it can be shown that there is a continuity between carbon miras and ECS's, and that the latter are only extreme miras undergoing mass loss at a huge rate [2].

One of the most interesting carbon stars is IRC + 10216. This object was discovered as an infrared source in a sky survey at 2.2 μm; it owes its name (IRC) to this circumstance. Early studies [3] showed that it is variable with a period of ~ 600 days and that it appears extremely red with a colour temperature of 650 K over the range 1 to 20 μm; such an energy distribution can only be understood if the central star is surrounded by an optically thick CDS which absorbs stellar radiation and re-radiates it at longer wavelengths. Its distance from the Sun is evaluated to be ~ 200 pc. Many molecules have been detected at radio wavelengths in its circumstellar shell and, from modelling of the CO emission, a mass loss rate of $\sim 10^{-5}\ M_{\odot} yr^{-1}$ has been derived. Being so near to the Sun and undergoing mass loss at such a large rate, this carbon-rich source is one of the best studied and is often considered as the prototype of ECS.

2. The Shell of IRC + 10216

Its proximity has allowed spatial resolution of its shell. Already in 1969, its optical counterpart was noted to be diffuse and elongated at position angle (PA) ~ 30° [3]. This diffuseness is mainly produced by scattering of stellar photons in the CDS; however, especially at short wavelengths ($\lambda < 0.5$ μm), photons scattered from the interstellar radiation field may also contribute. At infrared wavelengths (2–10 μm), the source is observed to be extended, with a typical size of the order of 1″ or less; in this spectral range, thermal emission by dust in the CDS is dominating. Using one-dimension speckle-interferometric techniques, the source is seen elongated in the North-South direction; furthermore, at 2 μm, it appears asymmetrical, being more extended towards the North and the North-East [4]. A large polarization is also observed in the optical as well as in the infrared ranges. This information is generally interpreted in terms of an axisymmetrical structure with an equatorial disk and polar lobes like in bipolar nebulae.

Although the bipolar nebula hypothesis is attractive, doubts have been cast on it. Molecular-line observations do not present any evidence of deviation from spherical symmetry on scales between 10″ and 60″. Also, deep images of IRC + 10216 were obtained through filters Gunn g, r, i and z, in April 1987, with the 2.2-m telescope at La Silla. They showed an extended structure up to at least 10″ with no evidence of axisymmetry [2]. Furthermore, the central part (< 1″) was seen elongated like in earlier images, but at a PA of 340° instead of 30°. Such a change of PA in less than 20 years is not easily reconcilable with a bipolar geometry which presumes a stable structure like an equatorial disk. Finally, the broad-band energy distribution of IRC + 10216 between 0.5 μm and 3 mm is well understood in terms of a radiative transfer model, consisting of a central star surrounded by a spherical CDS [5]; this result tends to support the idea that the geometry cannot deviate too much from sphericity.

To reconcile the evidences of sphericity (at least on large scales) with the evidences of asymmetry given by imagery of the central part (on scales < 1″), it has been proposed that mass loss occurs in an inhomogeneous manner with no systematic trend [2,4]. Convective cells at the surface of the star may be very large and induce mass loss, at a given instant, in a preferential direction. Due to stellar rotation, they move with respect to the CDS; also, with time these cells evolve, and the matter in the shell appears clumpy with no systematic deviation from spherical symmetry.

In Figure 1, a schematic representation of the inner part of the IRC + 10216 CDS, based on such a proposition, is presented. Matter has been flowing away preferentially from an active spot during the last 20 years. Dust is condensing out of the gas when it reaches a distance, R_c, such that grains can survive in the radiative field; this distance represents the internal radius of the CDS and defines a spherical cavity inside which no dust is present. If condensation temperature is around 1,000 K, the apparent radius of this central cavity is ~ 0.″15, whereas the apparent radius of the star is ~ 0.″02 (for a stellar effective temperature of 2,200 K). The dust density is enhanced in a preferential direction and the images at all wavelengths (i.e. in light scattered or emitted by dust, independently of optical depth) are observed to be elongated in that direction.

Also, in this scheme, the direction of polarization is always perpendicular to that preferential direction as is observed on IRC + 10216. Due to stellar rotation, the elongation, which was observed to be at PA ~ 30° in 1969, appears now at PA ~ 340°; dust which reached condensation point twenty years ago has travelled a distance, $R_1 \sim 3.0\ 10^{-4}$ pc, and is now at ~ 0.″5 from the central star. Finally, if this representation is correct, the star should appear offset to the South of the nebula; this consequence could give a natural explanation to the asymmetry of the profiles obtained at 2 μm.

3. High-Resolution Imaging

Such a scheme offers an interesting and plausible alternative to the bipolar nebula hypothesis, but is still highly speculative; imagery at high spatial resolution (~ 0.″1 or better) would be necessary to confirm it. The images obtained at the 2.2-m in April 1987 were acquired in good seeing conditions (FWHM of stellar images < 1″) but their spatial resolution was largely insufficient. However, two elements allow to consider improving their quality by numerical treatment. First, a star is close to IRC + 10216 (~ 36″ to the South-East) and could be registered simultaneously on the same CCD frames (see Figs. 1 and 2 in [2]). Second, the pixel size was small enough (0.″6) so that the images of this point source were well sampled. Therefore, it appeared possible to improve the resolution of these images with a deconvolution method using as point spread functions the profiles of the nearby star. In Figure 2, the images deconvoluted by the method of maximum entropy [6] are presented.

The result is striking: one sees a peanut-shaped nebula whose main axis is oriented North-South and concavity is turned towards East. The resemblance

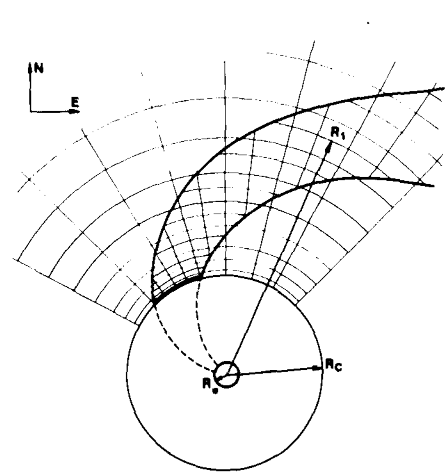


Figure 1: *Schematic representation of IRC + 10216 dust shell (adapted from [2]).* R_x *is the radius of the central star (~ 0.″02).* R_c *is the inner radius of the circumstellar dust shell (~ 0.″15); it corresponds to the distance at which grains are condensing out of the circumstellar gas.* R_1 *indicates the current position of matter which reached the condensation point twenty years ago. North is up and East at right.*

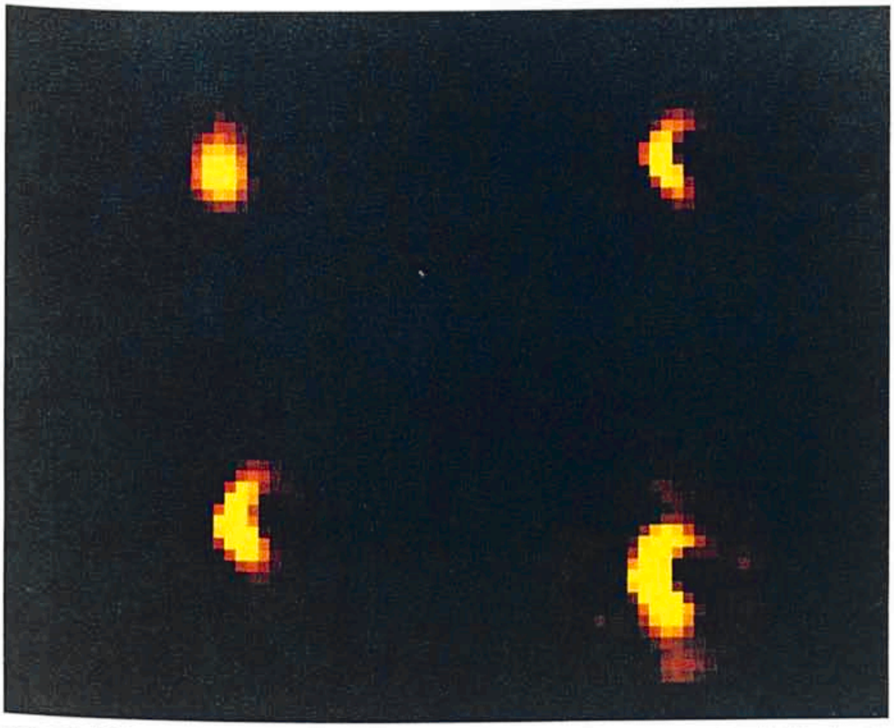


Figure 2: *IRC + 10216 images obtained in April 1987 through Gunn g, r, z and i (clock-wise starting from the upper left corner) and deconvoluted as explained in the text; pixel size is 0"26. The original Gunn r and z frames were presented in [2]. North is up and East at right.*

with the sketch presented in Figure 1 is so flagrant, that we ourselves could not believe it. As IRC + 10216 is more easily observed around maximum, we decided to wait for the next one (expected to occur around November 1988 [2]) and to perform new observations at such phase (with a smaller pixel size) in order to verify the meaningfulness of this result. In the meantime, the algorithm of deconvolution and the code were checked using artificial images. Also, various tests on convergence, consistency, etc. using the real IRC + 10216 images were performed; all resulted positive. For example, one of these tests consisted in rotating an original image by an arbitrary angle, deconvoluting it, then rotating the deconvoluted image backwards and comparing it to the image obtained by direct deconvolution; in all cases, the comparison was satisfactory. Finally, another image-restoration method [7] was used and gave similar results.

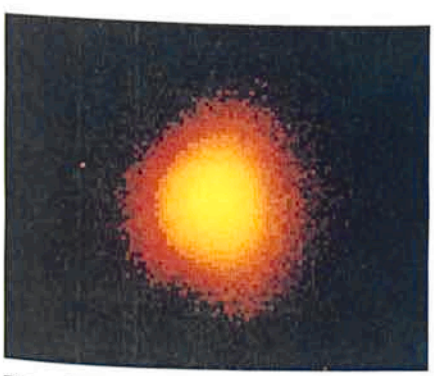


Figure 3: *IRC + 10216 image obtained in December 1988 through Gunn i; pixel size is 0"175. North is up and East at right.*

IRC + 10216 was reobserved on December 16/17, 1988 using the 2.2-m equipped with the recently commisioned CCD no. 15. The individual detector size is 15 μm which translates to a pixel size of 0"175 on the sky. The infrared monitoring performed at the 1-m was indicating that we had, as predicted, just passed the maximum by a few days and that the source was undergoing a maximum brighter than in April 1987. We were therefore expecting slightly larger images for IRC + 10216. On the other hand, the image quality was not as good, being around 1"3, as measured on the nearby star. The frames obtained through the same Gunn g, r, i and z filters were reduced using the standard procedures; the Gunn i image is presented in Figure 3. No basic difference can be noted with respect to the images obtained in April 1987 [2].

The deconvoluted Gunn i image is presented in Figure 4. The same structure as in Figure 2 is again clearly seen. The similarity between the April 1987 deconvoluted images and the December 1988 ones leads to the conviction that the peanut shape is not an observational artifact. Moreover, the fact that this structure is observed at 600 days difference indicates also that it is not a transient, but (on a time-scale of one stellar cycle) a permanent feature of the CDS. The observational confirmation of the scheme proposed earlier by us [2] is important not only because it supports our theses, but also because it contradicts the bipolar hypothesis and, therefore, the models relying on it. It definitively places IRC + 10216 among the normal carbon-rich miras, and not, as sometimes suggested, among the protoplanetary nebulae.

From a more general point of view, it can be noticed that a lot of information is often present in astronomical data which is not exploited. An illustration of overlooked information was given recently in the *Messenger* [8]; our work gives another example. It would surely be worth to apply the same kind of technique to the IRC + 10216 images obtained in the optical range during the last 20 years. Such an investigation could give indications on the recent mass loss history and on the stellar rotation period. Moreover, our work demonstrates the interest in good seeing and good sampling of the point spread function.

4. What is in a Name?

Finally, astronomers are used to give fancy names to their pet objects (derived from their food habits?), e.g.: the Egg Nebula, the Hamburger Nebula and, even, the Rotten Egg Nebula! For IRC + 10216, we propose: the "Peanut Nebula"; as its circumstellar shell is known from observations in the radio range to be rich in organic molecules, we hope this denomination will also satisfy our colleagues from radio astronomy.

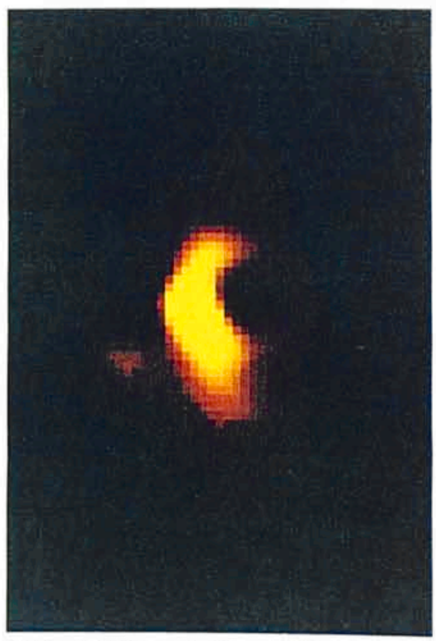


Figure 4: *Same as in Figure 3, but deconvoluted as explained in the text.*

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List of ESO Preprints

December 1988 – February 1989

SCIENTIFIC PREPRINTS

625. (1) C.N Tadhunter, R.A.E. Fosbury, S. di Serego Alighieri: Beamed Ionizing Radiation in Radio Galaxies.
(2) R. Morganti et al.: What Are the Emission Line Filaments Along the Radio Axis of Centaurus A?
Papers presented at the Como Workshop on BL Lac Objects: 10 Years After (September 1988).
626. G. Garay, R. Gathier, L.F. Rodríguez: Radio Recombination Line Observations of Compact Planetary Nebulae. *Astronomy and Astrophysics.*
627. I.F. Alania, O.P. Abuladze, R.M. West: uvbyβ Photometry of Peculiar B and A Stars, Discovered at Abastumani. *Astronomy and Astrophysics, Supplement Series.*
628. E. Gosset et al.: Analysis of the Photometric Variability of WR 40. *Monthly Notices of the Royal Astronomical Society.*
629. P. Molaro et al.: NaI Interstellar Absorption in the Direction of Two LMC Supergiants in the Field of SN 1987A. *Astrophysical Journal,* Letters.
630. G. Meylan, S. Djorgovski: UM 425: A New Gravitational Lens Candidate. *Astrophysical Journal,* Letters.
631. P. Crane et al.: Cosmic Background Radiation Temperature at 2.64 mm. *Astrophysical Journal.*
632. R.M. West, H.E. Jørgensen: Post-perihelion Observations of Comet Halley at r = 8.5 A.U. *Astronomy and Astrophysics.*
633. (1) A.F.M. Moorwood: Near IR Spectroscopy of Active Galaxies.
(2) A.F.M. Moorwood, E. Oliva: Infrared [FeII], H and H_2 Lines in Galaxy Nuclei.
To appear in Proceedings of the 22nd ESLAB Symposium, *Infrared Spectroscopy in Astronomy.* ESA SP-290 (A.C.H. Glasse, M.F. Kessler and R. Gonzalez-Riesta eds.).
634. E. Covino et al.: EE Aquarii: a Marginal Contact System. *Monthly Notices of the Royal Astronomical Society.*
635. G. Contopoulos et al.: Comparison of Stellar and Gas Dynamics of a Barred Spiral Galaxy. *Astrophysical Journal.*

Guidelines for Authors of Articles for the ESO *Messenger*

The *Messenger* is ESO's house-journal and serves as a link between ESO and the user community. It brings information about scientific and technical developments at ESO and also about administrative measures. At the same time it aims at providing interesting news about astronomy and astrophysics to a broader public, including policy makers, science teachers, amateur astronomers, inside and outside the ESO member countries. At the present time, the *Messenger* is distributed free of charge to about 4,000 addresses (airmail to overseas destinations).

The *Messenger* is abstracted by several services, including AAA.

Since there are limits to the size of each issue, set by the available manpower and by the budget, it has now become necessary to establish a minimum of guidelines for authors. They are not intended to restrict the information flow; on the contrary, they aim at keeping the "fresh" look of the *Messenger,* by ensuring that each issue carries a broad variety of "interesting" and informative articles.

Deadlines

The *Messenger* normally appears at the beginning of March, June, September and December. The corresponding deadlines are 6 weeks before, i.e. on January 20, April 20, July 20 and October 20.

Last-minute, "spectacular" (and short) news items can be received during the editorial process; please contact the editor immediately.

Contributions

Contributions must be written in English. For the benefit of our Spanish-speaking readers, condensed versions of some articles may be published in this language.

Normally, the editor will solicit contributions to the ESO *Messenger* by writing to prospective authors, 6–8 weeks before the next deadline. Unsolicited manuscripts are welcome, but the editor reserves the right not to publish them.

Submitted manuscripts will be checked for obvious, technical errors as far as possible, but it is not possible to undertake major revisions of the language. Therefore, if you are worried about your English, please ask a colleague to help, before you submit your article.

Messenger articles are normally not refereed; however, in certain cases the editor may solicit the advice of other ESO astronomers before accepting an article.

On rare occasions, especially if there are important news items which necessitate last-minute layout revisions, an article will have to be delayed to the next issue. The authors will be informed about this immediately and will have the opportunity to revise the article, if so desired.

Text and Style

All articles brought in the *Messenger* must have some connection to ESO. They will often be based on results from observations at La Silla, but may also concern developments elsewhere of direct implication for ESO programmes.

An article should normally not exceed 4 printed pages, including figures, but shorter contributions, down to a picture with an appropriate caption, are of course most welcome. One printed text page is roughly equivalent to 3.5 double-spaced A4 typewritten pages, 7,000 characters or 1,200 words. The maximum manuscript size is therefore about 10 A4 typewritten pages (20,000 characters or 3,500 words), plus figures.

The style should be light, but informative. **The *Messenger* is no substitute for the professional journals** and its articles should contain less detail and more background than what is usual in scientific papers. Remember that the *Messenger* is read by many people from different fields and with a range of background knowledge from the amateur to the specialist.

A "personal touch" in the form of an associated event, an unusual result, etc., will be appreciated. Similarly, a *Messenger* article may contain information which is not normally included in a scientific article, for instance about technical problems, rather speculative ideas, suggestions for future work, advice to other observers, etc. Early, tentative reports of new results are welcome, but cannot serve to replace proper accounts in referee journals.

An article should not contain more than 10–15 references. Please use the style of *Astronomy & Astrophysics.*

Figures

A maximum of 6 figures is normally allowed per article. They should be submitted in the form of sharp photographic prints or slides. Photocopies of already published figures will not be accepted.

Colour pictures may be used, if the subject justifies the extra cost.

Reprints

No reprints are made of *Messenger* articles, but the author(s), *upon request,* may receive a small number of copies of the issue in which their article appeared. This request should be made when the article is submitted.

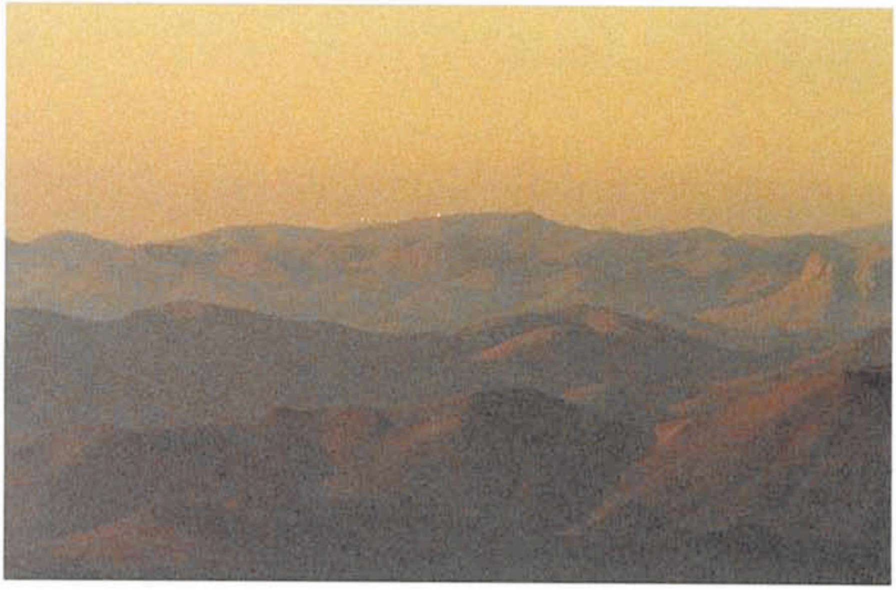
TECHNICAL PREPRINTS

1. R.N. Wilson et al.: Active Optics III: Final Results with the 1 m Test Mirror and NTT 3.58 m Primary in the Workshop. *Journal of Modern Optics.*
2. B. Delabre et al.: Astronomical Spectrograph Design with Collimator Compensation of Camera Chromatism (4C). Proceedings of SPIE No. 1055.

A Distant View of La Silla

W. C. KEEL, University of Alabama, USA

The domes and related structures on La Silla are prominent features of the Atacama landscape as seen for many kilometres, and would be for many more were it not for the intervening Andean foothills. Under proper conditions, they may be seen (with the unaided eye) for even greater distances. Possibly the most distant normally occupied vantage point (barring a *SPOT* image) is from the Inter-American Observatory on Cerro Tololo, about 103 km south-southwest of La Silla. For month-long periods twice a year (when the sun's declination is about −10°) the domes at ESO are prominent shortly before sunset, as shown in the photograph taken in mid-October of 1988. Five structures are prominent with another two visible on the original print. Part of La Silla is hidden behind a foreground mountain, identified in the *Mapa Fisico de Chile* as Cerro El Pozo (east of Almirante Latorre); its presence accounts for the greater difficulty of locating Cerro Tololo from La Silla, even using binoculars.



It is of some interest to examine the circumstances that make the ESO domes visible over such distances. Key clues are the time at which they may be seen, from about 15 to 10 minutes before apparent sunset at CTIO, and the 4–5-minute period over which they are seen. Such a short timespan suggests a specular or semi-specular reflection off a surface which is flat in at least one dimension. Reflections from the domes themselves are thus ruled out, since the brightness of such a reflection would change very little over most of the day. Reflections from the flat walls of structures such as the Administration Building would be prominent indeed, but could not be seen over a range of solar declination of more than 0.5 degree, in conflict with the observed month-long range of visibility. The cylindrical sides of many of the domes are the most likely source of short-lived reflections, but additional checks are needed to make sure their properties are fully consistent with the time of appearance and duration of the observed reflections.

Since CTIO and ESO are at comparable elevations, to a good approximation the condition for reflection off a vertical surface is that the sun should have an apparent zenith distance of 90 degrees at La Silla. This astronomical condition can be tested from the known situation of the observatories and the known time of visibility relative to the apparent sunset at Tololo. First, how long before apparent sunset at La Silla is the apparent sun horizontal, and second how much difference in the times of sunset is there between La Silla and Tololo?

The dip of the horizon from the altitude of ESO is about 1.6 degrees, and at this time of year the sun requires about 435 seconds to traverse this vertical distance solely from geometrical considerations. An additional time between the sun at 90 degrees zenith distance and apparent sunset is produced by atmospheric refraction, which produces a deceleration of the apparent sun amounting to about 160 seconds for typical meteorological conditions; most of the refraction seen at sunset arises in the last few degrees above the horizon. Finally, apparent sunset at Cerro Tololo is 80 seconds later than at La Silla due to the small longitude difference. Adding these up, the horizontal-sun condition is satisfied from about 13 to 11 minutes before apparent sunset on Cerro Tololo, in good agreement with what we actually see. The reflections are bright for somewhat longer than the 2 minutes expected from the sun's angular size and a perfectly smooth surface, presumably due to the roughness of the corrugated metal used for the cylindrical sections of some of the telescope buildings. (Unfortunately for sunset watchers on La Silla, most of the domes at Cerro Tololo have rectangular base structures and thus any reflections will be visible for only a couple of days each year; furthermore they are at unfavourable orientations for catching sunlight as seen from almost due north).

Examining the photograph once more, the 3.6-m dome is the brightest (far right), as befits the large size of the support building. One can also identify (left to right) the small cluster of domes dominated by the Dutch 90-cm, the ESO 1.5-m, the ESO 1.0-m and Danish 1.5-m (both rather faint), and the ESO/MPI 2.2-m. It is fitting that visibility phenomena of this kind may be understood with some of the astronomical observer's most basic methods.

STAFF MOVEMENTS

Arrivals

Europe:

FERRARO, Francesco (I), Fellow

KÄUFL, Hans Ulrich (D), Infrared Instrumentation Scientist

PASIAN, Fabio (I), Fellow (Senior Archive Scientist ST-ECF)

Departures

Europe:

BUYTENDIJK, Felice (NL), Receptionist

GROTE, Rainer (CH), Projekt Draughtsman

MEYLAN, Georges (CH), Fellow

SCHNEIDER, Karin (D), Secretary

VAN RIJN, Gunilla (NL), Administrative Assistant

Chile:

HAGSTRÖM, Magne (S), Associate (Microwave Engineer SEST)

OLBERG, Michael (D), Telescope Software scientist

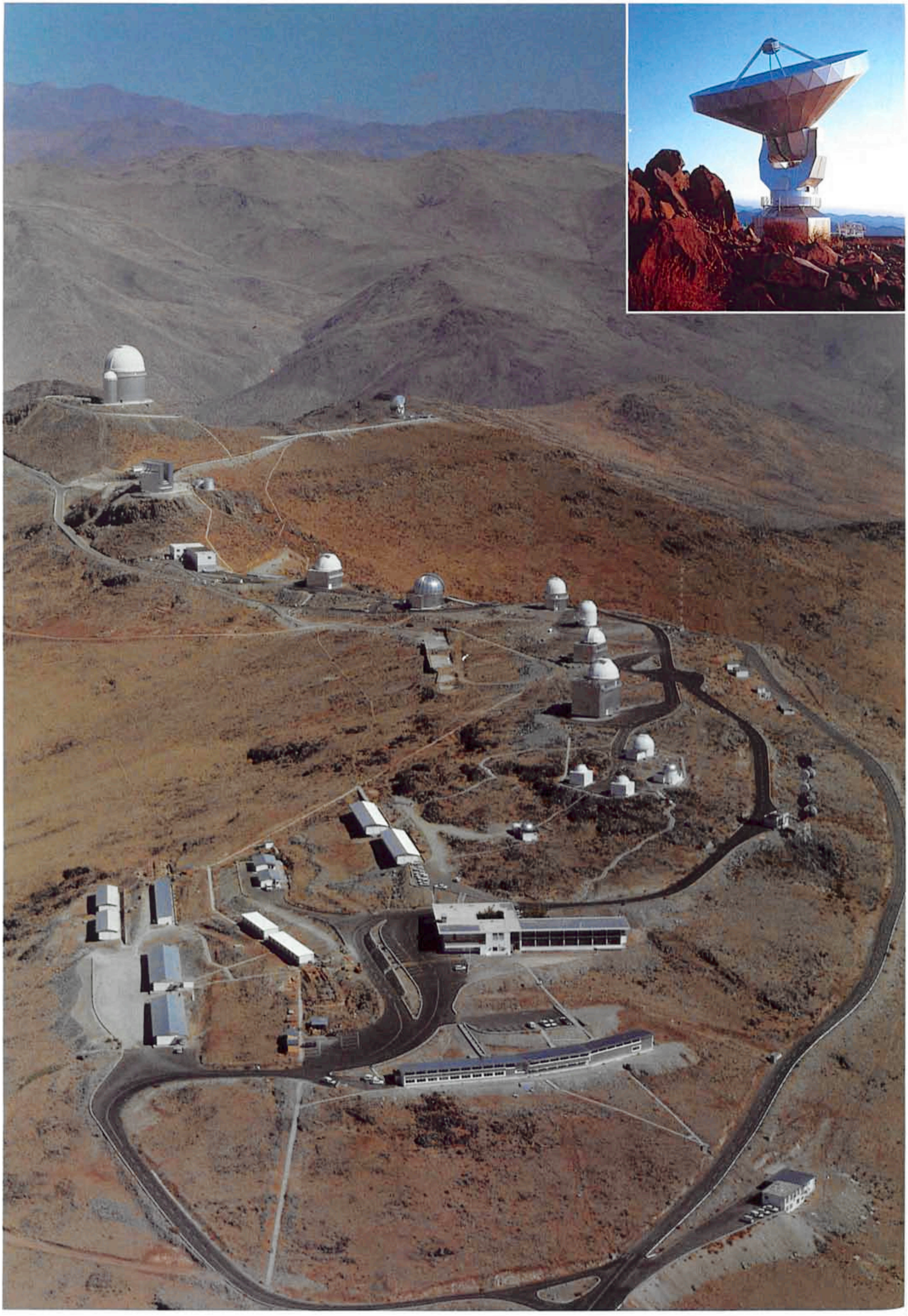


Fig. 1

Fig. 2

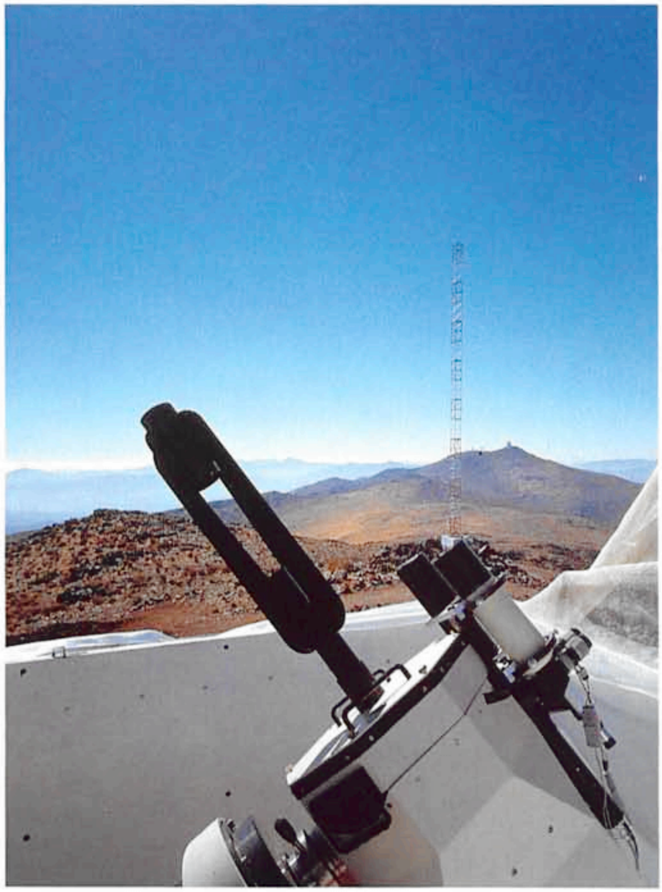


Fig. 4

THE CHANGING SKYLINE OF LA SILLA

The fact that ESO has come a long way since the earliest days, described in the articles by Prof. Blaauw (this and the previous issue of the *Messenger*), is well illustrated by these photographs obtained in mid-December 1988, e.g. of the SEST (Fig. 1), the only instrument of its kind in the southern hemisphere, or of the NTT (Fig. 2), now nearing completion, changing the "skyline" of La Silla (Fig. 3). The seeing monitor (Fig. 4) used for VLT site tests at neighbouring Cerro Vizcachas is an indication of times yet to come.

C. MADSEN

Fig. 3

Signposts of Low Mass Star Formation in Molecular Clouds

B. REIPURTH and C. MADSEN, ESO

Regions of massive star formation are easily recognizable because of the presence of bright, often very extended H II regions. The more quiescent places where only low mass star formation takes place are not so immediately obvious to identify. Most of the low mass star forming regions known today were found in the 1950's, mainly through objective prism surveys for Hα emission stars done by Joy, Herbig, Haro and others. Their results are summarized and supplemented by later findings in a new catalogue by Herbig and Bell (1988), which lists 742 mainly low mass pre-main-sequence stars. Another recent and rich source of low mass young stars is the IRAS catalogue. IRAS data towards clouds, however, often suffer from source confusion and, in particular, extraction problems because of background emission.

Reflection and Emission Nebulae

The youngest and generally most interesting stars are still intimately associated with their placental material, and therefore often show small, faint reflection nebulae. In the earliest evolutionary stages a star is normally not visible at all, but through cavities blown open to the cloud surface it may illuminate the surrounding cloud. Perhaps the finest known case is the Re 50 nebula in Orion, shown in a CCD image through a red broadband filter in Figure 1. This object was found by inspection of deep red Schmidt plates of the L 1641 molecular cloud in Orion (Reipurth 1985). The northern elongated nebula is a beam of light that escapes from a 250 $L_\odot$ embedded infrared source. The southern nebula is a molecular cloud clump which is illuminated by the same star through a channel hidden from view. The whole object is highly variable, to the extent that it looks different each time it has been observed during the last 6 years. Moreover, inspection of older Palomar Schmidt plates from 1955 shows nothing of the nebula. Perhaps we are here for the first time witnessing the emergence of a young star from its cloud-enshrouded birthplace (Reipurth and Bally 1986, Scarrot and Wolstencroft 1988). Some other similar reflection nebulae, apparently in slightly more evolved stages, are the PV Cep, Re 5 and IRN nebulae (Cohen et al. 1977, Graham 1986, Schwartz and Henize 1983).

After a young star has broken through its cloud cover to the outside world it passes through phases where strong outflowing winds create shocks in the ambient medium, the so-called Herbig-Haro objects. These are normally found as chains of small nebulae stretching away from an infrared source. They can be identified by their very characteristic emission line spectra. In recent years it has become clear that a subset of the Herbig-Haro objects take the form of highly collimated jets, remarkably similar in appearance to the jets from extragalactic radio sources (for a recent review, see Mundt 1988).

One of the finest jets known to be associated with a young star is the HH 34 jet. It was originally noted on a deep red Schmidt plate, and subsequent CCD imaging revealed its extraordinary nature (Reipurth 1985, Reipurth et al. 1986). Figure 2 shows an almost 30 arcsecond long jet emerging from a faint emission line star, and pointing right towards HH 34 in the lower part of the image. We are here witnessing mass loss from the star ejected in a collimated supersonic beam, ending in a bow shock where the outflowing material rams into the ambient medium. A comparison between the original discovery image from 1982 with a series of identical images taken up to 1989 shows that the shock structures seen as knots in the jet have a proper motion in the direction away from the source. A second oppositely oriented bow shock was found on the other side of the jet by Bührke et al. (1988), demonstrating that the outflow is bipolar. Studies of such objects provide key information on the earliest phases of stellar evolution.

Given the success of the initial examinations of Schmidt plates in identifying new and unusual regions of low mass star formation, a more ambitious project was initiated.

A Survey of Molecular Clouds with the ESO Schmidt Telescope

Because of their large field, Schmidt plates are ideal for surveys. The fine-grained IIIa-F plates are, when properly hypersensitized, particularly useful for searches for the often intrinsically red and heavily obscured small reflection nebulae, as well as for Herbig-Haro objects, since their emission lines mainly fall within the spectral sensitivity curve of the IIIa-F emulsion. Using the ESO 1-m Schmidt telescope at La Silla, Chile, equipped with a RG 630 filter, a large scale survey of molecular clouds all along the southern galactic plane has been carried out during the last two years. All plates were taken by H.-E. Schuster, Guido Pizarro and Oscar Pizarro. More than two hundred tiny nebulae in dark clouds have been identified.

Seen on deep Schmidt plates, exposed to their best S/N ratio, such small nebulae appear to be superimposed on a background of relatively high density. Thus at times it is difficult to recognize the tiny objects by merely visually inspecting the plates. The well known photographic technique of diffuse-light amplification brings remedy to the problem by "removing" the chemical fog contributing to the high overall density, and by increasing the contrast of the image at the density level required. However, as such nebulae are sometimes found in regions with nearby OB stars surrounded by bright H II regions, there can be large density variations over the photographic plate. Therefore, pure amplification will effectively obscure as much as it reveals, due to the very limited dynamic range which this process offers. Consequently it is often necessary to employ a strong unsharp mask during the amplification process. The technique of unsharp masking has been described elsewhere and shall not be dealt with here. Serving as an analogue low frequency filter, the mask brings down the overall contrast of (a larger part of) the plate to a level which allows for contrast amplification of the whole area under study.

The follow-up Observations

In order to separate reflection from emission nebulae, one should ideally obtain a spectrum of each nebula. However, most of these tiny objects are so faint that it would require immense amounts of observing time on large telescopes to complete such a programme. But another simple and fast technique exists. For each object direct CCD images were obtained at the Danish 1.5-m telescope at La Silla, one through a far-red broadband Gunn z filter extending to the CCD cutoff beyond 1 micron, and one through a narrow-band interference filter centred on the [SII] 6717/6731 emission lines. A reflection nebula associated with a partly embedded young low-mass star is very red and will show up prominently in the broadband Gunn z filter, but rarely in the narrow-band sulphur filter. On the other hand, Herbig-Haro objects are strong emitters in the 6717/6731 lines, but have no

Figure 1: *A Gunn r filter CCD image taken 4 March 1986 at the Danish 1.5-m telescope. An infrared source is hidden above the upper nebula, which is a beam of light escaping from the newborn star. The lower nebula is a molecular cloud clump illuminated by the embedded star.*

Figure 2: *A [S II] filter CCD image taken at the Danish 1.5-m telescope of the HH 34 region. Here a shocked emission line jet flows supersonically away from a faint young star. The jet cools to invisibility, but continues and eventually rams into the ambient medium in a bow shock.*

strong lines in the Gunn z bandpass and virtually no continuum, so they will show up very bright in the narrow-band sulphur filter, and barely, if at all, in the Gunn z filter. In this way the number of known Herbig-Haro objects have been doubled. Since such objects have most of their emission concentrated in a couple of strong emission lines, it is feasible to study spectroscopically this subset of the list of new small nebulae. These additional observations are important for final confirmation, since distant H II regions sometimes can mimic HH objects. But the gradual build-up of experience helps: at the beginning of the survey only 15 % of the objects which on the plate looked to be Herbig-Haro objects were actually confirmed as such, while at the end the rate exceeded 90 %.

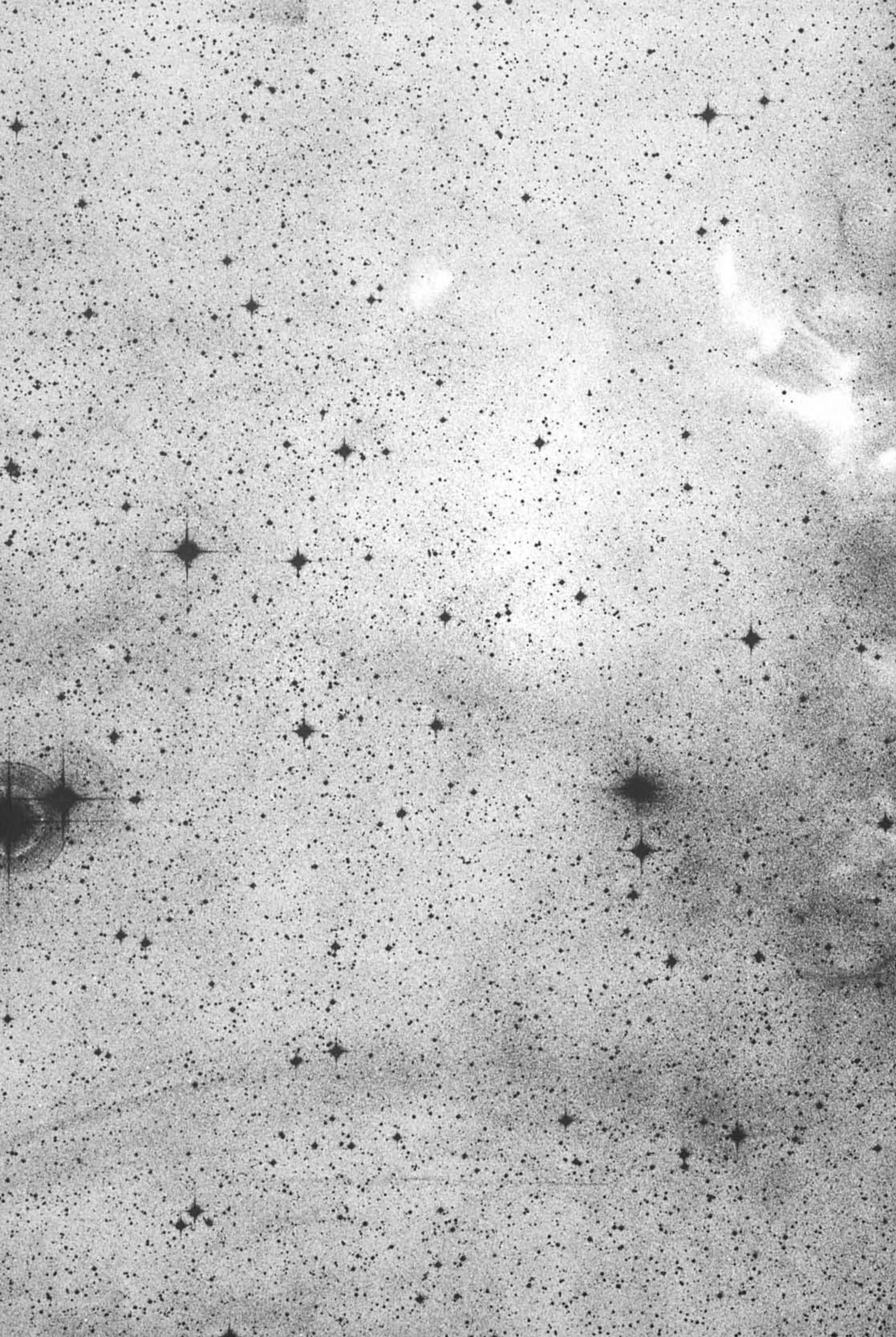
It should be noted that the selection of a [S II] 6717/6731 filter, rather than an Hα filter, is essential to this technique, as most stars show Hα emission, which will then also be present in the surrounding reflection nebula. [S II] emission is, on the other hand, a clear indicator of shocks, when associated with a low-mass, low-luminosity star. Van den Bergh (1975) employed an early version of this scheme.

Such a survey has a value in providing firmer statistics on the frequency and timescales of shocked outflows from young stars. But it is the detailed follow-up observations of selected objects which provide the most fun and which occasionally can provide new insights on early stellar evolution. For example, the new objects HH 80/81 are almost as bright as HH 1 and 2 (the first objects to be discovered by Herbig and Haro and still the brightest), but they are at least three times more distant and are thus the intrinsically brightest objects known (Reipurth and Graham 1988). Moreover, they do not emerge from a solar-type star, but from a young B-star, and they show the highest velocity dispersion hitherto observed. Or take the case of the new object HH 111, probably the largest and best collimated jet known to date to emerge from a young star. Besides the jet it has four bow shocks, moving supersonically in pairs of two in opposite directions from an embedded infrared source, from which there also streams a large molecular flow (Reipurth, in press).

The Orion Region

The molecular clouds in Orion are the most active sites of low mass star formation known. Figure 3 shows a deep red Schmidt plate of the Orion nebula and beneath it the L 1641 molecular cloud stretching to the southeast. The whole region is full of many hundreds of Hα emission stars, variable stars, flare stars and infrared sources. The L 1641

Figure 3: *The cometary shaped molecular cloud L 1622 in Orion as seen on a deep red ESO Schmidt plate. The cloud is active in low-mass star formation, and contains many nebulous stars, Hα emission stars, infrared sources and one Herbig-Haro object.* ▶



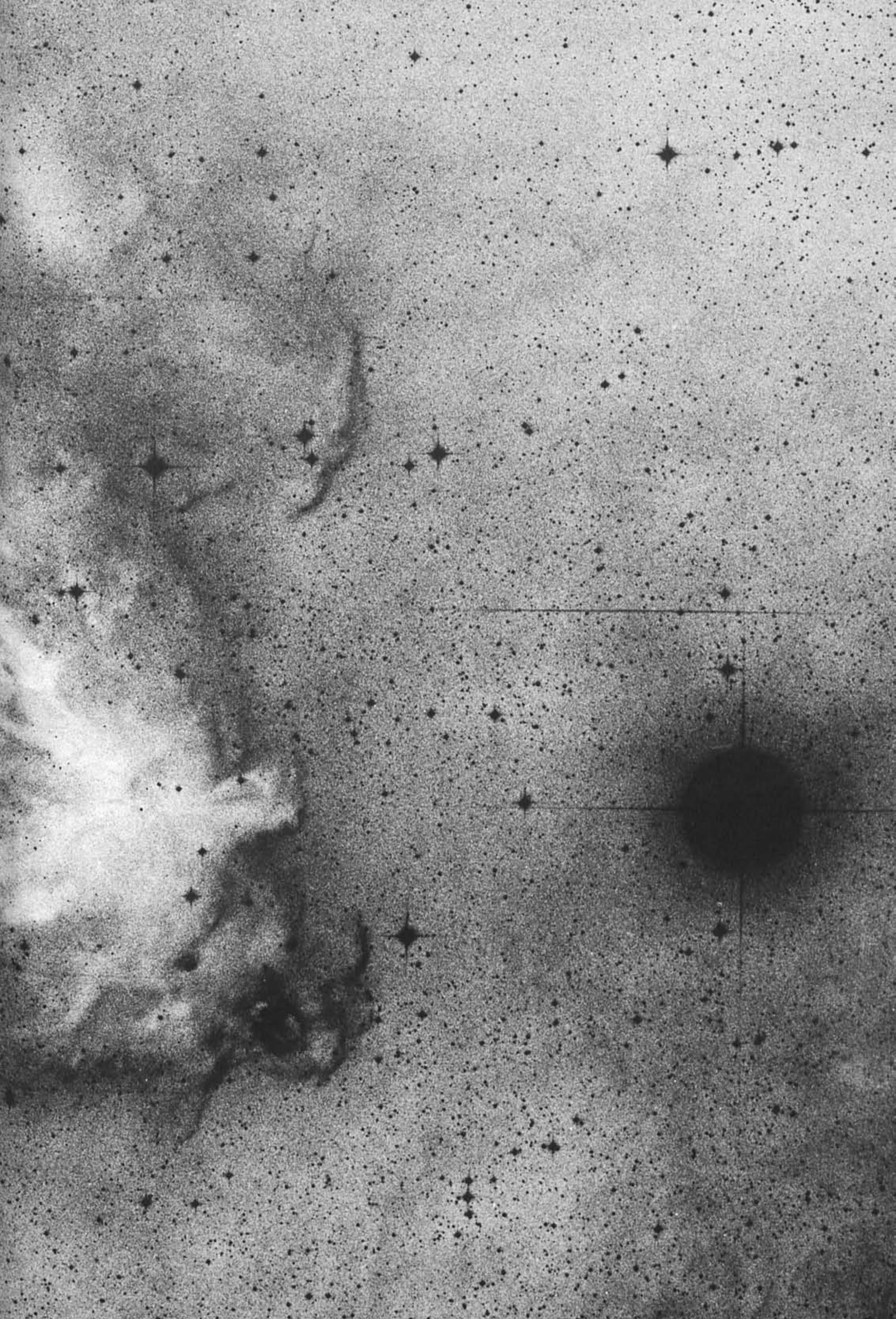


Figure 4: *A deep, red ESO Schmidt plate (IIIa-F, 150 min., RG 630) showing the Orion Nebula. The print was produced by subjecting the plate to unsharp masking, followed by diffuse-light amplification. As M42 itself is not interesting in this context, the mask was prepared in such a way that it would not influence M42 in any appreciable manner, but so that the low-surface-brightness filamentary structures stand out in great detail.*

cloud appears as a rather homogeneous obscuration, but a detailed map made at ^{13}CO by Bally et al. (1987) shows that the cloud is really composed of long infiltrated strings and clumps of denser material embedded in a lower density gas and dust environment. Closer examination of the region shows that the youngest stars, those found as infrared sources, are almost invariably located in association with the denser clumps.

The region is also rich in Herbig-Haro objects, indeed it has the highest concentration of such objects found anywhere. Star formation therefore has not only taken place here over the last few million years, but is a still ongoing process. Moreover, it is not confined merely to the dense L 1641 cloud. Figure 3 has been processed in such a way as to bring out the faint outlying structures, to which only little attention has been paid to date. Our survey uncovered several Herbig-Haro objects in these more peripherical regions, and shows that star formation also occurs here, albeit on a very modest scale.

Orion contains many smaller, less well-known clouds, in which stars are being born. Figure 4 (centerfold) shows the beautiful L 1622 cloud. With its bright rims and long tail it gives the impression of being strongly affected from the outside. It is in fact pointing directly towards the young massive O-stars in M42, which bath it in ultraviolet radiation. This outside influence may be the cause of the vigorous formation of stars occurring in this small cloud: there are several nebulous stars, Hα emission stars, and embedded infrared sources, and we have found a new Herbig-Haro object (HH 122, seen as a tiny group of small nebulae near the eastern edge of the cloud). A detailed optical infrared/radio study is currently being made of L 1622 at La Silla.

Acknowledgements

We are very grateful to Hans-Emil Schuster, Guido Pizarro and Oscar Pizarro, who took all the plates used in this survey.

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Professors J.H. Oort, H. van der Laan and A. Blaauw looking at the La Silla model.

On Friday, January 27, Professor Adriaan Blaauw opened the ESO Exhibition in The Hague, the Netherlands, with a review of ESO's history since 1952. This was preceded by a speech from the Director General about ESO's future and its role in European astronomy.

Among many prominent guests were Prof. Jan Hendrik Oort and Dr. Henk Bannier, both former Presidents of the ESO Council, and the present members of Council, Prof. Wim Brouw and Dr. Jan Bezemer.

The Exhibit, which lasts till March 12, 1989, is hosted by the beautiful new Science Museum of The Hague called MUSEON. ESO is especially grateful to Dr. Wim van der Weiden, MUSEON's Director, for his enthusiastic reception. The Exhibit was set up by Mr. Claus Madsen of ESO and Dr. Peter Wisse, staff astronomer of MUSEON.

The festive opening was co-hosted by OMNIVERSUM, Europe's first space-theatre, next door to MUSEON. OMNIVERSUM openend in December 1984 and is the result of a sustained initiative by Prof. Harry van der Laan between 1977 and 1984, while he was Chairman of nearby Leiden Observatory.

Observation of the ^{12}CO ($J = 1 \rightarrow 0$) Line in NGC 613 with the SEST

E. BAJAJA, Max-Planck-Institut für Radioastronomie, Bonn, F.R. Germany*
E. HUMMEL, University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield, Cheshire, U.K.

Introduction

The availability of the Swedish-ESO Submillimeter Telescope (SEST) on La Silla opened the possibility of extending the radio observation of molecular lines to the very southern galaxies. In particular the observation of the CO lines in the nearest galaxies will permit not only to increase the sampling for statistical purposes but also to study in more detail the distribution and kinematical properties of the molecular clouds in relation to other components of the galaxies. The HPBW of the SEST, at the frequency of 115 GHz of the ^{12}CO ($J = 1 \rightarrow 0$) line, is 43″ which means that galaxies with diameters between 5.5 and 10 minutes of arc are well suited for mapping since they do not require a prohibitive amount of time and the arms can be resolved if the inclination angle is adequate.

We had selected NGC 613 some time ago as a candidate for CO observation because of several interesting features,

* Member of the Carrera del Investigador Científico of the CONICET, Argentina.

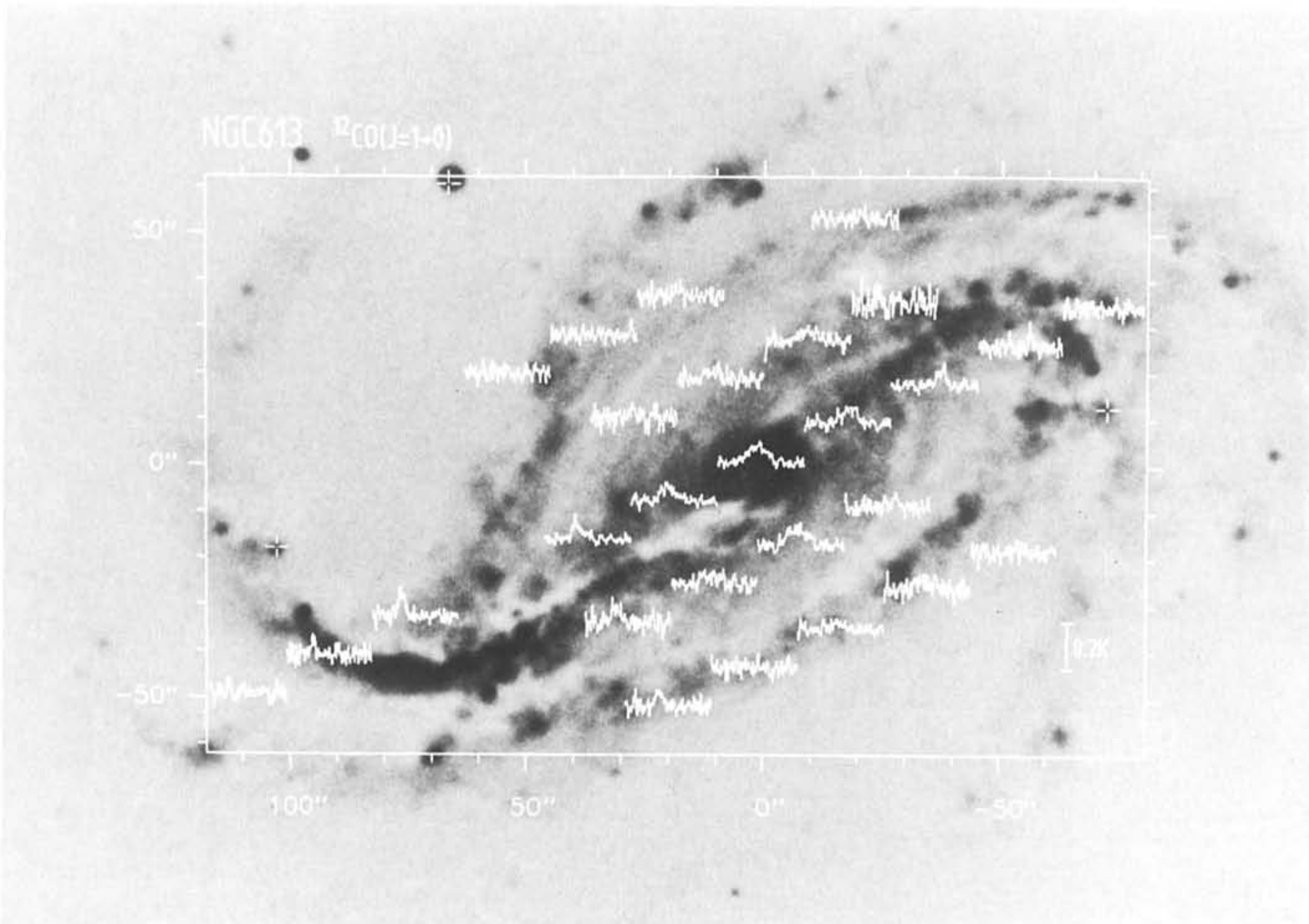

Figure 1: *The ^{12}CO ($J = 1 \rightarrow 0$) profiles (velocity range 1,000 to 2,000 km s^{-1}, resolution 7.2 km s^{-1}) in NGC 613 overlayed on an optical picture of the galaxy. Coordinates on the frame indicate offsets with respect to the centre. North is at the top, east to the left.*

which will be described in the following section, and since it fulfills the size condition (diameter about 6′) we proposed it for the observation with the SEST. The observations were made in July 1988. Here we present the preliminary results.

NGC 613

NGC 613 is a moderately southern ($\delta = -29\overset{\circ}{.}66$) barred spiral galaxy, classified as SB(rs)bc by de Vaucouleurs (1976). The bar and the several arms are well delineated by prominent dust lanes and H II regions. The galaxy has been studied with optical spectroscopy by Burbidge et al. (1964) who were able to determine the position angle (115°), the central velocity (1,534 km/s, heliocentric) and the rotation curve.

It has also been observed in the radio continuum at λ 6 cm and λ 20 cm and in the Hα and [O III] λ 5007 lines by Hummel et al. (1987). These observations show that there are jet-like structures extending from the centre indicating the presence of nuclear activity. The linear scale of these features is of the order of 5″ to 30″, thus unresolvable by the SEST beam.

The galaxy has been observed previously in the ^{12}CO ($J = 1 \rightarrow 0$) line by Elmegreen and Elmegreen (1982) who reported a marginal detection at the centre with an upper limit of 0.04 K using the NRAO 10 m dish at Kitt Peak. Observations in the H I 21 cm line were made by Bajaja (1978) and Reif et al. (1982).

Observation and Reduction

The SEST has been described by Booth et al. (1987). The antenna parameters, at λ 2.6 mm, are: HPBW = 43″, beam efficiency = 0.78, aperture efficiency = 0.67. At the front-end a dual polarization 85–117 GHz receiver with cooled Schottky diode mixers and a single side-band noise temperature of 250 K was available. At the back-end we used a wide band Acousto-Optic Spectrometer (AOS) with 1,700 channels spaced 690 kHz (1.8 km s^{-1} at λ 2.6 mm).

The observations were made between the 25th and the 29th of July, 1988. The beam was switched in position, every 2 minutes, between the source and a reference point at 12′ to the west. The integration time per point was, in general, 16 minutes but some positions, especially along the major axis, were observed longer. A total of 27 points were observed on a square grid with 20″ spacing, aligned with the major and minor axis (position angle = 115°), covering the central part of the galaxy. During the time these observations were being made, it was realized that there was a problem with the telescope pointing. Sudden jumps of the order of 1′ occurred near azimuth = 0°. Since NGC 613, however, was observed from rising to meridian crossing, only few spectra, which could be easily identified, were lost because pointing parameters used by previous observers were adopted. We believe, that the accuracy of the positions is within 5″ which is 12 % of the beam size.

The spectra were saved on tape with FITS format and read at the MPIfR Microvax converting it to CLASS readable format. This facility was employed to correct the baselines and to do Hanning smoothing. The average rms noise, in the spectra with a velocity resolution of 3.6 km/s, is 0.03 K of corrected antenna temperature.

Results

Figure 1 shows the obtained profiles. The CO profiles were Hanning smoothed two times so the velocity resolution of the displayed profiles is 7.2 km s^{-1} and the rms noise goes from 0.01 K to 0.03 K depending on the integration time and observing conditions. The velocity range on each profile is 1,000 to 2,000 km s^{-1} from left to right. Along the major axis we have the profiles with the lower noise. In spite of the fact that one profile is missing in the sequence (at the offset 60″ to the SE) the position-velocity diagram (Fig. 2b) clearly shows the velocity variation along this axis. From this diagram it is possible to determine the heliocentric velocity of the centre of the galaxy which is 1,470 ± 10 km s^{-1} and the rotation curve (correcting for the inclination).

The differences between this central velocity and the velocities obtained from global H I profiles by Bajaja (1978) (1,431 km s^{-1}) and by Reif et al. (1982) (1,493 km s^{-1}), are consistent with the noise in the spectra. The difference with the velocity derived by Burbidge et al. (1964) from optical observations, however, is rather large (64 km s^{-1}). The highest velocities along the line of sight, with respect to the centre, in Figure 2b, are about 150 km s^{-1}. This value is also smaller than the highest velocities seen optically by Burbidge et al. (200 to 250 km s^{-1}). At both ends of the diagram appear features at velocities that correspond to the other side of the galaxy which would imply rotation in the opposite sense. These features are most probably due to the noise. It should be mentioned that Burbidge et al. (1964) also found strong irregularities at both sides of the centre, although neither at the same distance nor with the same velocity differences. Along the minor axis (Fig. 2a) the velocities cover a range of about 275 km s^{-1}. This is a consequence of the steepness of the rotation curve and the width of the beam. The CO emission is asymmetrically distributed, being mainly concentrated on the SW side.

The derivation of the molecular gas mass from the areas of the profiles of Figure 1 depends on the distance to the galaxy and on the conversion factor to H_2 column densities. Both contain large uncertainties. Assuming a distance of 19 Mpc as derived from the systemic velocity, corrected for the motion with respect to the Local Group, assuming a Hubble constant of 75 km s^{-1} Mpc^{-1}, and a conversion factor of 4 10^{20} cm^{-2} (K km $s^{-1})^{-1}$, the mass of the gas in the form of molecular hydrogen would be about 3.1 10^9 $M_\odot$. The mass of the neutral hydrogen estimated by Reif et al. (1982) is about 3.6 10^9 $M_\odot$, which means that the total gas (H I + H_2) mass would be about 6.7 10^9 $M_\odot$. Assuming an inclination angle of 45 degrees, the highest rotational velocities, which are measured at about 80″ from the centre, (Fig. 2b) are of about 212 km/s. With these values it is possible to estimate roughly the total mass within that radius as about 7.6 10^{10} $M_\odot$. The ratio between the gas and the "total" mass would then be of the order of 9% if the assumed values for the parameters used in these calculations are valid.

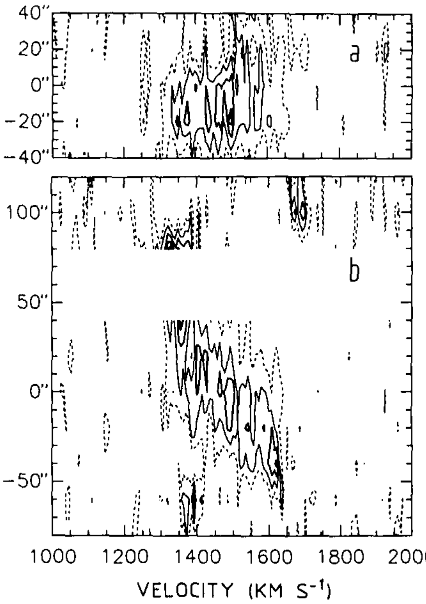

Figure 2: *Position-velocity diagrams along (a) the major axis, (b) the minor axis. Velocities are heliocentric. Ordinates indicate offsets, along each axis, with respect to the centre of the galaxy. First contour lines (dashed) correspond to the level 0.02 K of antenna temperature. The contour interval is 0.02 K.*

Acknowledgements

We are grateful to all the ESO staff members who made these observations possible.

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High Resolution Hα Spectroscopy of Nova Centauri 1986: Tracing a Transient in the Spectral Evolution

R. BANDIERA, Osservatorio Astrofisico di Arcetri, Firenze, Italia
P. FOCARDI, Dipartimento di Astronomia, Università di Bologna, Italia

We present here some preliminary results and considerations regarding high resolution spectroscopy of Nova Centauri 1986. This object was discovered on November 22.7 UT as a 5.6 V magnitude star (1), and observed by us in Hα two months later, when it was of about 10 magnitude. A considerable change in the Hα line profile, basically consisting in the disappearance of the original flat-top profile substituted by a more regular multicomponent profile, is clearly visible in our set of spectra, obtained monitoring the nova for nearly a week. A fitting of the line profile by means of three gaussian components shows a narrowing of the components and a rapid fading of one of them as a function of time. This behaviour can be interpreted in terms of blobs which have been formed in a non-spherical explosion and that were evaporating at the time of the observations.

The Observations

The spectra were obtained during the "spare time" of an observing run with the 1.4-m CAT telescope, and the CES spectrograph equipped with the Short Camera (2) and a double-density RCA CCD. Our main goal was a search for binarity in P Cygni-type stars and red supergiants: part of the results we obtained can be found in 3, 4. The instrumental setting is of extremely high efficiency, allowing to obtain spectra of superb quality with a S/N ratio exceeding 200. The slit width was 2 arcsec on the sky, corresponding to a resolving power of nearly 40,000; the original spectra were ≈ 50 Å wide, centred on the wavelength 6560 Å. The log of observations is reported in Table 1. Preliminary reduction (flat field correction, wavelength calibration) has been performed with the MIDAS package available at the Bologna and Arcetri Institutes. For these spectra, no absolute measurement is available to us; therefore they will be presented here, normalized to their peak value.

The Evolution of Spectra

Spectrum # 1 appears as a flat-top spectrum, with many subcomponents and a red wing, in reasonable agreement with high-resolution spectra obtained by Pacheco (private communication) during the period 4–9 January, using the 1.4-m CAT telescope equipped with a Reticon detector. With respect to Pacheco's spectra, the Hα line is narrower, the red wing is less evident, while a blue component becomes visible.

After only 4 days (spectrum # 2) the Hα profile has changed considerably (see Fig. 1), taking on a more regular shape. Further variations are seen by a direct comparison of spectra # 2–5 (see Fig. 2, left side): the Hα profile is getting thinner and thinner; in the meanwhile, the component on the blue side is getting fainter and fainter.

Derived Parameters

To give a quantitative description of the spectral evolution we fitted the profiles # 2–5 with three gaussians (two for the main component, plus one for the blue component), added to a second-order continuum: the gaussian components are labelled from 1 to 3 bluewards; for each of them A_i indicates the line amplitude, $\bar{\lambda}_i$ the central wavelength, and W_i the full width half maximum, while the continuum is approximated by $A + B\ (\lambda - 6560) + C\ (\lambda - 6560)^2$.

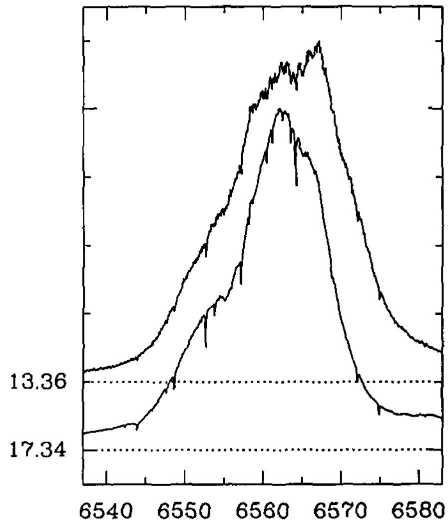

Figure 1: *Comparison between Spectrum # 1 (upper spectrum) and Spectrum # 2 (lower spectrum). Both spectra are normalized; dashed lines give the zero levels for the two spectra. The dates of the observations (see Table 1) are reported on the left side.*

This fit gives good results: synthesized profiles (Fig. 2, middle) reproduce the original ones well, and the residuals are limited to a few per cent (Fig. 2, right side). The main parameters of the spectra are listed in Table 2. The time dependence of the various parameters is rather clear, with the exception, for a few of them, of the Jan. 17.34 spectrum: this probably because in this spectrum the components are too blended to be separated correctly, and therefore the parameters derived from it are less accurate.

TABLE 1.

Spectrum	Date (UT)	Exposure Time (s)
No. 1	Jan. 13.36	1200+900
No. 2	Jan. 17.34	600+600+600
No. 3	Jan. 19.35	600+600
No. 4	Jan. 20.33	600+600
No. 5	Jan. 22.36	600+600

The relative amplitude of components 1 and 2, in the main peak, remain stable with time, while component 3 fades with respect to the others with a time scale of 5 days (computed on the last 3 spectra). All components present a slight decrease of their width, as well as a slight shift of their central wavelengths with time. The continuum cannot be determined precisely: its slope seems to decrease with time, and the data are consistent with an intensity evolving as that of the former two components.

Is there any physical meaning for the three gaussian components fitted above? One could alternatively imagine that an otherwise symmetric line is partially absorbed on its blue wing, by a P Cygni-like effect. However, one would expect this effect to disappear with time, while the observed trend is the opposite. Furthermore, by fitting with gaussians the positive peak of a P Cygni line, the central wavelength of these fictious components will shift redwards when the effect is stronger; the derived parameters, instead, go in the opposite way. Therefore we think that the line is physically composed of emission components. What we fitted with the former two components could actually be a

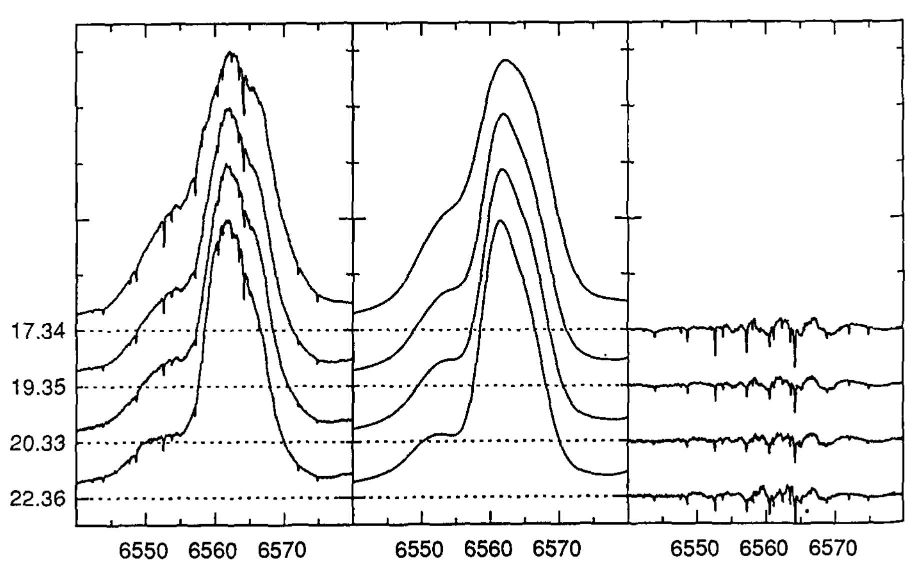

Figure 2: *Comparison between Spectra # 2–5 (increasing number, i.e. increasing time, downwards). The original data are on the left; the fitted models, in the middle, are composed of 3 gaussians plus a second-order continuum; the residuals after fitting are shown on the right. All spectra are normalized; dashed lines give the zero levels of spectra. The dates of the observations (see Table 1) are reported on the left side.*

TABLE 2.

Date:	Jan. 17.34	Jan. 19.35	Jan. 20.33	Jan. 22.36
$\bar{\lambda}_1$	6566.0	6565.4	6565.3	6564.7
$\bar{\lambda}_2$	6560.8	6560.9	6560.9	6560.5
$\bar{\lambda}_3$	6553.4	6554.0	6553.4	6552.5
W_1	7.5	7.1	6.8	6.9
W_2	6.6	5.3	5.2	5.0
W_3	8.7	9.7	9.2	8.6
A_2/A_1	1.01	0.98	1.06	1.04
A_3/A_1	0.47	0.41	0.32	0.22
A_1/A	4.81	5.74	6.16	6.04
A_3/A	2.27	2.31	2.10	1.36
B/A	$8.5\ 10^{-3}$	$7.1\ 10^{-3}$	$5.8\ 10^{-3}$	$1.9\ 10^{-3}$
C/A	$-0.9\ 10^{-3}$	$-0.8\ 10^{-3}$	$-1.0\ 10^{-3}$	$-1.0\ 10^{-3}$

unique non-gaussian component: however, the result of the two-component fit looks remarkably good.

Discussion

It is difficult to explain the details of this line evolution by a spherically symmetrical model and, on the other hand, there is evidence for departures, in nova events, from spherical symmetry (e.g. 5, 6). In our case one could imagine that, while most of the nova shell disappeared due to dilution effects, some denser blobs began dominating the Hα emission. The velocity dispersions of the three components are respectively 190, 140 and 250 km/s, and represent their expansion velocities.

Assuming that all blobs have similar sizes, the time scale for the fading of the line emission is inversely proportional to the blob expansion velocity, and in fact component # 3, the broader one, gets dimmer faster than the others. Let us define τ_{12} as the time scale for the fading of the former two components, and τ_3 as that for the latter one; since the decrease of component # 3 relative to the others is 5 days, its absolute time scale is $\tau_3 = 1/(1/5 + 1/\tau_{12})$. Requiring also that time scales are inversely proportional to the components' expansion velocities, τ_{12} and τ_3 can be derived separately as, respectively, 3 and 1.9 day.

Unfortunately we do not possess absolute calibration of our spectra; anyhow, we observed that the continuum was evolving, in those days, as the components # 1 and # 2. But a rough estimate of the continuum evolution can be given by taking the decrease of the visual magnitude: by using visual magnitudes measured during the month of January (7, 8), the average decrease turns out to be 0.35 mag/day, corresponding to a time scale of 3.1 day, in close agreement with our previous derivation.

A decrease in line amplitude can then be ascribed to expansion of condensations in the nova envelope; they have typically a size of $\approx 10^{13}$ cm, much smaller than the envelope size at that time ($\approx 5 \cdot 10^{14}$ cm); since the components are partially blended, they should be confined to the inner regions ($\approx 10^{14}$ cm).

Therefore a way to explain the observed Hα behaviour of Nova Centauri 1986 involves the presence of a non spherical explosion, with the formation of small condensations.

We are indebted to M. Friedjung and E. Oliva for interesting suggestions, and to J.A. de Freitas Pacheco for giving us a copy of his spectra.

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The European Working Group on Chemically Peculiar Stars of the Upper Main Sequence: The First 10 Years

G. MATHYS (Genève), H. M. MAITZEN (Vienna), P. NORTH (Lausanne), H. HENSBERGE (Brussels), W. W. WEISS (Vienna), S. ANSARI (Vienna), F. A. CATALANO (Catania), P. DIDELON (Strasbourg), R. FARAGGIANA (Trieste), K. FUHRMANN (Göttingen), M. GERBALDI (Paris), P. RENSON (Liège), H. SCHNEIDER (Göttingen)

1. Introduction

A fraction of the B and A type stars have chemical peculiarities (CP). 4 subgroups are recognized: CP1 or Am, CP2 or magnetic Ap (with enhanced Sr, Cr, Eu, Si lines), CP3 (or non-magnetic Ap, with Hg Mn enhanced) and CP4 (B type stars with He peculiarities, a fraction of them appear to be a hot extension of CP2).

For 10 years now, European astronomers interested in the study of CP stars, and more particularly of Ap-Bp (or CP2 to CP4) stars, have gathered their efforts in a working group (WG). Many of the results obtained by members of this WG have been derived from observations obtained at ESO-La Silla. In the *Messenger* No. 34, an overview of the activity of the group during its first five years of existence was given. On the occasion of the 10th anniversary of our WG we want to present a new report on its work with emphasis on those studies carried out during the last five years.

Beside the original research work of the various group members, a *Catalogue of CP-stars* has been compiled by P. Renson. This list was set up after a large critical survey of the literature; it contains more than 6,000 stars, half of which are CP1 (i.e. metallic line) stars. A number of remarks are provided for each star. They concern mainly other designations, misidentifications, duplicity, variability of different parameters (light, spectrum, magnetic field). With this catalogue, which will soon become available through the "Centre des Données Stellaires" (Strasbourg), will also be published a list of bibliographical references established by P. Renson, M. Gerbaldi, F. Catalano and M. Floquet.

2. Variability

Variability in Ap and Bp stars occurs in (at least) two flavours: on the one hand with periods ranging from the order of half a day to several years, on the other hand with short periods of about 4 to 15 minutes. These latter, rapid variations will be discussed in a following section. The former type of variability is ubiquitous among CP2 and CP4 stars, almost all of which undergo periodic variations of their brightness, spectral features and magnetic field. For most of the cases these are well explained by the *Oblique Rotator Model:* the star is regarded as a rigidly rotating body with an essentially dipolar magnetic field, whose axis does not generally coincide with the rotation axis. Surface inhomogeneities likely related to the magnetic structure are responsible for the observed variations, as a result of the changing aspect of the visible stellar hemisphere along the rotational cycle.

However, as will be argued below, it is not yet quite clear whether all the observed "slow" (as opposed to rapid) variations of CP stars can be explained in terms of the Oblique Rotator Model. In particular, some CP3 stars appear to show photometric variability (studied at ESO mainly by Schneider, 1987) with amplitudes generally lower than for CP2 and CP4 stars.

The most convenient way to determine the rotational period is to make precise, multicolour photometric observations. The Strömgren system has been widely used for this purpose, and Geneva photometry has contributed to this effort.

All periods known up to the beginning of 1983 have been gathered in a catalogue published by Catalano and Renson (1984). About 250 stars had a known period at that time. The first supplement has just been published (Catalano and Renson, 1988) and contains further 58 stars, so that more than 10 per cent of all known Ap stars have a known rotational period.

The contribution of the members of the European WG is quite important, since three quarters of the new periods published since 1983 come from them. Of these (representing 41 stars) most of them have been published by North (1984: 5 stars, 1987: 18 stars) and Manfroid and Mathys (1985: 5 stars, 1986: 8 stars). In these statistics we did not include the few CP eclipsing binaries, but added 3 stars not contained in Catalano and Renson (1988). The new periods found since 1983 are presented in the histogram of Figure 1. Compared to the histogram shown in the *Messenger* No. 34, there is an excess of short periods. The scarce appearance of periods shorter than 0.5 days is worth mentioning; only one of them is quite certain. The other three should still be confirmed.

Now, what is the "completeness" of the period determinations? In order to answer this question, we selected all Southern (i.e. with negative declinations) Ap stars with $V < 7.1$ (which are members of the BS catalogue plus its Supplement) from the general catalogue of Ap and Am stars of Renson (excluding those of peculiarity types Hg, Mn, HgMn and MnHg, which show less or no variability). Figure 2a (top) shows the number of stars with determined periods as a function of Right Ascension. The cross-hatched area concerns the unambiguous periods, the hatched area indicates uncertain or ambiguous periods and white areas are for constant or suspected long period stars, for which no period could yet be found. Figure 2b (bottom) shows the fraction of Ap stars with known periods. From 250 bright stars, 32 per cent have a well-defined period, and this percentage increases to 42 per cent if uncertain or ambiguous periods are included, as well as stars with very long period or no variation. A smaller number of stars that are observable in the southern winter have been sufficiently studied to allow the determination of the period; the contrast is, however, less striking in terms of percentage than of total number, due to the distribution of known Ap stars across the sky.

In addition, the number of periods known for cluster or association members now reaches about 40. This allows to see how the rotation period varies with age, and it seems that it decreases at the exact rate expected from conservation of angular momentum during the stellar evolution on the main sequence.

It is on the other hand noteworthy that among those stars with well-determined periods, by far the largest fraction are CP 2 stars with enhanced Si or CP 4 stars. This is quite certainly a selection effect, since these stars have periods which very rarely are longer than 10 days, in contrast to the CP2's with enhanced Sr, Cr and/or Eu, among which about 25 per cent have periods in excess of 10 days.

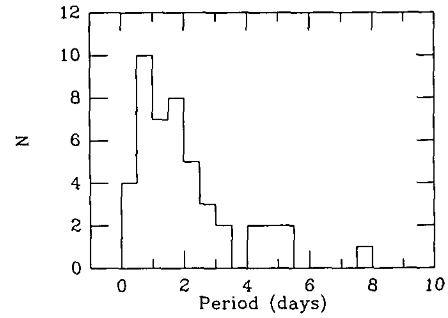

Figure 1: *Histogram of the periods determined since 1983. Some periods are uncertain, especially three of those that are smaller than 0.5 days. Three more stars have periods longer than 10 days.*

Let us now discuss some interesting aspects related to photometric variability. Mathys et al. (1986) present 12 B to early F type stars which proved variable (they were used as comparison stars), and five of them show strictly periodic variations which are reminiscent of CP stars. Their spectral type, however, is not known to be peculiar, although all have an MK classification (four of them are in the *Bright Star Catalogue*). One of these stars (HD 90994) is even a primary standard for MK classification! It is very interesting to note that three of these

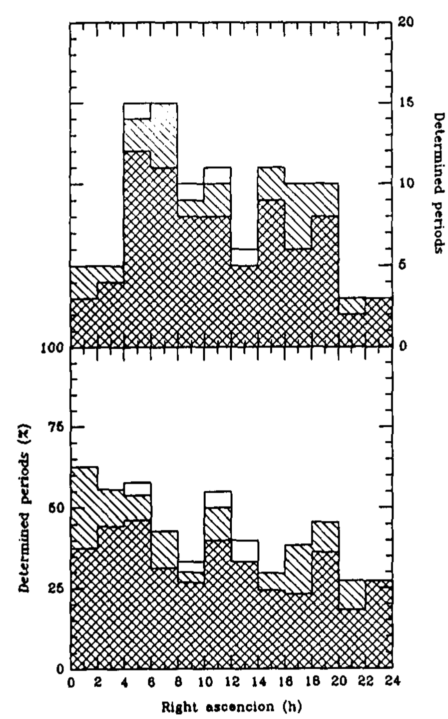

Figure 2a *(top): Histogram of the periods determined up to now for bright non-HgMnAp stars as a function of right ascension. Cross-hatched area: well-defined periods. Hatched area: uncertain or ambiguous periods. Blank areas: stars for which no variation could be found.*
2b *(bottom): Percentage of bright Ap stars with known period (compared to the total number of known bright Ap stars) as a function of right ascension. Same code as in 2a.*

five stars have a rather early spectral type, i.e. B6V, and that all five stars have periods smaller than 3 days, apart from one (uncertain!) exception. This implies that, although the periods and lightcurves of these stars resemble those of classical CP stars, their properties are equally, and perhaps even more, reminiscent of the so-called variable mid-B type stars, discussed by Waelkens and Rufener (1985) as probably being non-radial pulsators, like the 53 Per variables. The lack of any *photometric* peculiarity (indicated by Maitzens's Δa or Geneva $\Delta(V1-G)$ parameters) would tend to confirm this analogy, as well as the fact that Waelkens and Rufener (1985) considered HD 74560 as typical "mid-B variable" while it is a B4pMgSi star. The photometric variations of the latter star would undoubtedly have been interpreted in the framework of the Oblique Rotator Model by an Ap specialist!

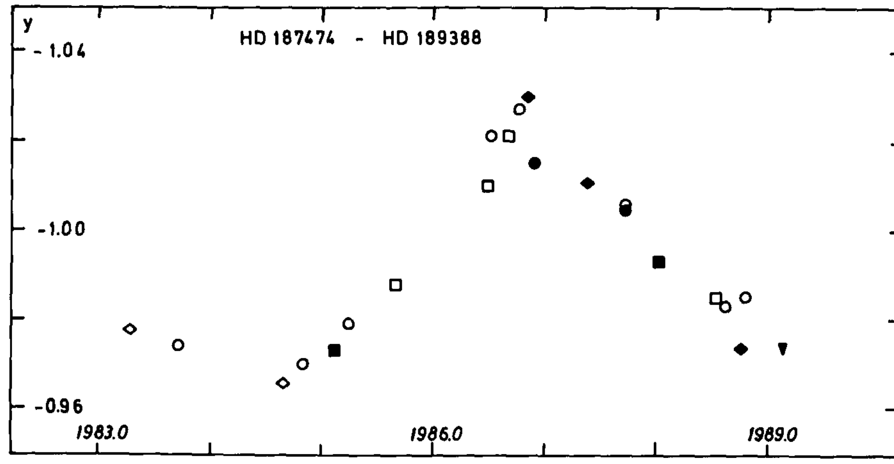

Figure 3: *Lightcurve of HD 187474 in Strömgren y. Open symbols refer to LTPV-group observations, closed symbols to older observations that have been shifted by 6.3 or 12.6 years. Different shaped symbols refer to the telescope + photometric system: ESO 50-cm (circle), Danish 50-cm (square), Bochum 60-cm (diamond), all at La Silla, and CTIO 1-m (triangle).*

Similarly, it can be questioned whether the variability of Hg Mn Bp stars should not be attributed to non-radial pulsations rather than explained by the Oblique Rotator Model.

Another interesting feature in the progress made since 1983 is the quantitative description of the lightcurves. North (1984) has shown that practically all lightcurves of CP stars can be satisfactorily represented by a sinusoid and its first harmonic. This was confirmed by Mathys and Manfroid (1985), who presented a large, homogeneous sample of *uvby* lightcurves for 56 stars and listed the fitted Fourier coefficients. The fact that no higher frequency is needed to represent these lightcurves suggests that there are only two important *spots* (or, conversely, a unique *ring*) with anomalous abundances *on the surface* of Ap stars.

A few especially interesting stars should still be mentioned. The long period star HD 187474 has been monitored in Strömgren photometry, in the framework of the long-term photometric programme of the Sterken group at ESO. Figure 3 shows the visual lightcurve of this star which is a famous spectrum and magnetic variable with a period of about 6.3 years. Data before 1983 (*i.e.* before the Sterken group) are probably less homogeneous. A number of other CP stars with suspected long periods are regularly observed within the same project.

The stars HD 98457 and HD 57946 have an extreme photometric amplitude, i.e. about 0.2 mag in the near ultraviolet. This is comparable to the amplitudes previously found for HD 215441, GC 17353 (CpD-55 5216) and for HD 187473. The SiMg star HD 60431 has been monitored in the Geneva system because it shows extreme photometric peculiarity. Surprisingly, its period is as short as 0.476 days, and it is probably the shortest, non-ambiguous period among the Si stars.

Finally, two stars have at least two periods: HD 25267 (τ9 Eri) and HD 37151. They might be intermediate cases between Ap stars and the mid-B variables, one period being due to abundance inhomogeneities and rotation, the other period possibly due to non-radial pulsation.

3. CP2 Stars and Astroseismology

Ten years ago, Don Kurtz announced the discovery of light variations with a period of about 12 minutes for the peculiar CP2 star HD 101065, also known as "Przybylski's Star". Weiss and Kreidl (1980) observed this object at the same time at ESO with Hβ photometry and presented the first evidence that pulsation is the relevant mechanism for its photometric variability.

Observing stars of this class means to detect light amplitudes which are frequently of the order of less than one millimagnitude. Therefore, even for bright stars one needs telescopes of the 1-metre class in order to reduce the photon noise and the scintillation noise due to our terrestrial atmosphere during integration times of only 10 seconds (periods range from about 4 minutes to 15 minutes!). By spectroscopic observations, in particular radial velocity measurements, one can *see* a star pulsating, but obviously still larger telescopes are required to achieve the desired S/N ratio from integration times of one minute at a spectral resolution of R = 100,000.

For stars where one is able to observe several successively excited pulsation modes, one can derive important parameters, like mass and age, internal rotation, depth dependency of a magnetic field, location of a convective zone and the radial dependency of temperature and density. Thus, astroseismology offers a unique way to look into stars and to check the theory of stellar evolution. Further contributions at ESO from our WG: Weiss and Schneider (1984) observed the brightest member of this group, α Cir, with the Walraven photometer attached to the 90-cm Dutch telescope. For the first time, it was possible to investigate amplitudes and phase shifts of pulsation modes in a large spectral range. During a compaign, coordinated by Don Kurtz in South Africa (SAAO), Schneider and Weiss (1986) observed HR 1217 and were able to restrict possible mode identifications. They also took part in a second international observing campaign for HR 1217 in 1986 which resulted in a pulsation frequency spectrum with the highest yet known accuracy (down to the noise limit of 0.1 mmag), besides the sun (submitted). Baade and Weiss computed synthetic spectral line profiles for non-radially pulsating stars, taking different aspect and pulsation parameters into account (1987). Simultaneous spectroscopic and photometric observations of α Cir, obtained by Schneider and Weiss (1989), yielded an upper limit for possible radial velocity variations of 100 m/s in contradiction to 1 km/s claimed by other authors, although the star was pulsating with an amplitude of 6 mmag in Stroemgren *v*. A similar paper on γ Equ is presently being prepared for publication by the same authors. Last year, Schneider and Weiss participated in an international observing campaign, similar to that for HR 1217. The results for HD 203932 are being prepared for publication.

4. Main Sequence Evolution: Search for CP2 Stars in Open Clusters

The study of CP stars in open clusters yields information and constraints on the time dependence of the Ap phenomena. During the discussions in the first two meetings of the WG (Vienna and Paris 1979) it became clear that one has first to identify CP stars in open clusters as completely as possible and to enlarge the sample of open clusters in order to derive statistically sound results. Hitherto published spectroscopic surveys were regarded as insufficient concerning both requirements mentioned.

The way out of the limitations of the time consuming, subjective spectroscopic surveys was provided by the use of photometric indices sampling the Ap typical broad band flux depression around 5200 Å. The first observing runs at the end of 1979 at the ESO 50-cm telescope by Maitzen and Hensberge (1981) used the Δa-index (Maitzen, 1976) to pick out CP2 or CP4 stars in NGC 2516 and NGC 1662. Maitzen and Vogt (1983) demonstrated with a large sample of field Ap stars that Δa has the same detection capability for magnetic Ap stars as the high qualitiy classification dispersion spectroscopy of Bidelman and MacConnell (1973).

Meanwhile 13 papers (for references see Maitzen et al., 1988) have been published on 33 open clusters with slightly more than 1,000 stars surveyed, most of them after 1983. Observations for another 32 clusters have been obtained and are being evaluated.

Our limiting magnitude has been set by telescopes in the range 50 to 100 cm, and is about 11–12 mag, respectively. The number of clusters where a sizable number of objects (i.e. more than 10) can be surveyed in the domain B5–A5 with these limits, is roughly 80. Thus, with our technique and telescopes available we are approaching the end of our programme.

The relatively large number of clusters in our survey is justified by a preliminary evaluation of the results which do not, contrary to Abt (1979), exhibit a simple, clear-cut picture, i.e. dependence with time. Other parameters are probably playing a role in determining how many CP2 stars are present in a cluster and how strong their peculiarities will develop. A careful statistical examination of the data (which are much more homogeneous than spectroscopic results) to be carried out in our WG during this year will try to find out whether there is now enough evidence for statistically sound conclusions. If not, fainter clusters may be included using larger telescopes and CCD techniques. Our actual sample should comprise of the order of 100 peculiar stars, taking into account the frequency of field CP2 stars (about 5 per cent).

The outstanding role of ESO instruments is underlined by the fact that more than half of all observations have been made using either the ESO 1-m, ESO 50-cm or Bochum 61-cm telescopes. This percentage rises to 87, if one considers only the southern hemisphere observations. So far the following participants have contributed to the project: H. Schneider (Göttingen), H.M. Maitzen (Vienna), K. Pavlovski (Zagreb), H. Jenkner (Baltimore-ESA), F.A. Catalano (Catania), H. Hensberge (Brussels), W.W. Weiss (Vienna), T. Kreidl (Flagstaff), G. Deridder (Brussels), M. Floquet (Paris), H.J. Wood (La Serena-CTIO) and C. Tanzer (Vienna).

5. Magnetic Fields

One of the most remarkable characteristics of the Ap stars of the Sr-Cr-Eu, Si, He weak and He rich types is that they possess a magnetic field with a large-scale organization, a unique property among nondegenerate stars. The presence of an organized magnetic field is thus intimately related to the appearance of other peculiarities, in which it most probably plays a key role. Moreover, the magnetic field is likely to have a significant influence on the observed stellar properties, so that its knowledge is an essential part of the proper understanding of the physics of Ap stars. (For instance, the magnetic field must be taken into account when deriving elemental abundances).

Since 1984, a Zeeman analyzer is available as standard option on the CASPEC at the 3.6-m telescope, providing European astronomers with the opportunity of studying magnetic fields of Ap stars from circular polarization measurements in their spectral lines. An observing programme aiming at the determination of the spatially unresolved structure of the magnetic field of a number of stars has been initiated in our WG by Mathys, taking advantage of the unprecedented possibility offered by the Zeeman analyzer of the CASPEC to record simultaneously the *profiles* in circular polarization of a large number of spectral lines, with high S/N ratio. This is a long-term project, since spectra suitably distributed over a stellar rotation cycle are needed in order to untangle the geometry of the field. The acquisition of the data is now mostly completed, for 9 stars a good phase coverage could be achieved; more partial data have been obtained for 25 additional stars. Their analysis is in progress.

Spectra recorded through a Zeeman analyzer essentially contain information about the component of the magnetic field vector along the line of sight. By observing on very high resolution spectra (recorded without a polarimeter) the subtle broadening induced in the spectral lines by the magnetic field, it is possible to study its modulus. This information complements that obtained through spectropolarimetry and thus permits to set more constraints on the stellar magnetic field. The interpretation of the magnetic broadening, however, is not straightforward. A programme is being carried out by Didelon in order to determine whether the Robinson (1980) technique, which has been successfully applied to magnetic field determination in late-type stars, can be employed to measure magnetic fields in Ap stars. The principle of the technique is to compare the profiles of two lines, one which is sensitive to the magnetic field and the other which is not, in order to derive the magnetic field from the difference in their widths. Didelon's observations are being made with the CES at the CAT.

The magnetic field determined with the Robinson technique from unsplit lines is compared with that obtained from lines which are fully split into their Zeeman components by the magnetic field. Not that the latter effect can be observed only in a few stars where the relevant parameters (magnetic field, rotational velocity, angle between the rotation axis and the line of sight) have quite favourable values. One can advantageously use these stars to calibrate the Robinson technique, which can later be applied to determine magnetic fields in less favourable, more widespread cases. A progress report on this project was published recently in the *Messenger* No. 49 (Didelon, 1987).

6. Spectroscopic Studies

The main characteristics defining the various types of CP stars is the anomalous strength of some of their spectral lines. These spectral peculiarities reflect the overabundance or underabundance of some chemical elements in the stellar atmosphere. Abundance determinations are thus an essential part of the study of Ap stars, all the more since they can strongly constrain the theoretical models which are developed to explain the origin of these objects.

Spectroscopic investigations in the region covered by the *International Ultraviolet Explorer* (IUE) have been performed for a number of CP stars. Most of the concerned spectra have their resonance lines in this range. However, line identification is generally hampered by the high density of competing transitions.

Fuhrmann devoted special interest to the well-known CP2 star HR 465, while others like HR 7775, HR 4072, $\varkappa$ Cnc, α2CVn, HD 101065, as well as their "normal" congeners π Cet, ν Cap and Vega were preferably used for comparison purposes. The spectra show a huge number of absorption lines, most of which belong to FeII and CrII. Other elements – like MgII or SiII – have only few, but strong transitions. In the spectra of the CP2 star α2CVn a remarkable number of ions with $Z < 20$ is not well pronounced. This is most obvious in the case of neutral and ionized carbon.

As far as the Rare Earth elements are concerned there are identifications for some second spectra (e.g. HoII, GdII, ...) in the tracings of HD 101065 – Przybylski's star. The spectra of the somewhat hotter HR 465, however, show only marginal contributions from this group of elements. IUE spectra are well suited to show the definite presence of heavy elements like platinum and mercury, as well as the overabundances proposed from optical spectra. Additionally, absorption lines of BiII are observable. There is also strong evidence for transitions due to gold (AuII).

In the *visible,* Gerbaldi and Faraggiana have been extending the investigation of abundances to elements not easily observable with photographic plates. They have derived intriguing results from observations of the neutral lithium resonance line at λ 6707 now easily accessible with modern detectors. The first observations made by them at ESO with CES and Reticon of the LiI 6707 line in cool Ap stars, raised several problems since the feature at this wavelength shows an asymmetric profile different from star to star and an intensity which is not related to the atmospheric parameters of the stars. Surprisingly, the only rough relation detected was that between the equivalent width of λ 6707 and the number of other, mainly unidentified lines present in this spectral range (Gerbaldi, Faraggiana, 1986). Subsequent observations at the Observatoire de Haute-Provence, complementary to those performed at ESO, indicate that a line of another element, so far unidentified, is present at a wavelength very close to the Li line.

Spectroscopic studies of HgMn (CP3) stars were carried out by Schneider (1986), who showed that more than 60 per cent of these stars are binaries. Using new observations he raises this value to more than 70 per cent. This fact puts the CP3 group close to the CP1 (Am) stars, in contrast to the CP2 stars with a binary frequency of only about 30 per cent. The CP3 stars show a concentration towards circular orbits for short periods and a lack of periods less than two days. Stars with periods less than 10 days tend to synchronized rotation. They are all slow rotators with *v·sini* of about 30 km/s.

Abundance analysis of some CP3 stars were carried out by Ansari who carefully studied the effect of rotational broadening of spectral lines on the derived abundance values.

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AK Scorpii: A New Pre-Main-Sequence Spectroscopic Binary

J. ANDERSEN, Copenhagen University Observatory, Denmark, and Center for Astrophysics, Cambridge, Mass., USA
H. LINDGREN, ESO
M.L. HAZEN, Center for Astrophysics, Cambridge, Mass., USA
M. MAYOR, Observatoire de Genève, Switzerland

While we know that perhaps ~25% of normal main-sequence stars are spectroscopic binaries, very few of their progenitor systems have yet been detected among (low-mass) pre-main-sequence stars: Mathieu's (1988) review at the recent IAU General Assembly lists only 11, and for only three had orbits been published at that time. This meagre yield must be due mainly to selection effects mitigating against the discovery of pre-main-sequence binaries. These stars are intrinsically faint and generally found in highly obscured regions, so systematic and accurate radial-velocity observations were impossible until the advent of efficient cross-correlation techniques. Due to their importance for the understanding of star formation processes in general, pre-main-sequence binaries are now being searched for very actively, and the sample will no doubt increase sharply over the next few years. We would like

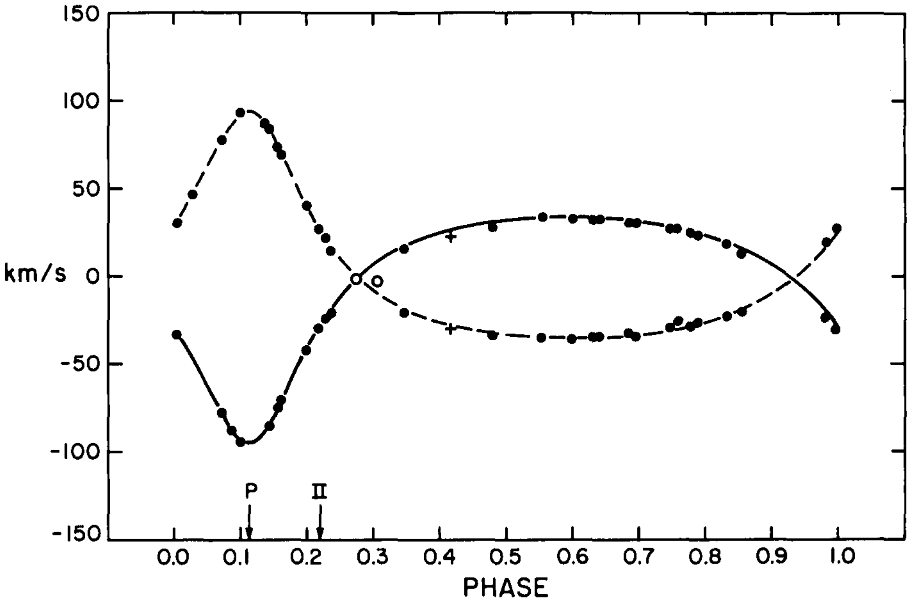

Figure 1: *Spectroscopic orbits for AK Sco. Phases are counted from a hypothetical primary eclipse; the phases of secondary eclipse (II) and periastron (P) are indicated. Cross: coudé spectrum; dots: CORAVEL observations; circles: single-lined CORAVEL observations, not used in the solution.*

to share with readers some of the fun we have had with one of these new systems, AK Sco (full details will appear in *Astron. Astrophys.*).

AK Scorpii: Classical or "Naked" T Tauri Star?

AK Scorpii is an 8th magnitude mid-F type variable star projected on the southern outskirts of the Sco-Cen association. Herbig and Rao (1972) found it to have a strong Li*I* line at 6707 Å as well as strong Hα emission with a central reversal, showing it to be very young. It shares its large-amplitude light variations and infrared excess with the "classical" T Tauri stars, but the absence of emission lines other than Hα makes its optical spectrum more similar to those of the "naked" T Tauri stars (Walter et al. 1988), which may owe their lack of conspicuous circumstellar matter to the presence of a binary companion.

A coudé spectrum of AK Sco taken with the ESO 1.5-m telescope in May 1986 showed it to be a double-lined spectroscopic binary with approximately equal components. As AK Sco had once been considered to be an eclipsing binary, we hoped that it would be possible to determine the masses, radii, luminosities, and composition of its components. Comparing them with stellar evolution models, age, helium abundance, and other interesting parameters might then be determined.

Orbital Parameters

We therefore observed AK Sco in 1986–87 with CORAVEL on the Danish 1.5-m telescope on La Silla and determined its spectroscopic orbit as shown in Figure 1. The orbital eccentricity is $e = 0.47$, the period is 13.6093 days, both minimum masses ($m\sin^3 i$) are 1.06 ± 0.01 solar masses, and the orbital semi-axis major is about 31 solar radii. The origin of the phases plotted in Figure 1 is where a primary eclipse would occur; the phases of a possible secondary eclipse and of periastron passage are also indicated.

Unless we can determine the inclination of the orbit, we cannot find the absolute masses of its components, and unless the system eclipses, we cannot directly determine their radii either. Now that we know when to look for eclipses in AK Sco, do they in fact occur? We searched for the answer in a nearby "gold mine", the vast Harvard plate collection going back about a century. And yes indeed, it holds more than 2,000 plates on which AK Sco can be measured! The period 1910–12 had a particularly dense coverage of plates (83), so we estimated the brightness of AK Sco on these plates and plotted the resulting magnitudes against spectroscopic phase. Alas – no correlation whatever! So, while shallow eclipses might still be discovered by careful photoelectric photometry, most of the ~1-magnitude variations we do see must have some other origin, probably in nearby dust clouds.

A Model of the Binary

If we cannot actually determine the masses and radii of AK Sco, what might they reasonably be? Spectroscopically, the components of AK Sco look just like F5 main-sequence stars. Popper's (1980) review indicates that reasonable ZAMS masses and radii are 1.3 $M_\odot$ and 1.26 $R_\odot$; the orbital inclination is then $i \approx 69°$. If the orbital and axial rotation periods are equal, we expect to measure rotational velocities of $v\sin i \approx 4$ km s^{-1}. However, due to tidal effects, convective stars in eccentric systems are expected to rotate faster than this, about 2.5 times faster for the orbital parameters of AK Sco. This revises our prediction to $v\sin i \approx 11$ km s^{-1} for both stars.

What we actually measure from the width of the CORAVEL cross-correlation profiles is $v\sin i = 19 \pm 1$ km s^{-1}, so the stars either spin faster or have larger radii than first assumed. Consideration of the time-scales for synchronization suggests that the former is unlikely, especially since the stars were probably even larger and easier to synchronize when they were younger. Hence, the stars in AK Sco are probably well above the ZAMS.

Published models of pre-main-sequence evolution are relatively old and still largely untested, so we searched instead in Popper's (1980) review for a real, suitably evolved binary as a "role model" for AK Sco. The F5-type system RZ Cha (1.5 $M_\odot$, 2.2 $R_\odot$), an old friend of ours from early days on La Silla, seems to fit the bill (and the rotation) for an inclination of $i \approx 63°$. In this model, the stars still narrowly fail to eclipse. Assuming an effective temperature of 6,500 K, AK Sco is about 200 pc distant, consistent with membership in the Sco-Cen association.

The Environment of AK Sco

Although, spectroscopically, AK Sco itself looks rather ordinary, it appears to live in quite a lively place, judging by its irregular variability, which seems too large (≈1 mag) to be reasonably explained by star spot activity. The UBVRI photometry of Kilkenny et al. (1985) shows that the star gets redder as it gets fainter, with a ratio of total to selective absorption $R = A_V\ E(B-V) \approx 4.6$. This is much higher than in ordinary interstellar matter (R = 3), as often occurs in circumstellar dust and is usually considered due to a relatively large grain size.

There is additional evidence for circumstellar dust from infrared photometry of AK Sco: Figure 2 shows the energy distribution derived from the UBVRIJHKL photometry by Kilkenny et al. (1985) and the 12, 25, and 60 μm IRAS fluxes. The fluxes have been corrected for an average amount of extinction. Three black-body curves have been fit to the data. In addition to the flux from AK Sco itself, they show the

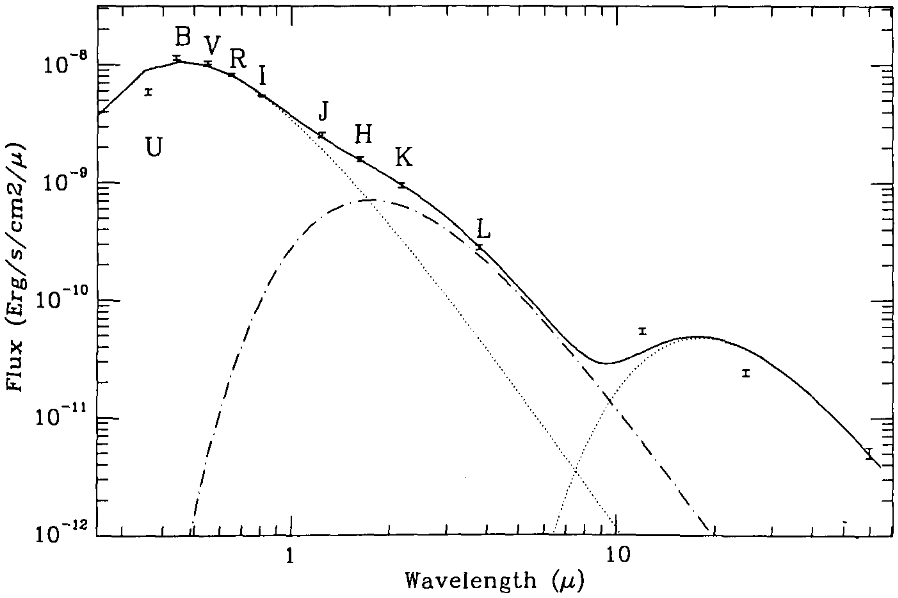

Figure 2: *Blackbody fit to the optical-infrared energy distribution of AK Sco. The three curves correspond to temperatures of 6,500, 1,600, and 160 K.*

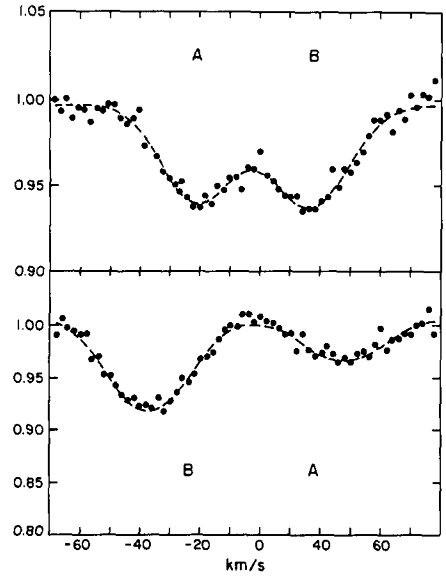

Figure 3: *Cross-correlation profiles for two CORAVEL observations (phases $0^{\rm P}\!.23$ and $0^{\rm P}\!.48$), separated by only 1.2 orbital cycles.*

presence of two dust components at approximate temperatures of 1,600 K and 160 K. The total energy emitted in these components amount to about half of that received from AK Sco, roughly consistent with the light loss at intermediate brightness levels.

Size of the Dust Clouds

We can obtain an order-of-magnitude estimate of the sizes of the two dust clouds by requiring that the energy emitted by a grain be equal to that it absorbs from the star. The resulting distance from AK Sco is then 25–50 solar radii for the hot dust, and about 10 AU – the orbital radius of Saturn – for the cool component. Thus, the hot dust cloud has essentially the same size as the binary orbit and presumably consists of material left over from its formation, while the cool dust cloud has the size of a typical planetary system (assuming that the one in which we live is typical!).

The CORAVEL data contain one striking piece of information supporting this picture: The luminosity ratio between the two components, as measured by the equivalent widths of their cross-correlation dips, changes up or down by up to a factor two from one orbital cycle to the next (Fig. 3). Again, star spots are unlikely to cause such large variations; even if they did, they should significantly distort the profiles, which is not seen. Moreover, the variations are largest when the stars are farthest apart.

The simplest interpretation appears to be that we are seeing the effect of inhomogeneities in the hot dust cloud not only *in front of*, but probably also *between* the stars. This opens an exciting possibility for mapping out the dust clouds near the system, in the following way: At any given time, we know the precise position of both stars in their orbit. Photometry tells us the *total* obscuration in front of the two stars, and a simultaneous CORAVEL or other spectroscopic observation can give us the *ratio* of the light losses for each component. We can therefore compute, point by point, the amount of dust in front of each star as it goes through an orbital cycle, and draw a map of the dust clouds and eventually of their motions. Perhaps one could even measure the velocities of circumstellar lines at high resolution?

Thus, AK Sco no doubt has lots more fun in store for the observers: There are eclipses to look for and dust clouds to map. Spectroscopically, one can investigate the Li and other element abundances, indicators of chromospheric activity, and signatures of possible magnetic fields: AK Sco is within reach of the CES. And perhaps, one day, it will be possible to resolve the system interferometrically (with the VLT?), although the angular separation is only of the order of 1 mas; its absolute masses and distance could then be determined even if eclipses should not occur.

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Supershells and Galactic Fountains

B. M. SHUSTOV[1], Astronomical Council, Moscow, USSR

In the gaseous disk of our Galaxy as well as in other galaxies, H I structures (shells, bubbles, holes, etc.) on scales of 0.1–1 kpc are recognized to be common features; see e.g. the comprehensive review by Tenorio-Tagle and Bodenheimer (1988). The larger ones are usually named with the prefix "super". The estimated energies which are required to produce such large objects are high – up to some 10^{54} erg. These energetic events must exert a significant influence upon the gaseous galactic disk and corona.

In our Galaxy, the disk and the corona are believed to be evolutionarily coupled in a recycling process, although there is no common opinion about details of the

[1] Visiting astronomer, ESO – Garching.

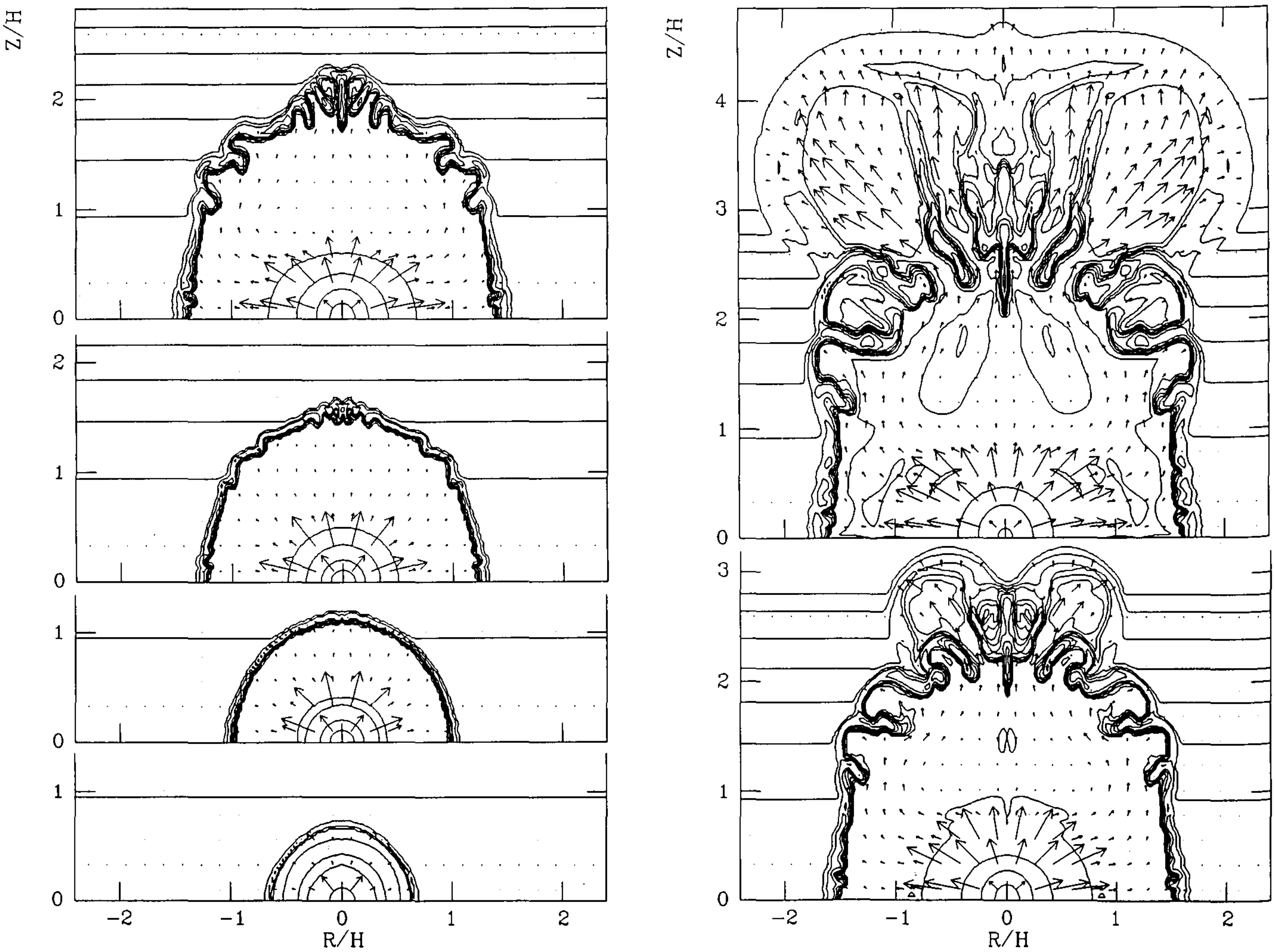

Figure 1: *Evolution of a supershell ($\dot{E}$ = 2 × 10^{39} erg s^{-1}) in a gaussian galactic disk, with* n_0 = *1* cm^{-3}*, H = 140 pc. Density contours are shown with logarithmic spacing of 0.5 dex at times 0.2, 0.8, 1.5, 2.1, 2.5, 3.0 Myrs. The maximum velocity is 2,200 km* s^{-1}.

process. An evaluation of the density *n* and temperature *T* in the corona and elucidation of the distributions *n(z)* and *T(z)* in the disk remains a challenging subject for observers and theoreticians. It would appear that it is possible to arrive at a better understanding of the topic by interpreting the high energy processes in the disk and corona in a consistent way. The construction of theoretical models of large scale HI structures in galaxies may be considered as a step in this direction.

Several mechanisms have been proposed to explain large scale HI structures in galaxies. The hypothesis of supernova explosions appears to be most consistent with the idea of heating and supporting of the corona by galactic sources (Cox and Smith 1974). However, a single supernova event seems to be unable to break out of the HI disk unless the explosion is presumed to take place substantially off the plane. This means that single explosions can hardly be considered as a source of hot gas for replenishing the corona. Multiple supernova outbursts are more probable, since OB stars are well known to be born in groups, which in the solar vicinity on the average contain some tens of these stars (Ambarzumian 1947, Blaauw 1964).

In order to investigate the evolution of (super)shells which originate as a product of interaction of supernovae with interstellar matter, we have calculated 2D hydrodynamical numerical models. Some important values that are not well known from observations, like energy input rate $\dot{E}$, parameters of gas distribution in z-direction, etc., were considered as model parameters. A typical value of $\dot{E}$ for an OB association in the Galaxy seems to be of the order of 10^{38} erg s^{-1}. According to the models, a break-out from the gaseous galactic disk occurs in the course of the evolution of an OB association in the plane of the disk with gaussian density distribution and density scale height H = 140 pc for $\dot{E}$ = 2 × 10^{38} erg s^{-1} in ~7 × 10^6 years. For the more energetic case ($\dot{E}$ = 2 × 10^{39} erg s^{-1}) this event occurs after ~2.5 × 10^6 years. In Figure 1, the evolution of the latter model is illustrated.

The first phase of this evolution is rather well understood in terms of the theory of interstellar bubbles driven by stellar wind (Weaver et al. 1977). Supernova explosions are interpreted in our models as a continuous and powerful stellar wind. The freely expanding wind soon stops and the velocity of expansion decreases from ~2,000 km s^{-1} to ~100 km s^{-1}. The stopped wind then acts as a giant, hot isobaric gaseous piston driving a massive cool shell. A dense, relatively cool HI shell contains swept interstellar gas. This gas is shocked (the shell velocity is much greater than the sound speed in an ambient interstellar medium) and heated up to ~10^7 K. Then it cools down to T ≈ 10^4 K or less, due to radiative losses of internal energy. The top of the shell becomes unstable (Rayleigh-Taylor instability) when it reaches ~1.5 H and then breaks into fragments. The fragments can be as massive as ~10^3–10^4 solar masses and move with ~100 km s^{-1}. For the less energetic case (typical for the Galaxy), the masses and velocities of these fragments are 2-3 times lower. The number of fragments is of the order of ten, and the total mass never exceeds 0.1 times the mass of the shell. Calculations with an exponential atmosphere reveal a smaller tendency to fragmentate. As said above, however, it is not yet possible to make an appropriate choice of the galactic atmosphere. Moreover, the structure of the disk in the z direction appears to be dependent on blow-out events and the following dynamical evolution of the expelled gas. Corbelli and Salpeter (1988) have for instance shown that relatively weak current blow-out activity can be effective in compressing an outer H I disk and, possibly, in giving it a sharp edge.

The evolution of the expelled gas may be described in terms of a "galactic fountain" model, as proposed by Shapiro and Field (1976). Due to thermal instability, the rising hot gas converts into H I clouds falling onto the disk. These clouds resemble some of the so-called "high velocity" clouds (HVC) discovered by Dutch astronomers in the middle of the 60's; see the recent survey paper of Hulbosh and Wakker (1988). Such models of the galactic HVC – the first one was elaborated by Bregman (1980) – seem to be attractive. The main problem of the models is poor knowledge of n and T in the galactic corona and consequently a badly known cooling time scale. For typical $T = 2 \times 10^6$ K and $n = 2 \times 10^{-3}$ cm^{-3}, say, the (radiative) cooling time exceeds 10^8 years, which appears to be longer than the time scale of heating by supernovae.

Without discussing in detail the results obtained in our model calculations (see Igumentshchev et al. 1988, 1989; very recent results are in preparation for publication), we note that cool fragments may be interpreted as seed clouds for HVC. The masses of observed HVC, when estimated under the assumption that they are situated at mean galactic distances, are 10^4–10^7 solar masses. The fragments seem to be smaller, but it is possible for them to grow. They are massive and large enough (R $\sim$20–50 pc) to persist against evaporation. Moreover, if rising with the given velocities up to 0.7–2 kpc over the plane, they could act as a sink of thermal energy of hot coronal gas. A simple estimate, according to the theory of McKee and Cowie (1977), shows that the largest fragments are resistant to evaporation (radii exceeding the critical value) and should condense.

Note also that the proposed mechanism of sequential supernova explosions cannot explain the extremely large ($R \simeq$ 1 kpc) supershells unless one assumes very low densities $n \simeq 0.01$ cm^{-3}. Even in that case one must suppose enormously rich OB associations in order to explain the large kinetic energies. On the other hand, the most common supershells with radii $\sim$0.2–0.5 pc are explained quite well by this model.

I am grateful to the staff of ESO for help and friendly assistance during my stay in Garching.

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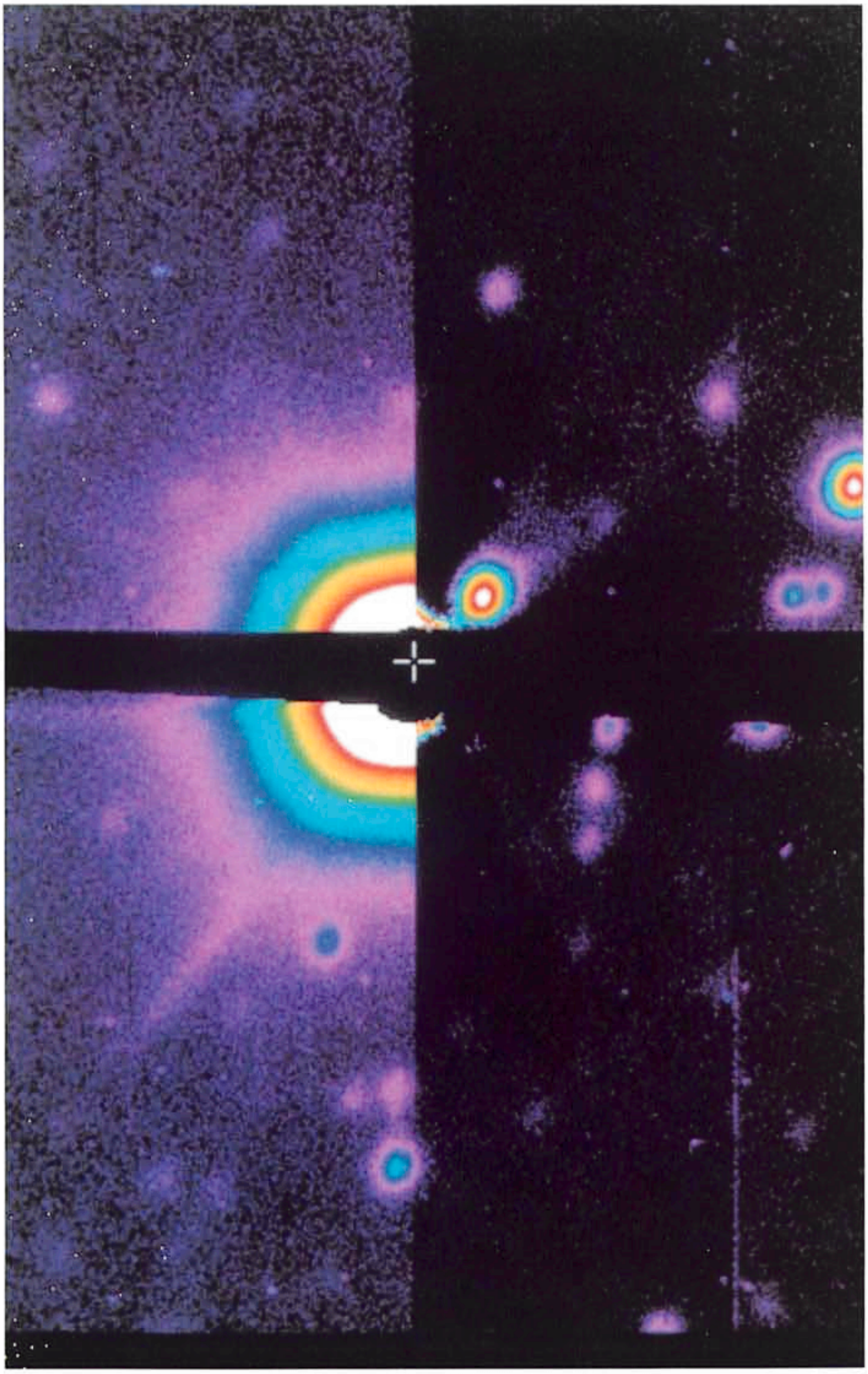
Searching for Light Echoes from Circumstellar Dust Shells Around SN 1987A

F. PARESCE, Space Telescope Science Institute, Baltimore, Maryland, USA, and Astrophysics Division, Space Science Department of ESA

The Space Telescope Science Institute coronograph (described in the *Messenger,* **47,** p. 43) mounted on the 2.2-m telescope at La Silla was used by myself and my colleague Chris Burrows to look for light echos in the immediate vicinity of the SN 1987A in the LMC. This technique allows us to probe circumstellar regions from about 2 to 20 arcseconds in the vicinity of very bright objects such as the SN 1987A for faint features otherwise completely lost in their glare. At the time of the observation reported here, carried out on December 21, 1987, the SN brightness was V = 6.2. Echoes at these angular distances and time of observation correspond to linear distances from the SN roughly in the range of 1–15 parsecs in front of the star near the observer's line of sight. At these distances, any echo would most probably be emitted from matter expelled from the SN itself at some earlier epoch when it was a hot main-sequence giant and/or a red giant star in its way towards eventually becoming a SN. Theory predicts and many observations confirm that shells of swept-up stellar material including dust formed in the outer layers of an expanding photosphere or wind would be expected to linger in the general vicinity of the SN and be observable by the delayed scattering of the SN light pulse. The echo would manifest itself in the form of a luminous ring of several arcseconds radius centred roughly on the SN itself. The ring might, in practice, be incomplete if the shell structure were not homogeneous. Rings of this type located much further away have been observed around SN 1987A (see the *Messenger,* No. 52, p. 13) but are thought to be due to scattering from sheets of interstellar dust lying between us and the SN and not related to the SN itself.

The accompanying composite image corresponding to a 10-minute exposure taken with the ST ScI coronograph through a standard B filter illustrates graphically the result we obtained. The full field of view shown in this image is 22 by 36 arcseconds with North up and East to the left. The occulted centre of the SN is located at the position of the cross at the centre of the image where the occulting wedge running EW is 1.9 arcseconds thick. Each pixel in the 512 × 320 pixel frame corresponds to an area of $5 \cdot 10^{-3}$ arcseconds^2 while 1″ corresponds to a linear scale of $\sim$0.83 light-years at the source. The left or



eastern half of the image corresponds to the eastern half of the cleaned, bias-subtracted, flat fielded image of the SN and its surroundings. In this portion, the seeing broadened image of the bright central source extending to approximately 5 arcsec from the centre is very prominent. The seeing during this exposure was 0.″8 approximately, as evidenced by the size of the stars in the field and the narrow diffraction spike in the SE.

The right or western half of the composite image represents instead the western half of the image obtained from the first by careful subtraction of the purely stellar profile. We found that a comparison of the observed profile with the theoretically expected one from atmospheric turbulence theory provides an effective means of assessing the residual circumstellar emission down to ≃ 2 arcseconds from the star. As can be seen from even a superficial inspection of the right half of this image, no conspicuous features appear anywhere in the field beyond the dozen or so stars and a few artifacts associated with the detector. All the stars observed were known to be there before the eruption including star 2 of the Sk-69 202° complex located at 2.″8 and 320° p.a. in the image shown here. This is the first sighting of this star after the SN 1987A eruption and its magnitude (B = 15.1) confirms the pre-eruption measurements. The rather surprising result we obtain is that excluding the thin occulted strip running EW through the image, the presence of significant amounts of circumstellar material in the region probed by the light pulse at the time of observation can be excluded to a reasonable degree of confidence. Specifically, the absence of detectable rings around the SN to brightness levels greater than approximately 22.5 blue magnitudes arcsec^{-2} implies upper limits to shell column densities of hydrogen ranging from about 10^{16} atoms cm^{-2} in the innermost observable regions to about 10^{18} atoms cm^{-2} in the outer ones. If the shell is broken up into smaller and isolated components, these limits would have to be revised upwards, of course, since irregular diffuse features are harder to detect.

Since the echo emission pattern around the SN is very time dependent owing to the rapid expansion of the echo ellipsoid as it sweeps out into the surrounding circumstellar medium, it will be interesting to see whether this result will continue to hold true. If it does, it implies that this particular SN is located in a cavity of suprisingly low gas density. How this can come about is now a subject of some speculation. Continued monitoring of the SN as it fades and the delay ellipsoid sweeps into areas unobservable in the December 21, 1987 time period should provide exciting new information on the past evolution of this amazing object.

Note added in proof

On February 6, H.E. Bond, N. Panagia, R. Gilmozzi, and M. Meakes, Space Telescope Science Institute, report (IAU Circular 4733) that direct CCD images of SN 1987A, obtained in B, V, and R at Cerro Tololo on January 24, 1989, appear to show a new light-echo feature. In addition to the two previously known echo rings, which now lie at radii of approximately 46″ and 78″ from the supernova, a new, nearly circular feature is seen at a radius of only 9.″5 (projected radius 2.4 pc). Its surface brightness is comparable to that of the two outer rings, but is highest in a rim on the eastern side of SN 1987A. This feature would imply the existence of dust lying at a distance of 5.9 pc from the supernova (assuming that it is illuminated by light emitted at the optical maximum in May 1987).

The Geneva Photometric Monitoring of SN 1987 A

G. BURKI, N. CRAMER, M. BURNET, F. RUFENER, B. PERNIER, C. RICHARD,
Geneva Observatory, Switzerland

A systematic photometric monitoring of SN 1987 A has been carried out from the Swiss station at the ESO La Silla Observatory (Chile), by using a 70-cm telescope equipped with the P7 photometer (Burnet and Rufener, 1979), devoted to the Geneva 7-colour photometric system. The supernova has been measured 463 times from Feb. 24, 1987, to Jan. 17, 1989 (see Burki et al., 1989).

The variations of the Geneva V magnitude with time is shown in Figure 1. From HJD 2446980 to 2447285, the decline of the V curve was strictly linear, with a slope in good agreement with the thermalization of the γ radiation resulting from the ^{56}Co radioactivity.

From HJD 2447285 onwards, the expanding envelope began to become transparent to γ radiation which could thus escape without being thermalized. The decrease of the V luminosity became steeper than the former linear variation. From this point, however, the steadily increasing relative importance of the two close companion stars of SK −69°202, which are unavoidable with the present measurement technique, cannot be neglected. The later portions of the corrected V light curve is shown in Figure 2 on a larger scale. The corrections applied are respectively +0.001 mag for the first, and +0.065 mag for the last value in Figure 2. A good mathematical description of that portion of the corrected V light curve is obtained by fitting a parabola over the interval HJD 2447270 to 2447450 (see Fig. 2).

After HJD 2447450, the luminosity in the V band started to decrease more slowly than the parabolic description. This inflexion of the V light curve, approximately 600 days after core collapse, could be interpreted as the effect of an additional energy source, such as *the expected central pulsar* in interaction with the surrounding material ejected by the supernova progenitor (see Arnett, 1988, for the theoretical light curves of SN 1987 A with various pulsar luminosities). One must, however, bear in mind the possible contributions of other slower decaying radionuclides such as ^{57}Co, ^{44}Ti and ^{22}Na produced during the initial explosive nucleosynthesis (Nomoto et al., 1989; Woosley et al., 1989), and which would affect the light curves in a similar manner. According to the model calculated by these authors, the energy supplied by these radioisotopes exceeds that of ^{56}Co after about 1,200 days following core collapse.

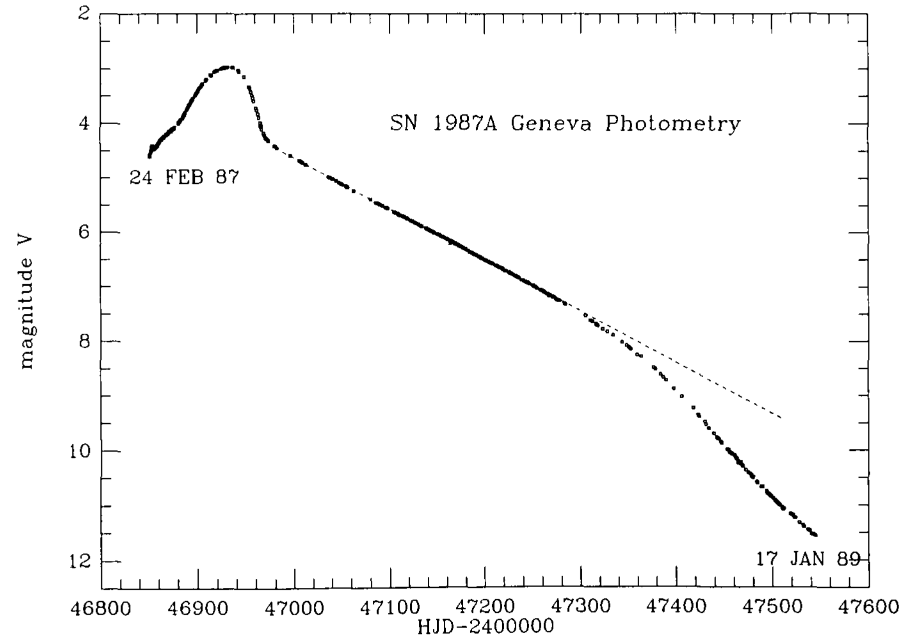


Figure 1: *The V magnitude curve, uncorrected for the contributions of the two faint companion stars of Sk −69°202. The dashed curve is the linear fit in the range HJD 2446980 to 2447285.*

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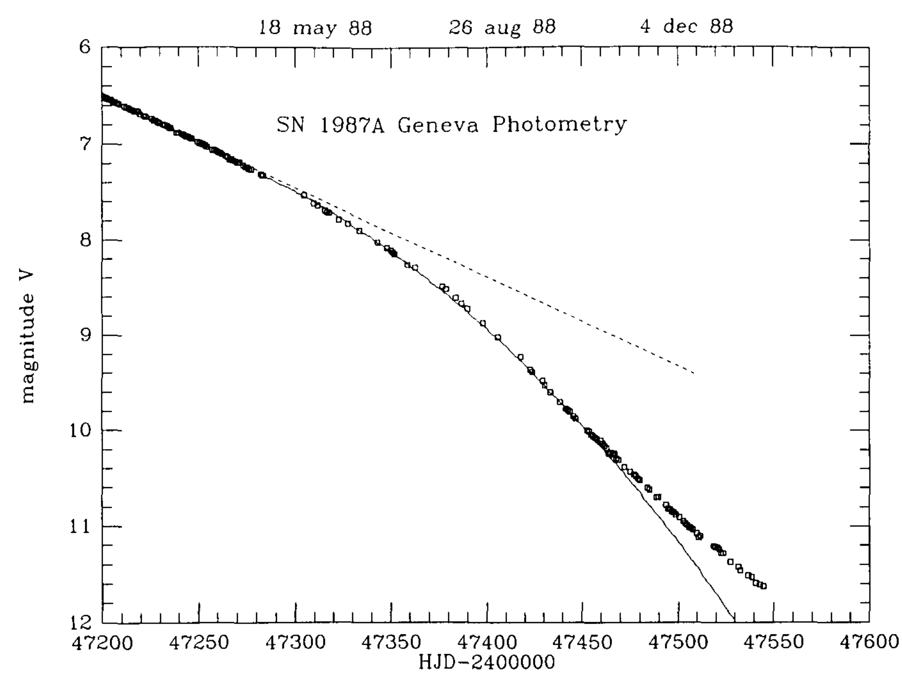

Figure 2: *Enlargement of the last portion of the V curve with magnitudes corrected for the two companion stars. The dashed line is the same linear fit as in Figure 1. The full line is the fit of a parabola calculated for the values within the range HJD 2447270 to 2447450.*

Is there a Pulsar in Supernova 1987 A?

A recent announcement of the discovery of a pulsar in Supernova 1987 A in the Large Magellanic Cloud has excited the world-wide astronomical community. New observations at the La Silla Observatory by a group of European astronomers[1] from the Max Planck Institute for Extraterrestrial Physics and the European Southern Observatory, however, do not confirm the reality of this object. More observations are now needed to settle this important question.

Searching for the Pulsar in Supernova 1987 A

Since the explosion of the now famous supernova in the Large Magellanic Cloud on February 23, 1987, astronomers have been eagerly waiting for the emergence of a newborn *pulsar*. Current theories predict that the explosion of a heavy star as a supernova will result in most of its mass being blown out into surrounding space, but also that some of it will be compressed into an extremely dense and rapidly rotating *neutron star* at the centre. Such an object would later manifest its presence in the supernova by the emission of regular light pulses (hence the name "pulsar"). Neutron stars measure no more than 10–15 kilometres across, but they weigh as much as our Sun which is about 100,000 times as large.

Of half a dozen pulsars known in supernova remnants, the most famous are those in the Crab Nebula and the Vela Nebula. The detection of a pulsar inside SN 1987 A, the first naked-eye supernova in nearly four centuries, would provide the definitive confirmation of the creation of pulsars in supernova explosions. Extensive searches for such a pulsar have therefore been made at some southern observatories since the explosion was first recorded, almost exactly two years ago. This is done by observing the supernova light with a "rapid" photometer, capable of measuring the light intensity many times each second. A pulsar would reveal itself by the presence of brief "flashes" of extra light, regularly spaced in time.

Immediately after the explosion, the dense cloud around the supernova did not allow a look at its centre, but as the clouds become thinner, light from the new pulsar should eventually become visible. Many astronomers have been waiting for this exciting moment.

First Detection?

On 8 February 1989, a group of American astronomers[2] announced the discovery of a very fast pulsar in SN 1987 A, flashing no less than 1969 times per second. This is referred to as 1969 cycles/second and supposedly corresponds to the number of rotations per second by the pulsar. No other pulsar has ever been found to rotate this fast. These observations were made on January 18, 1989 at the Cerro Tololo Interamerican Observatory, situated about 100 km south of La Silla. Surprisingly, the American group did not see any pulsations when the observations were continued 12 days later with another telescope.

At the European Southern Observatory, the light of the supernova has been monitored with a special, rapid photometer at the 3.6-m telescope at regular intervals during the past year. The intensity of the supernova light was measured 1000 times per second, a rate which was determined from theoretical considerations about how fast the predicted pulsar in SN 1987 A might rotate. However, it is too slow to show variations at the rate observed at Tololo.

New Observations Fail to Provide Confirmation

In order to confirm the presence of a pulsar with the higher pulsation rate, the ESO instrument was modified immediately after the announcement by the American group, so that it can now measure the supernova light up to 10,000 times per second. On February 14 and 15, observations were performed at the 3.6-m telescope during a total of 8 hours. The data tapes were rushed to the ESO Headquarters in Garching near Munich. The detailed results of a careful analysis at the Max Planck Institute for Extraterrestrial Physics have now been published on IAU Circular 4743 (24 February 1989).

The European team finds that no pulsating signal is present in the ESO data near 1969 cycles/second, to a limit of 1/4000th of the intensity of the supernova light. Nor is there any obvious signal at any other frequency in the interval from 1 to 5000 cycles/sec. These observations therefore do not provide confirmation of the presence of a pulsar.

If there is a pulsar in SN 1987 A, then the absence of observed pulsations in the measurements obtained after January 18, both by the American and the European groups, possibly indicate that the pulsar is being intermittently obscured by dust clouds around the supernova.

Further observations will therefore be needed to definitively demonstrate the reality of a pulsar in Supernova 1987 A.

(From ESO Press Release 02/89, 24 February 1989.)

[1] The group consists of Hakki Ögelman, Günther Hasinger and Wolfgang Pietsch (Max-Planck-Institut für Extraterrestrische Physik, Garching bei München, F. R. Germany), Christian Gouiffes, Jorge Melnick, Thomas Augusteijn, Flavio Gutierrez, Preben Grosbøl and Christian Santini (ESO) and Holger Pedersen (formerly ESO, now Nordic Optical Telescope Scientific Association).

[2] *This group is headed by John Middleditch, Los Alamos National Laboratory; the announcement was made on Circular 4735 of the International Astronomical Union (IAU).*

Squeezing the Most from the CES

H. BUTCHER and T. SCHOENMAKER, Kapteyn Observatory, Roden, the Netherlands

Introduction

In the *Messenger* No. 51 (p. 12–15), an attempt to use the CES for radioactive chronometry of the Galaxy was described. Two instrumental aspects of the observations were noted as being not yet under adequate control: (i) The determination in detail of the instrumental profile, the wings of which cannot be determined well, except at laser line wavelengths, and the shape of which is found to depend on the often variable focus across the array detector format, and at least sometimes on the signal level in the detector used. (ii) The markedly asymmetrical distribution of the noise from the Reticon detector (caused by energetic particle detections) for low flux levels and integrations of an hour and longer. Treatment of the data in an optimum way is problematical due to

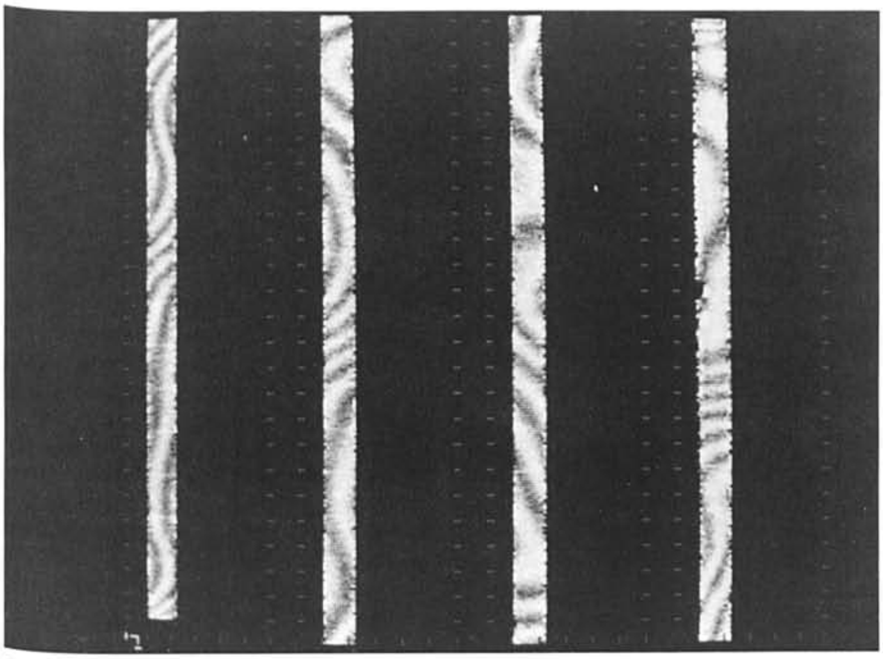

Figure 1: *Flat field correction frame displayed in four segments, starting at lower left and finishing at upper right. The frame has a mean correction of 1.000, with fringes and small scale sensitivity variations visible as deviations from 1.0 wherever there is sufficient signal for meaningful correction.*

these effects, and although the CES remains one of the world's best instruments of its type, study of such deficiencies can be expected to improve its performance significantly.

A satisfactory way of deriving the instrumental profile is, to our knowledge, still lacking, but with the possibility of using the new double density RCA CCD on the long camera, it seemed possible to substantially improve the noise characteristics of the data. That is, one can image the spectrum so that each spectral channel covers several pixels, and discriminate and eliminate (mostly single pixel) particle detections during data reduction. When Daniel Hofstadt on La Silla was approached in late 1987 about when this detector might be available to long-camera users, he graciously promised to help provide it for a CAT/CES run on 15–22 April 1988 – but only if a detailed report of the experience would be prepared! This article is adapted from that report.

The CCD we used was ESO CCD No. 9, an RCA SID 503 high resolution, thinned and backside illuminated device, with 1,024 × 640, 15 micron square pixels. We used a data format of 1,030 rows of 61 pixels each, with the spectrum recorded along the long dimension. The noise is quoted at 40 electrons rms when used in the fast readout mode. We decided to use the slow readout mode, however, for which we could discover no precise noise figure; our data are consistent with a system noise of about 35 electrons rms. The dark current was said to be 2.5 electrons per pixel per hour, a value which agrees with our data. The charge transfer efficiency was reputed to be very good for this chip. Our spectral lines were all in the blue region, near 4000 Å, and we were pleased to discover that the overall detection efficiency at this wavelength was very reasonable. A bad column was present near the centre of the chip, but our sub-format could be set up to avoid it. The spectrum signal showed a roughly gaussian shape in horizontal profile, some 5 pixels FWHM for the stellar data and 8 pixels for the calibrations.

All things considered, this chip seems to be representative of the higher quality devices available to astronomers today, and we were particularly interested to determine what the limits of its photometric performance would be.

Analysis

To try to extract stellar spectra in an optimum way from the 2-D CCD data, we have used the following processing steps.

(1) Background subtraction and flat fielding

We use a constant for the background, because all our dark frames were beautifully uniform and flat. We had three kinds of flat field data: continuum light from the internal calibration lamp, from a rapidly rotating hot star observed under similar circumstances to our programme stars, and from an illuminated patch on the inside of the dome observed through the telescope. Unfortunately, the intensity of the dome flat field was never sufficient in the blue to allow adequate S/N to be achieved. The other two sources yielded very similar results: the spectra, even at 4000 Å, show fringing at the 5 % level, but luckily this fringing is rather stable and we could not really distinguish between internal lamp data and the stellar spectrum for this purpose.

We prepared the flat field correction by heavily smoothing the continuum spectrum in the direction of dispersion, then dividing the raw spectrum by the smoothed one, to yield a flat correction picture with data values near 1.0. For those parts of the frames where the signal is so low that this procedure would objectionably amplify the noise, or where division is by nearly or exactly zero, we simply replace the ratio value by exactly 1.000. This correction picture is then divided into the data frames, removing high frequency sensitivity variations and fringes, while leaving the low frequency echelle order intensity envelope unchanged. An example of the resulting flat field correction frames is shown in Figure 1. Again the fringes have peak-to-peak amplitudes of roughly 10 %, and in places are of such a spatial frequency and orientation that they could cause significant line strength errors without obviously being seen to do so.

(2) Extraction of one dimensional spectra

Because we want to maximize the final S/N in our extracted spectra while minimizing the effects of particle detections and single pixel defects, we choose to derive a template function in the direction perpendicular to the spectral dispersion, and fit this function by iterative least squares at each position along the spectrum.

The template is derived by averaging on the order of a hundred rows of data (each row consisting of 61 pixels cutting across the spectrum), selected from the centre region of the format so as to avoid obviously bad pixels. A typical template is shown in Figure 2 a. This averaging process ensures not only that the S/N of the template signal is much higher than that of the data to be fitted, but also that it represents an average signal strength in the data at hand, and hence should suffer minimally from any photometric non-linearities present.

Our fit of the non-analytical templates to the data assumes that three parameters are involved: a (flat) background level, a multiplicative gain factor for in-

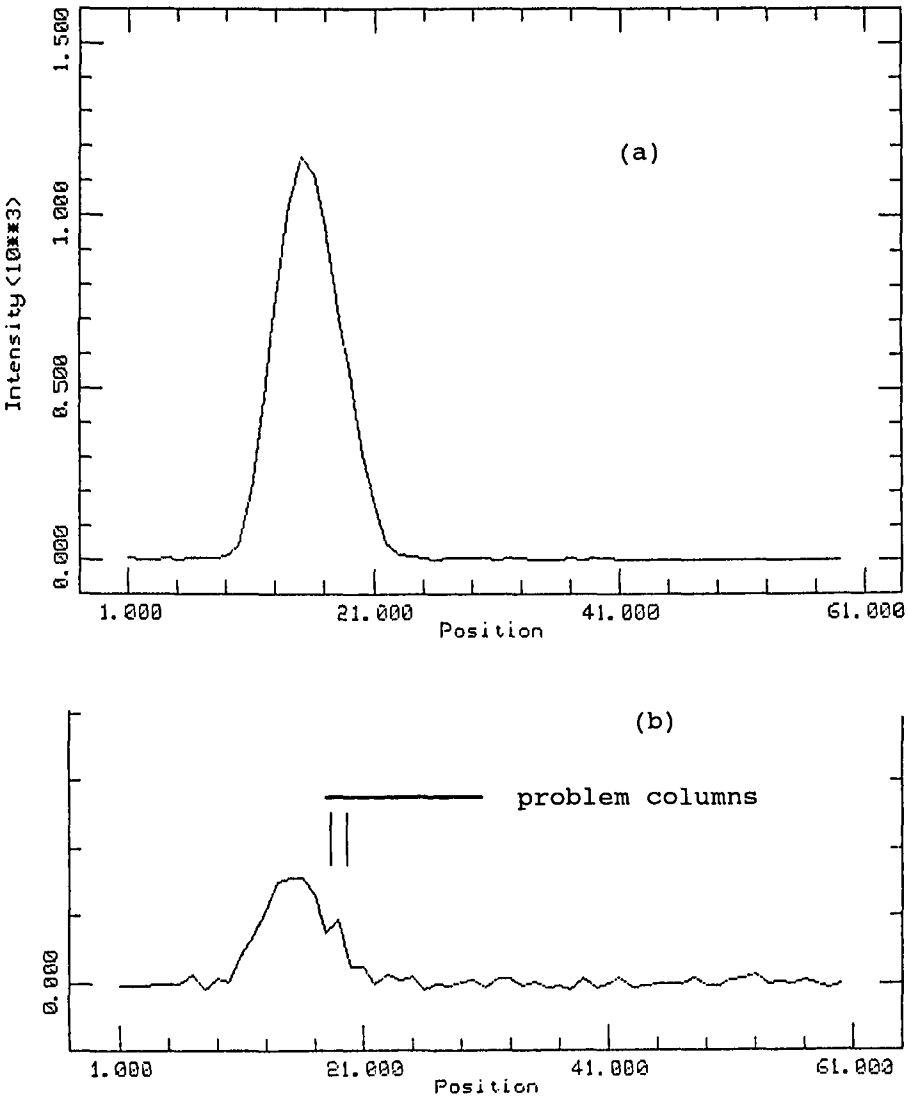

Figure 2: *(a) Typical signal template, used for fitting to each spectral channel. (b) Trace of data perpendicular to spectrum in the bottom of an absorption line, showing anomalous columns.*

tensity, and a shift in the x coordinate (i.e., perpendicular to the spectrum). At each channel (y position) along the spectrum we fit the template, calculating the derivative of the template with respect to the x coordinate using fifth order polynomial interpolation. The rms difference between the template and data is minimized by iterating until the calculated parameter changes are no greater than those expected from the *a priori* known noise, or until a maximum number (usually 7) of iterations has been made. For reasons sketched below, it has been found necessary to apply a mask to eliminate some of the data from the fitting process.

(iii) Wavelength scale and continuum correction

Finally, we have used the internal thorium lamp at the CES to obtain a wavelength calibration, and have extracted a spectrum from the (fringe corrected) flat field continuum data to provide a first correction for the large-scale sensitivity and echelle order variation along the spectra. As have other workers, we find that the scatter around the fit of the thorium emission lines is rather larger than estimated from the noise in the data. The resulting wavelength scale is adequate for our purposes, but it is clear that future calibration facilities for such high quality spectrometers should incorporate a solid Fabry-Perot etalon, to yield many sharp lines with precisely known spacings for the dispersion calibration.

We also note that our thorium calibration data show wavelength zero point jumps during one night of up to 1.9 km/s. We do not know the origin of these jumps, but evidently for radial velocity programmes it is important to take wavelength calibration spectra at regular intervals with the CES.

Assigning a temperature to the internal lamp spectrum of 2,800 K and ratioing it to a black body spectrum at that temperature yields a correction to the large scale sensitivity variations from one end of our spectra to the other which we estimate are accurate to better than 10%. The main uncertainty arises because of the differing optical paths of stellar and lamp light in the instrument, which in principle can give rise to illumination differences of the optics. At least to first order, however, this strategy provides a useful correction.

Results

In Figure 3 is shown a processed spectrum of a 3.6-mag star, from an integration of 15 min, and the difference between it and a second integration of the same star immediately following. The signal levels in the two cases differ by more than 30%, due to variable seeing. It is evident that the fitting procedure automatically normalizes all spec-

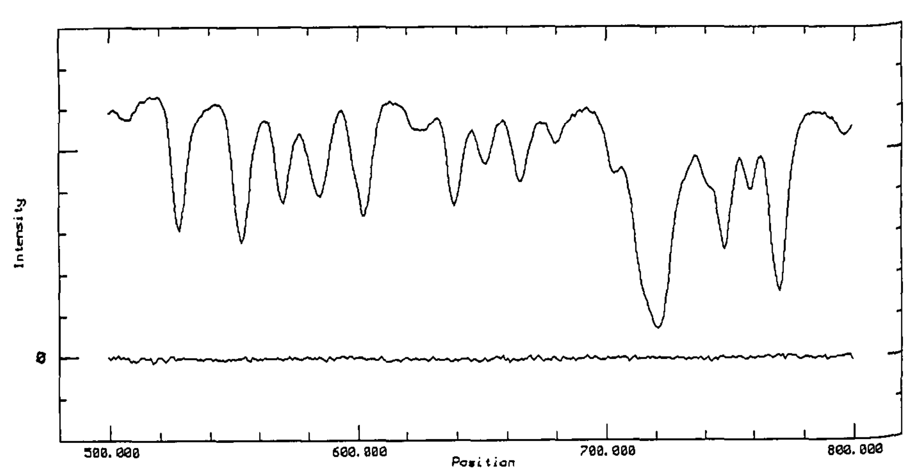

Figure 3: *Extracted spectrum from a single, well-exposed spectrum of a solar type dwarf star. The spectral resolution is 100,000. The strong absorption line at pixel position 720 is FeI 4132 Å. The noise trace near zero intensity is the subtraction of two such spectra, which differ in recorded signal level by 30–40%.*

tra to a common intensity scale (no scaling in intensity was made here), and that there is no significant detector nonlinearity present (which would be manifest as residual differences at the positions of strong lines). Furthermore, the difference of the spectra has an rms noise very near to the calculated photon shot noise limit, given the quoted 6.8 electron/ADU calibration.

From these and other results from the run it is clear that apparent S/N ratios of 300 : 1 are achievable with this detector. Higher ratios may be possible with multiple integrations.

The only serious problem found in our data is shown in Figure 2b. The two columns marked there consistently show residuals (data-minus-fit) dependent on signal level. We understand (Sandro D'Odorico, private comm.) that these RCA chips are known to exhibit such behaviour – that is, to have occasional column pairs in which part of the signal in one column seems to end up in the adjacent column, when the signal is above some threshold level. We have experimented with trying to fix this problem by applying an interpolated retransfer of signal after the fact, but could not convince ourselves that the results were always reliable.

Our solution to the problem is to mask the offending columns of data away, and exclude them from the template fitting process. We thereby lose some 15% of our signal, which we deem an acceptable loss to guarantee the quality of the photometry. The data in Figure 3 were processed with these columns masked away.

One negative side effect results, however. With two fewer signal columns, the fitting algorithm now no longer effectively ignores the single pixel outliers due to particle detections. We have had to include a routine, therefore, to test for pixels more than 5 times the (*a priori* known) noise sigma from the fit, and throw the worst single one out. Although not particularly elegant, this strategy has proven very effective in removing particle detections.

Focus Effects

Our data-minus-fit residual frames are exquisitely sensitive to focus variations along the spectra (although the final integrated intensities at each point should not be). We find that the width of the spectra does vary, being broadest at the two ends, but that the effect is so small that we cannot measure it in the widths of individual emission lines in the calibration spectra. We suppose that a small tilt of the CCD with respect to the focal plane of a half degree is sufficient to give the magnitude of what we see. From the residual frames we infer that over about a quarter of the total length of the recorded data, the instrumental profile is clearly constant enough for use in spectral modelling analysis with a single model profile. But of course, the derivation of the appropriate profile remains problematical.

Conclusions

Based on our, admittedly incomplete, analysis, we feel we can make the following conclusions.

(i) The double density RCA CCD on the CES long camera works very well, even at 4000 Å.

(ii) Its lower noise per pixel compared to the Reticon, and its registry of each spectral channel with multiple pixels, allows particle detections to be discovered and easily removed.

(iii) The expected quantum noise limit is achieved on single integrations, allowing S/N ratios of several hundred to be obtained. We have not done tests to determine whether S/N ratios of 1,000 and greater are possible, by summing multiple integrations.

(iv) Photometrically unacceptable columns on the detector have been discovered, which should be masked out during analysis if results of the highest quality are to be attained.

(v) Least squares fitting of templates for data extraction, and probably also for wavelength calibrations, seems a good way to determine the length of spectrum over which the instrumental profile is sensibly constant in shape.

What is the Mass-to-Light Ratio of the Old Magellanic Globular Cluster NGC 1835?

G. MEYLAN, ESO
P. DUBATH, M. MAYOR, Observatoire de Genève, Switzerland, and
P. MAGAIN, Institut d'Astrophysique de Liège, Belgium

1. Richness of the Southern Sky

We astronomers are lucky: our Galaxy has two companion galaxies, the Large and Small Magellanic Clouds, situated well above the galactic plane, which contain a huge potential of astrophysical information. For example, concerning star clusters, the realm of the globular clusters is much richer and more varied in the Magellanic Clouds than in the Galaxy: rich clusters of all ages are observed, from the youngest, having ages of a few tens 10^6 yr, to the oldest, having ages of the order or larger than $10\ 10^9$ yr. In this paper, only old Magellanic and galactic globular clusters are considered.

From the determinations found in the literature of the individual masses of the richest old clusters, a systematic difference seems to exist between the globulars in our Galaxy and in the Magellanic Clouds, Magellanic clusters appearing lighter than galactic clusters. This difference in mass between old rich Magellanic and galactic clusters obviously has direct consequences on the mass-to-light ratio determination of the considered clusters, reflecting perhaps systematic differences in mass function. This was challenged and discussed recently (Meylan 1988b). A way to resolve this controversy consists in obtaining good observational values of the central velocity dispersion, by detecting the very small line broadening present in the integrated light spectra.

2. Magellanic and Galactic M/L_V Ratio

2.1 Magellanic globular clusters

The method most often used for obtaining the total mass of Magellanic clusters is related to the systemic rotation of the Magellanic Clouds. The observed value of the tidal radius r_t of the cluster is transformed into mass, in a way similar to the case of galactic open clusters. It is assumed that the clusters are in rotation along circular orbits around the centre of mass of the Clouds, the old clusters seeming to form a disk-like system in the LMC. Tidal masses, particularly for the outer clusters, may be underestimated, if these clusters are in radial rather than circular orbits.

Observational determinations of the tidal radii by star counts in the outer parts of Magellanic clusters is pioneer work of a difficult nature, since the pollution by Magellanic field stars still induces uncertainties. Determination of tidal radius is a difficult task even for the galactic globular clusters, and the "observed limiting radius" determinations are rather weak for nearly all of them.

Using the above method, Elson and Freeman (1985) found for the following three old LMC clusters, NGC 1835, NGC 2210, and NGC 2257, total masses equal to, respectively, M_{tot} = 7.3, 1.9, and 3.7 10^4 $M_\odot$, with corresponding mean M/L_v ratios equal to 0.18, 0.11 and 0.56 (Table 1).

Reasonably good dynamical constraints – surface brightness profile and central value of the velocity dispersion – have been published so far only for one Magellanic cluster: NGC 1835. It is only in the case of this cluster that the determination of the velocity dispersion ($\sigma(V_r)$ = 5 km s^{-1}, obtained by Elson and Freeman (1985) from a Fourier method applied to integrated light spectra) can be converted into mass, by using the core radius and the dimensionless mass derived from the fit of the observed surface brightness profile to single-mass isotropic King models. Elson and Freeman (1985) find for NGC 1835, M_{tot} = 1.6 10^5 $M_\odot$, with M/L_v = 0.42 (Table 1).

All the former mass and mass-to-light ratio determinations concerning NGC 1835 (Freeman 1974, Chun 1978, Elson and Freeman 1985, and Meylan 1988b) are displayed in Table 1 and will be discussed in Section 4 with the results of the present study.

TABLE 1: *The different values of the total mass of NGC 1835 published during these last 15 years.*

Year	x	M_{tot} [10^6 $M_\odot$]	M/L_v [$\odot$ units]	r_a [r_c]	Authors
1974	...	0.045	0.2	...	Freeman 1974
1978	...	0.044	0.12	...	Chun 1978
1978	...	0.062	0.17	...	Chun 1978
1985	...	0.073	0.18	...	Elson & Freeman 1985
1985	...	0.16	0.42	iso	Elson & Freeman 1985
1988	1.75	0.39	1.30	iso	Meylan 1988b
1988	1.50	0.28	0.94	30	Meylan 1988b
1989	1.25	1.03	3.58	iso	present study
1989	1.00	0.81	2.83	30	present study

2.2 Galactic globular clusters

In our Galaxy, only six globular clusters have been studied so far with King-Michie multi-mass anisotropic dynamical models, consisting of about ten different subpopulations. The observational constraints for such models are the surface brightness in the central parts and star counts in the outer regions, with in addition the high quality radial velocities for numerous individual member stars. These six best studied galactic globular clusters are M3 (Gunn and Griffin 1979), M92 (Lupton et al. 1985), M2 (Pryor et al. 1986), M13 (Lupton et al. 1987), ω Cen (Meylan 1987), and 47 Tuc (Meylan 1988a, 1989). Apart from ω Cen, the (unique) giant cluster of the Galaxy (M_{tot} = 3.9 10^6 $M_\odot$), the total masses range from 0.4 to 1.1 10^6 $M_\odot$, whereas all the mass-to-light ratios are located between about 2 and 3. The above values can be considered as typical of the masses and mass-to-light ratios of the rich globulars of our Galaxy.

2.3 A difference in M/L_v by a factor of 10?

The typical mass of the globular clusters in the Clouds (less than 10^5 $M_\odot$) is smaller than the typical mass of the globular clusters in the Galaxy (greater than 10^5 $M_\odot$). This difference in mass between rich galactic and Magellanic clusters obviously has direct consequences on the mass-to-light ratio: $M/L_v \simeq 0.1-0.5$ for those in the Magellanic Clouds and $M/L_v \simeq 2.0-3.0$ for those in the Galaxy. Is there a genuine systemic difference in M/L_v, by nearly a factor of 10?

It is worth emphasizing that the above question does not only concern globular clusters. For example, despite the range of a factor of 1,000 in galaxy luminosities in the Local Group galaxies, the globular cluster luminosity distributions of these galaxies are consistent with being of the same form in all of them. It is generally accepted that the globular cluster population in galaxies was formed with the same distribution of globular cluster masses and luminosities in all galaxies. A clear systematic difference in M/L_v between Magellanic and galactic globular cluster populations would cast doubt as to their use as secondary distance indicators in the cosmological distance ladder.

At the present time, there is no definitive answer. We emphasize that only the rich old globular clusters in the Magellanic Clouds and in the Galaxy are considered here. It is essential to realize that any comparison between the M/L_v values of these two populations is so far strongly hampered by the fact that these values proceed from different determination processes. Comparison between galactic and Magellanic M/L_v values should be done only between results coming from the same kind of models constrained by the same kind of observational data. The more elaborated King-Michie dynamical models have been applied so far only to galactic globular clusters (with the exception of NGC 1835), due to the lack of observational data concerning the Magellanic clusters.

This situation is on the verge of change: if it is still difficult to obtain velocity dispersion profiles of Magellanic clusters, it appears now feasible to obtain at least the central value of the velocity dispersion, from integrated light spectra. The obtaining of such an essential observational constraint, in the case of the old Magellanic globular NGC 1835 is presented below, with a discussion of the application of this new result to a King-Michie model and the consequences on the M/L_v ratio concerning this cluster.

3. Core Velocity Dispersion from Cross-Correlation Technique

3.1 Optical and numerical cross-correlations

For more than twenty years, the cross-correlation spectroscopy has proven its exceptional efficiency in radial velocity determination (Griffin 1967, Baranne, Mayor, and Poncet 1979). The cross-correlation between a stellar spectrum and a template allows to condense the radial velocity information, contained in the stellar spectrum, into the equivalent of a single spectral "line": the cross-correlation function. For example, with the two CORAVEL spectrometers, using simultaneously about 1,500 spectral lines, a few minutes of integration provide a determination of the radial velocity of a 14th V-magnitude star with a precision of about 1 km s^{-1}.

In such spectrometers, the cross-correlation is done optically, but it is easy to

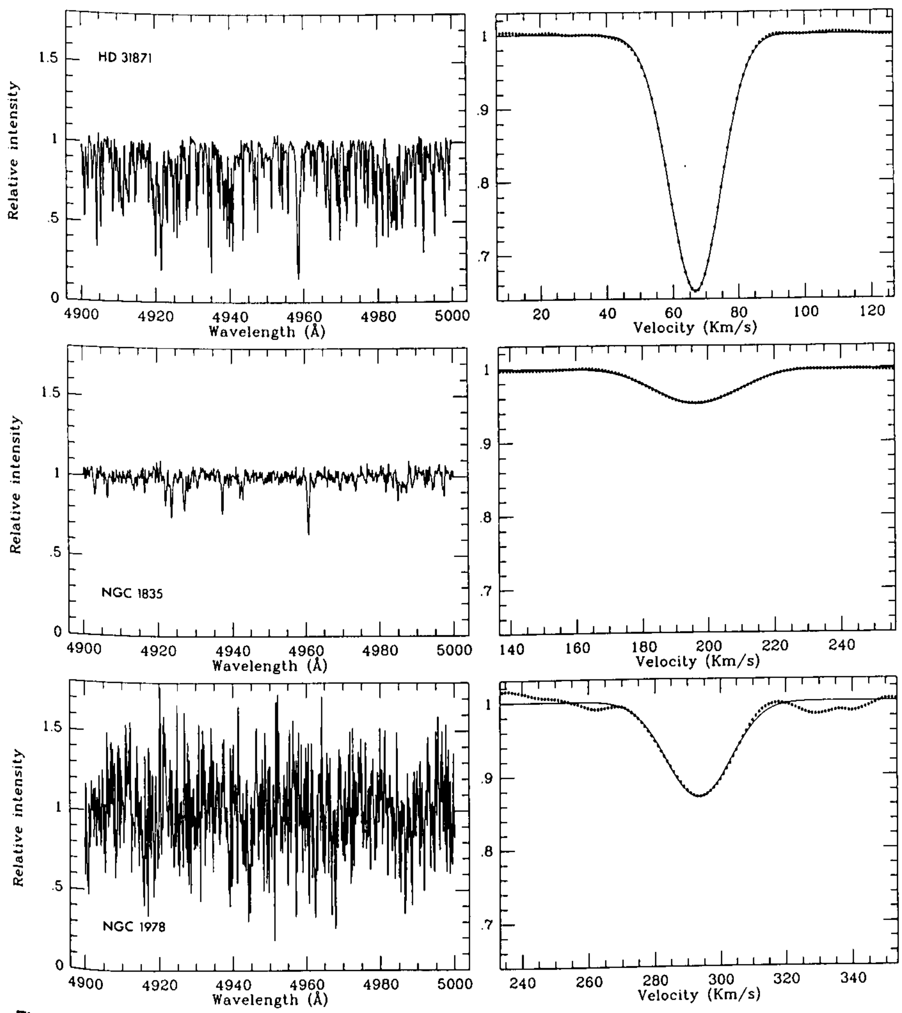

Figure 1: *Left: for the comparison star HD 31871 (K5 III, m_v = 9), and for the two old LMC globular clusters NGC 1835 and NGC 1978, 100 Å ranges from the spectra obtained with CASPEC (Cassegrain ESO Echelle Spectrograph mounted on the ESO 3.6-m telescope at La Silla) are displayed. Right: numerical cross-correlation functions for the same three objects; due to their low metallicities, the cross-correlation functions of the two clusters are much less contrasted than the cross-correlation function of the comparison star.*

visualize obtaining the same result from a numerical correlation between registered spectra. Such radial velocity measurements are obtained by D. Latham (CfA) and his collaborators, from numerical cross-correlation of registered spectra having a wavelength range of 50 Å. A numerical cross-correlation, using CASPEC spectra, would take advantage of a much larger spectral range (larger than 1000 Å). The numerical cross-correlation gives *a priori* a noticeable gain: the scanning required to build optically the cross-correlation function on the telescope is no longer necessary, providing an immediate gain of about 2.5 magnitudes. In addition, we can expect some further gain due to the high quantum efficiency of CCDs as compared to photomultipliers. Unfortunately the readout noise of the CCD is still the limiting factor.

If the cross-correlation spectroscopy is well adapted to radial velocity determinations, it shows the same efficiency concerning line broadening measurements, giving access to rotation through precise V sin i. Even more, the cross-correlation function of the integrated light spectra of globular cluster cores should allow a determination of the velocity dispersion of the stars in these cores. A resolution of about 20,000 is needed to have access through cross-correlation spectroscopy to Doppler broadenings of a few km s^{-1}, but a low signal-to-noise ratio (as low as 2-3) will be admissible. A similar approach was already used by G. Illingworth in 1976, to determine the velocity dispersion in the nucleus of a few galactic globular clusters, using Fourier transforms of integrated light spectra (on photographic plates).

3.2 Results from observations during a test night

In order to investigate the possibilities of CASPEC spectra applied to this technique, we obtained two hours of a test night at the ESO 3.6-m telescope. Spectra were obtained for two old globular cluster nuclei of the Large Magellanic Cloud as for two K5 III comparison stars. The integration times were two 20-minute exposures for NGC 1978 and two 30-minute exposures for NGC 1835. Due to the large difference in central surface brightness between the two clusters, the signal-to-noise ratio of the two cluster spectra are quite different (Fig. 1). The case of NGC 1978 is especially interesting for illustrating the potentialities of the method: the spectrum of this cluster has only a signal-to-noise ratio of about 2.

To increase the sensitivity to line broadening, we prefer to exclude strong saturated lines in the correlation process and use only small unsaturated lines selected from the CORAVEL template (here using its numerical version). Only the spectral domain of the CORAVEL mask between 4400 and 5200 Å has been used when cross-correlating CASPEC spectra with the numerical mask. In the left half of Figure 1, 100 Å ranges from the spectra of one comparision star (HD 31871, K5 III, m_v = 9) and from the two clusters NGC 1835 and NGC 1978 are displayed. In the right half of the same figure the cross-correlation functions obtained for these objects are plotted. Due to their low metallicities, the cross-correlation functions of the two clusters are much less contrasted than the cross-correlation functions of the two comparison stars (the width of the cross-correlation function does not depend on the metallicity!). After normalization of the cross-correlation function of the cluster NGC 1835 in order to have the same depth as the cross-correlation function of the comparison star (Fig. 2), we immediately notice the important broadening of the cluster cross-correlation function. Both comparison stars have been checked by direct CORAVEL measurements to have an almost zero rotation. Consequently, the velocity dispersion in the core of NGC 1835 is immediately derived:

$$\sigma_{V_r} \text{ (NGC 1835)} = 10.1 \text{ km s}^{-1}$$

During the integration, a scanning of the nucleus was done with the entry slit, in order to cover a zone of 6 × 6 arcsec, so that the velocity dispersion is based on the light coming from more than 100 giant stars. Data reduction of the spectra was done with MIDAS. It is worth mentioning that the cross-correlation technique allows us to determine accurately a broadening of only a few per cent of the FWHM of the cross-correlation function (at zero broadening factor,

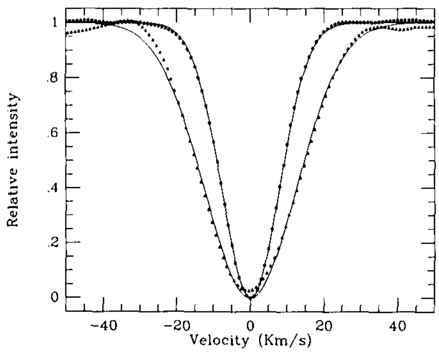

Figure 2: *Normalized cross-correlation functions of the cluster NGC 1835 (triangles) and of the comparison star HD 31871 (dots); the continuous lines are the corresponding fitted gaussians; the important broadening of the cluster cross-correlation function is conspicuous and allows an immediate determination of the velocity dispersion in the core of NGC 1835:* $\sigma(V_r) = 10.1\ km\ s^{-1}$.

the FWHM of the CASPEC cross-correlation function is equivalent to about 18 km s^{-1}, the pixel size being 9 km s^{-1}).

4. NGC 1835 M/L_v from King-Michie Model

4.1 Observational constraints

With this new determination for the velocity dispersion in the core of the old LMC globular cluster, $\sigma(V_r)$ = 10.1 km s^{-1}, it is possible to constrain King-Michie dynamical models. The other observational constraint, viz. the surface brightness profile, is a composite profile – namely CCD surface brightness photometry in the very central parts, centred aperture photometry and drift scan measures in the central and intermediate parts, and star counts in the outer parts – obtained by mixing Elson and Freeman (1985) and Mateo (1987) data (already used in Meylan 1988b).

Figure 3 displays the surface brightness profiles, as a function of the radius, of the observations and of one of the 8 best models (lowest reduced χ^2_v) obtained from a grid of about 400 models. The model profile, integrated along the line-of-sight, concerns only the subpopulation containing giants, subgiants, and stars at the top of the main sequence, i.e. all the stars emitting most of the light of the cluster. The residuals between observations (dots) and model (continuous line) are also displayed in the lower part of the same figure.

4.2 Mass function exponent, total mass, and mass-to-light ratio

The models are calculated by using the same mass function exponent x ($dN \propto m^{-x} d\log(m)$) for the entire range in stellar mass, i.e. from 0.1 to 100 $M_\odot$. Within the large range of values of x investigated (from 0.0 to 3.5 by steps of 0.25), only the values between 1.00 and 1.75 provide models able to fit the observations. Only models with small fractions of stellar remnants (neutron stars and white dwarfs) fit the observations: the fraction of the total mass in the form of neutron stars varies from 0.0 to 4%, whereas the fraction of the total mass in the form of white dwarfs varies from 9 to 26%, depending on the model.

From a structural point of view, NGC 1835 appears rather concentrated, with values of the concentration parameter c = log (r_t/r_c) ranging from 1.81 to 2.24 (similar to 47 Tuc). It is worth mentioning that the size of NGC 1835 ($r_t \simeq$ 50 pc) is quite comparable with the size of ω Cen and 47 Tuc.

Depending on the model, the values obtained for the total mass of the cluster range from 0.70 to 1.55 $10^6\ M_\odot$, with a *representative mean total mass* $\langle M_{tot} \rangle$ = 1.0 $10^6\ M_\odot$. From Table 1, we see that the best results obtained by transforming the tidal radius r_t into mass (under the assumption of systemic rotation of the old globular cluster system) are smaller than the results from King-Michie models by about a factor of ten.

The half-mass relaxation time and the central relaxation time are of the order of 10 Gyr, and 10^7 yr respectively, allowing a large fraction of the central parts of the cluster to have been relaxed. Both isotropic and anisotropic models are successfully fitted to NGC 1835. A real velocity dispersion profile, instead of presently only the central value, would allow perhaps a better evaluation of the quantity of anisotropy.

The central surface brightness μ_o varies from 6.53 to 6.72 mag/arcmin^2 with a representative mean value $\langle \mu_o \rangle$ = 6.66 mag/arcmin^2. The integrated visual magnitude V_t varies from 9.85 to 9.91 mag with a representative mean value $\langle V_t \rangle$ = 9.88 mag. This last model value is situated between the observed values: V_t = 9.48 (Chun 1978), V_t = 9.52 (Elson and Freeman 1985), and V_t = 10.13 (van den Bergh 1981). The global mass-to-light ratio M/L_v varies from 2.50 to 5.21,with a representative value $\langle M/L_v \rangle$ = 3.4, whereas the central mass-to-light ratio $(M/L_v)_o$ varies from 1.93 to 2.63. These values of the mass-to-light ratio are the direct consequences of the central value of the velocity dispersion, and depend also mainly on the mass function exponent x and on the quantity of anisotropy of the velocity dispersion.

5. A Universal M/L_v for Old Globular Clusters?

The present results (using King-Michie models) concerning the total

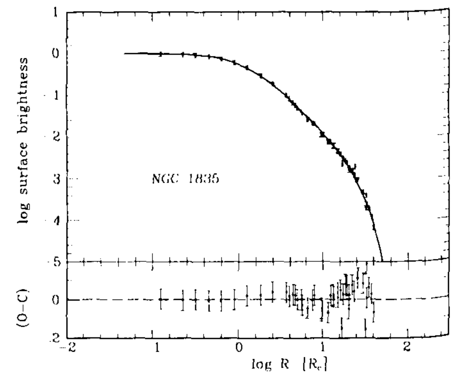

Figure 3: *NGC 1835: logarithm of the observed (dots) and model surface brightness profiles as a function of the logarithm of the radius.*

mass of NGC 1835 are larger than the best previous determinations (not using King-Michie models) by about a factor of ten, giving to this old LMC globular cluster a M/L_v ratio similar to those obtained for galactic globular clusters (Table 1). Consequently, the method based on the assumption of circular orbit (due to rotation) and on the transformation of the tidal radius into mass should be used only with great care in the case of Magellanic clusters. The systematic difference observed between the typical mass of rich globular clusters in the Galaxy (greater than $10^5\ M_\odot$) and in the Magellanic Clouds (less than $10^5\ M_\odot$) could be a simple artifact, a direct consequence of the idiosyncrasies of the different methods used.

In conclusion, when the same kind of dynamical models (King-Michie) constrained by the same kind of observations (surface brightness profile and central value of the velocity dispersion) are applied to an old rich Magellanic globular cluster, viz. NGC 1835, the results seem similar to those obtained in the case of 47 Tucanae. Consequently, the rich old globular clusters in the Magellanic Clouds could be quite similar (in mass and M/L_v) to the rich globular clusters in the Galaxy. The present study will be extended to as many Magellanic clusters as possible.

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High-tech Telescope on Top of Mount Wendelstein

H. BARWIG, Universitäts-Sternwarte München, F. R. Germany

A prominent feature of the silhouette of the Alps, the Wendelstein Mountain, can be seen from Garching on clear days. Extremely transparent skies sometimes even allow one to recognize on top of that mountain the domes of the Observatory of the University of Munich (USM). Only 75 km away, after one hour's ride, this site can easily be reached via cable car or by means of a famous 75-year-old cog railroad. Final access to the very top is achieved by an elevator climbing up 114 m within the mountain.

This Observatory had already a long tradition in solar research. First observations were started in 1940 (however, near the end of World War II they merely served the military to forecast radio disturbance caused by solar activity). Later, observations of solar prominences and of the solar corona began. After integration of the Observatory into the world-wide activities during the "International Geophysical Year" a 20-cm Zeiss Coudé Coronograph was installed; it was used since 1963 to provide data for international solar research.

About 20 years later, when corona observations were reduced to only a few days a year due to increased air pollution, these activities had to be stopped: it was high time to think about the future of the Wendelstein Observatory. On the other hand, a statistical evaluation of weather data obtained over 7 years clearly indicated favourable conditions, at least for stellar observations, on about 145 days a year and fairly good seeing quality as well.

Thus in 1983 a new concept was elaborated to adapt the facilities to night-time observations and to move the solar instruments to a site on the Canary Islands. After many struggles for the required financial support, finally the green light was given to the telescope builder DFM Engineering in Colorado to provide an 90-cm fork-mounted Ritchey-Crétien telescope and auxiliary equipment, including a grating spectrograph and a CCD camera with an image data analysis system.

Construction work for the new dome building (Fig. 1) started in autumn 1987. The telescope itself was delivered in November 1988, packed into a huge container that arrived at the bottom of Wendelstein after a journey of about 9,000 km. Helicopter flights scheduled for transportation to the mountain top had to be cancelled due to heavy snows and wind velocities up to 200 km/h. Therefore all of the equipment had to be brought up to the top using the cog railroad and two elevators.

The mechanical and optical setup was achieved within the scheduled time, although some problems were encountered in getting the telescope drive system to work because of strong signals from the nearby radio station. Extensive shielding measures finally solved this problem. "First light" through the telescope could be announced on January 18, 1989 when radiation reflected from Jupiter first passed through the new instrument.

However, long before this date our request to ESO concerning support of optical tests on the planned telescope had been answered positively – another example of the fruitful cooperation and of the mutual exchange of experience we had enjoyed with ESO in the past. For test purposes the ESO-Shack-Hartmann camera "ANTARES" could be made available just before this instrument had to be shipped to Chile for application as wavefront sensor at the NTT. The Hartmann exposures will serve to perform the final optical alignments and to determine the overall optical quality. Prior to the completion of these tasks visual observations have already yielded a surprising result: The atmospheric conditions on Wendelstein during several test nights yielded seeing disks well below 1" (Craters on the Moon about one arcsec of diameter still showed shadow structures in their centres!).

The probability of having such favourable atmospheric conditions as well as the number of useful nights promised by weather statistics seem to justify the installation of such a high-tech telescope. Its performance differs in several respects from those of conventional instruments of comparable size: The thin primary mirror of accordingly low heat capacity is supported by an airbag. Its pressure is adjusted according to the mirror's weight on three hard points. This device guarantees preservation of the mirror's shape and therefore optimal image quality regardless of the telescope position. Furthermore the lightweight mirror allows a very stiff mount-

Figure 1: *Ready for observation: the new telescope on Mount Wendelstein.*

Figure 2: *The Multichannel Photometer mounted at the 0.8-m DFM telescope.*

ing of low inertia to be used, which makes possible a slew speed of 4 degrees/sec. Computer control provides corrections for precession, aberration, nutation, refraction, azimuth and elevation misalignment, mechanical and optical non-perpendicularities and flexure. These corrections typically allow a pointing accuracy of better than 10 arcsec RMS to be achieved. Back-up instrumentation weighing up to 100 kg can be mounted at the instrument rotator. (Highly sensitive detectors which may be influenced by radio noise can be protected by means of a shielding box for RF radiation.) The telescope is operated from a separate control room. Two terminals respectively allow one to command the telescope motion via a menu and to display all relevant status parameters. An automatic dome drive and an autoguider that follows stars brighter than 15 mag provide an almost automatic observation mode.

The first astronomical instrument mounted (Fig. 2) was the High Speed Multichannel Photometer MCCP (cf. *The Messenger* No. 48, p. 29) developed at the USM which allows simultaneous UBVRI measurements of object, comparison and sky, thus compensating for changing atmospheric transparency. (This instrument has already been successfully operated at the ESO 1-m, 2.2-m and 3.6-m telescopes.) High-speed light curves of the dwarf nova U Gem were the first astronomical data recorded on Wendelstein. Application of the remotely controlled spectrograph with a Reticon detector and the CCD camera for narrow band imaging are planned in the near future.

In principle the new telescope should serve the following specific purposes:

– Thorough training of students and observers as preparation for observing runs at large telescopes.

– Performance of test runs in the course of instrument and detector developments.

– Execution of observing programmes which are so time-consuming that observing time at other sites will not be given to visiting astronomers – or programmes which concern singular events like nova and supernova eruptions or the appearance of comets. All of these tasks are favoured by the easy access to our observatory, as well as by the existence of a proper infrastructure.

In addition, astronomical observations simultaneous with those on satellite-borne telescopes, and cooperations with international observing campaigns are planned. Finally, a certain amount of telescope time will be granted to visiting astronomers to allow them to take a look through the blue Bavarian sky.

Acknowledgement

We would like to acknowledge the excellent support we encountered by people of the ESO Optical Group, in particular by P. Giordano, F. Merkle, L. Noethe and R. Wilson.

Spatial Resolution Imaging of the Radio Source 3C 255

The optical identifications of the 3CR sources are now nearly complete (Spinrad et al. 1988), and only 7 are lacking redshifts.

The radio source 3C 255 is one of these remaining sources, and the deep image presented here was taken to search for a possible underlying distant cluster. Three CCD exposures in V and R were taken with the 2.2-m ESO-MPI telescope on La Silla under moderately good seeing conditions (1.2 to 1.5 arcsec). Adding these images gives a total exposure time of 2 h. The visible counterpart of the radio source is the central object of the frame. There are three other objects, W, E, and S, located at about 7 arcsec from it.

Spinrad et al. noticed that the central object is elongated, as most distant 3CR sources are. On this CCD frame we resolve the elongated region of the source into at least three components (possibly five), the average distance between the components being about 2 arcsec.

The source itself may have four unresolved components (on 1 arcsec scale)

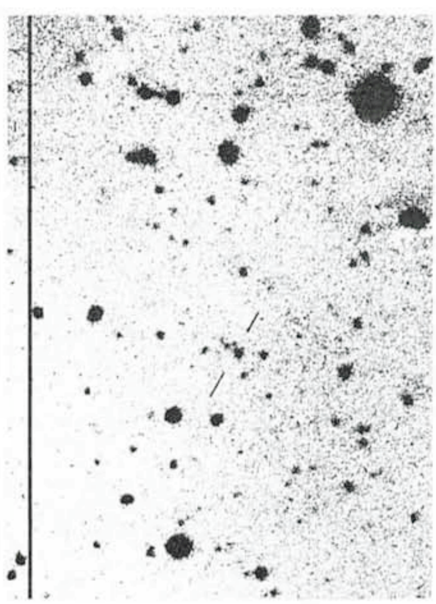

Figure 1: *A 90-minute CCD frame (V) obtained with the 2.2-m telescope at La Silla, showing the distant cluster of galaxies around the radio source 3C 255. The magnitude of the optical image of the source is ~23. The foreground cluster in the upper part of the frame is at redshift z ~ 0.2. North is up and East is to the right.*

or extensions, namely the central object, two extensions in the northern direction and one towards the south.

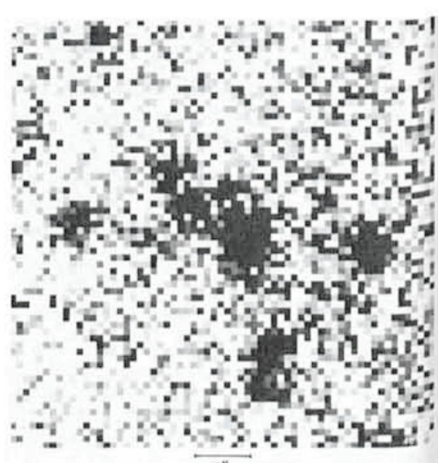

Figure 2: *A spatially resolved image of the elongated radio source 3C 255 obtained with the 2.2-m telescope on La Silla. Exposure time: 3600 s + 1800 s in V (seeing 1.2 arcsec) + 1800 s in R (seeing 1.5 arcsec). The optically identified source is resolved into a bright object and at least 3 fainter components. North is up and East is to the right.*

The simplest explanation is that we have found a distant aggregate of galaxies, the radio source being the first ranked object. Its magnitude suggests a redshift of $z \geq 0.6$.

Clusters of galaxies have been found up to z = 0.92 (Gunn et al. 1986) and it has been suggested that some of the most distant 3CR galaxies, near $z \approx 1.8$ might be cluster cores in the process of formation (e.g. 3C 326.1, Mac Carthy et al. 1987; 3C 294, Spinrad et al. 1988).

The dynamical time of galaxy clusters is of the order of the Hubble time. It follows that clusters should be dynamically young and may have had different properties at $z \geq 1$. It is also by no way obvious that the universe contains many clusters at high redshift. Thus it would be important to have a spectrum of this object.

Several distant 3CR elongated galaxies have been found to have a complex, probably multiple structure (Le Fevre and Hammer, 1988). These authors have proposed that some of the 3CR distant galaxies might be affected by gravitational amplification or lensing by foreground galaxies, an hypothesis that may also apply to this new case.

E. GIRAUD, ESO

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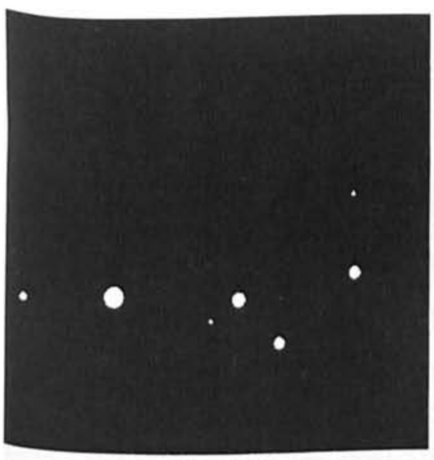
The Spectacular Binary System PG 1550+131

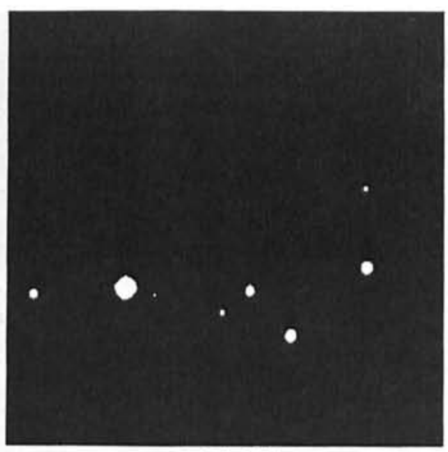
PG 1550+131 was known as a faint, very blue object (V = 16.8, U-B = −1.2) in the constellation Ophiuchus. Its optical spectrum showed the Balmer lines and the Balmer jump in emission. Scarce photometric data indicated large amplitude variations. So it seemed to be a relatively uninteresting member of the cataclysmic variables, not deserving further detailed observational attention. Nevertheless, it was included in a programme to search for eclipsing, faint cataclysmic variables and aiming at the determination of primary masses in such systems. The observations were performed using the CCD camera at the Danish 1.5-m telescope at La Silla. PG 1550+131 turned then out to be the most spectacular eclipsing system found during this survey.

On 1988 July 2 at about UT 0 : 28, after monitoring this object for approximately one hour, it suddenly disappeared almost completely from the frame and reappeared after some seven minutes, indicating the occurrence of a short, very deep eclipse. On-line reductions revealed a regular, sinusoidal variation of the brightness, quite different from that of common cataclysmic variables and it soon became clear that the next occultation would occur about three hours later. In fact, this following eclipse and another one during the next night could be observed at the expected time.

The photo shows a sequence of five CCD images covering the third eclipse monitored on 1988 July 3. At UT 1 : 20



1:20 UT



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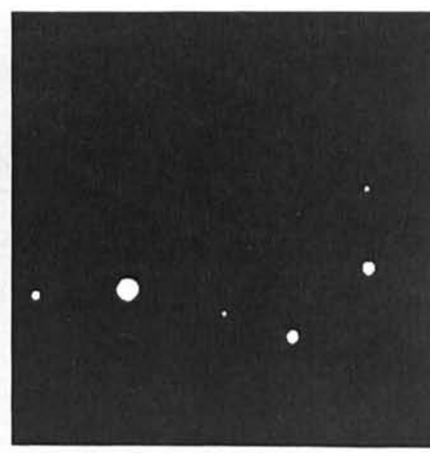

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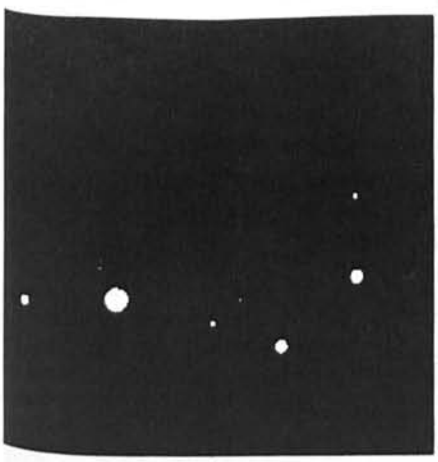

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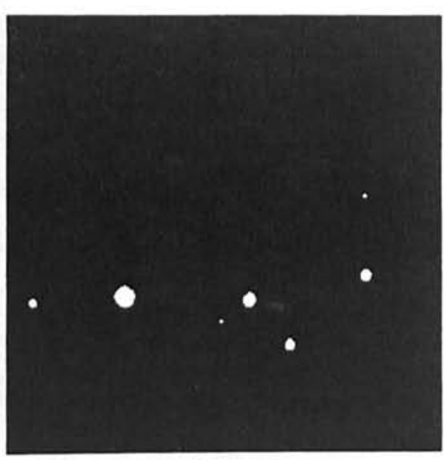

1:35 UT

PG 1550+131

Eclipse on July 3, 1988

the eclipse has not yet begun; at 1 : 24 the bright star in the system has dimmed notably; at 1 : 28 it is completely eclipsed; it weakly reappears at 1 : 31 and reaches its normal brightness at 1 : 35. The exposure time was three minutes for all frames. The main spectral response is in the red region since no filter was used.

Folding the data with the (orbital) period of 187 minutes yielded a smooth, sine-shaped (full amplitude ~0.6 mag) light curve outside eclipse which occurs half a period after maximum light. Its depth is at least 4.8 mag and the time between first and last contact amounts to about 12 minutes. In fact it must be deeper and narrower since due to the relatively long integration time its true shape is not resolved. Thus PG 1550+131 exhibits eclipses which are among the deepest if not actually the deepest ever recorded for a binary. Two EFOSC spectra obtained near maximum respectively minimum light demonstrate that the Balmer emissions (indicatively superimposed on absorptions) disappear near minimum light, leaving the Balmer series in absorption.

These results show that PG 1550+131 is a precataclysmic rather than a cataclysmic binary. It consists of a small hot degenerate object (very probably a white dwarf with $T \approx$ 18,000 K) and a late main-sequence star ($T \approx$ 3,000 K) which does not yet completely fill its roche lobe to enable mass transfer to the compact object typical for cataclysmic binaries. The compact object is heating up the facing side of the companion to about 6,000 K, thus producing the sinusoidal shape of the light curve during orbital revolution. The heated hemisphere is also responsible for the emission lines which cannot be seen near the eclipse of the compact object.

Only very few eclipsing systems in this transitory phase are known so far which allow an accurate determination of the basic parameters that in turn place constraints on those for cataclysmic variables. A detailed study of PG 1550+131 may therefore contribute to our knowledge of both the precataclysmic as well as the cataclysmic states of binary evolution.

R. HAEFNER, Universitäts-Sternwarte, München, F. R. Germany

Report on the Last Observing Run of Multiobject Spectroscopy: OPTOPUS is Alive and Kicking

G. AVILA, S. D'ODORICO, M. TARENGHI, ESO
L. GUZZO, Osservatorio Astronomico di Brera, Milano, Italy

1. Fibre Multiobject Spectroscopy at ESO

The ESO fibre facility for multiobject spectroscopy at the Cassegrain focus of the 3.6-m telescope, OPTOPUS, has been operating since March 1985. A complete description of the system is given in the ESO Operating Manual No. 6. It is possible to observe with OPTOPUS a maximum of 52 objects distributed over a field of 33′. Special aperture plates are prepared in advance of the observations in the ESO workshop from accurate α and δ coordinates of the selected objects. These plates are eventually mounted at the telescope and the fibres are manually inserted in the apertures; at the other end they form the entrance slit of a CCD spectrograph. In the last four years OPTOPUS has been used in 33 nights for 14 different programmes. It has always operated with high reliability, collecting some 6,000 spectra. The limiting magnitudes at a resolving power of about 500 in the visual are about 18.5 for galaxies and 20 for quasars in a two-hour exposure. While these limits allow useful work for a large number of programmes, there are two aspects of the present system which must be considered as unsatisfactory: the poor blue-UV transmission of the fibres and the reduced efficiency of a number of them, mainly due to imperfect centring of the microlenses at their input ends. As the interest in using

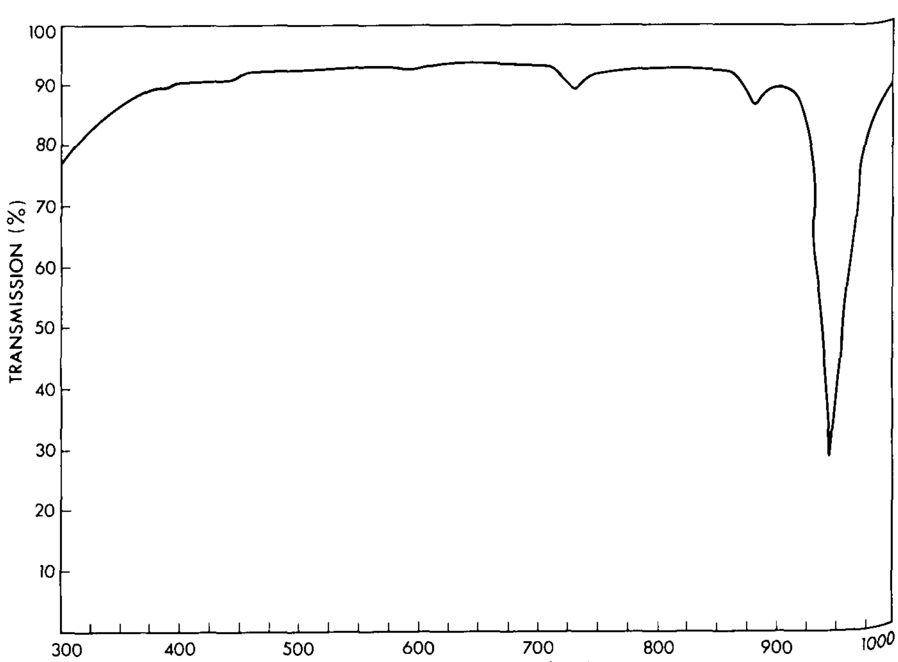

Figure 1: *Total transmission (including reflection losses) of a 3-m polymicro fibre used in the new OPTOPUS head.*

the facility is actually increasing (see e.g., DAEC Workshop, 1988), ESO started a programme to improve the weak points while keeping the basic concept unchanged.

2. The New Configuration of the OPTOPUS Head and the Future Steps to Improve of the Facility

Extensive tests on the efficiency and focal ratio degradation of different commercial fibres were carried out in the ESO laboratory (Avila and D'Odorico 1988, Avila 1988). The fibre selected for the new OPTOPUS head was an all silica, wet (high contamination by the OH radical to enhance the UV transmission) fibre from Polymicro. The transmission of 3 metre of this fibre is shown in Figure 1. A prototype head based on 31 fibres was prepared in the ESO fibre laboratory and in the workshop in the first half of 1988. At their input ends, the fibres were polished and mounted in connectors which fit in the standard aperture on the OPTOPUS plates. In this way the fibres are placed "naked", that is without microlenses, in the focal plane of the telescope. With a core of 320 μm, they subtend 2.3 arc sec on the sky and since they preserve well the beam focal ratio, they can still be used with the F/8 collimator of the ESO B & C spectrograph. From laboratory measurements of the average efficiency of the fibres in the old head and in the new prototype, we could predict an improvement in the efficiency by a factor of two. This was essentially confirmed by the observations (see below) which indicate a gain of about one magnitude with respect to previous results.

By the end of 1989, ESO plans to implement a new head with 50 fibres to be coupled with a new F/6 dioptric collimator now on order. In the final configuration, the upgraded OPTOPUS will be a highly efficient instrument. Further improvements can be expected when CCDs with high efficiency and lower read-out-noise become available.

The weak point or if you want the bottleneck of the facility will then rest in the preparation of the aperture plates in the ESO workshop. It is a demanding operation in terms of manpower and ESO is forced to set an upper limit to the number of plates which can be prepared for a given observing run. The way to solve this problem is by building a system in which the fibres are positioned at the location of the targets in the focal plane of the telescope by a mechanical device under computer control. Two systems of this type have recently been put in operation: one at the Steward Observatory (Hill and Lesser, 1988) and the other at the AAT (Parry and Gray, 1986). ESO is currently discussing the procurement of an analogous facility through a joint project with the Observatory of Meudon. This will take time, however, and ESO will continue to offer the aperture plate version for the next three years.

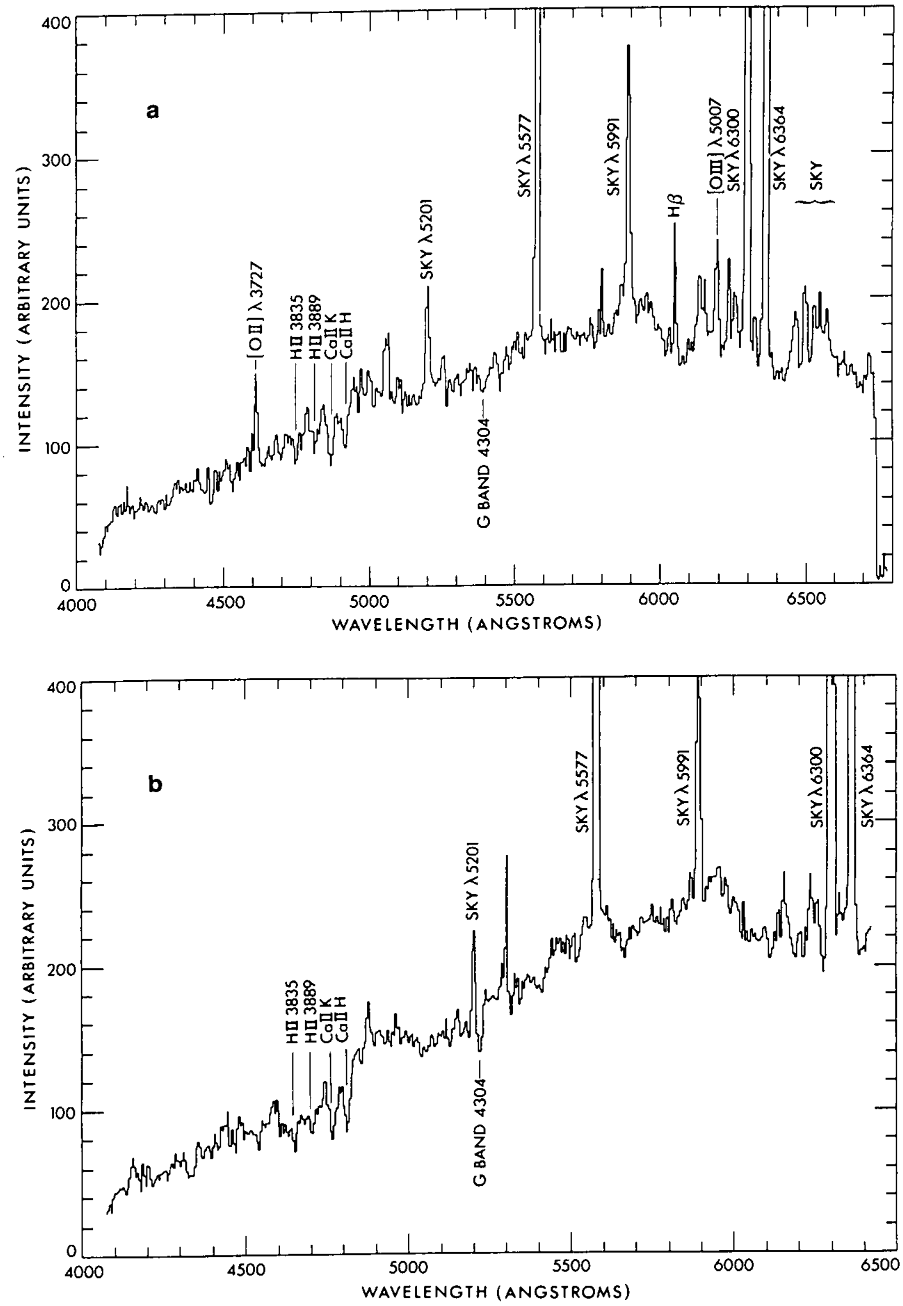

Figure 2: *Spectra of two galaxies from the average of two 30-minute OPTOPUS exposures (a: bj = 19.5, z = 0.24; b: bj = 18.4, z = 0.12). The magnitudes are COSMOS derived values for the entire galaxy from ESO-SRC J. survey plate. The sky has not been subtracted. The redshift is estimated from the H and K lines.*

3. The Observations in September 1988: Probing the Feasibility of a Faint Galaxy Redshift Survey

Two of us had obtained 4 nights of observing time with OPTOPUS to investigate the possibility to use the system for extensive surveys of galaxy redshifts at faint magnitudes (see Guzzo and Tarenghi, ESO Internal Report, October 1987). The use of an efficient fibre spectrograph would reduce by a factor of 20–30 the telescope time normally necessary for such a kind of work, while allowing on the other hand to study the galaxy distribution to much fainter limiting magnitudes than those of the deepest existing wide-angle surveys (which are presently limited to m < 15.5, see e.g. Geller et al., 1988 and Giovanelli et al., 1988). Indeed, to have 30–50 galaxies in the OPTOPUS field, one has to select a sample limited to magnitudes as faint as bj < 18.5–19 (where the magnitudes are measured from plates of the ESO-SRC sky survey, J colour): at these magnitudes the mean density of objects over the field matches the total number of fibres and the instrument can then be used at its maximum efficiency. It was a clear conclusion of the feasibility study that it would be possible to carry out the survey to such a depth at a rate of about 1.5 square degrees per night. This means that, for example, to survey a strip of 100 x 1 square degrees would take about 70 nights of 3.6-m telescope time. Here we are not going to enter into details neither on the best way to conceive such a survey, nor about the fundamental importance that its results would have for the study of the topology of the Universe and consequently for the theory of galaxy and large-scale structure formation. For an excellent discussion of these points see the review article by Rood (1989).

Before starting the run, it was planned to use the new prototype head just for a couple of nights for testing, and then shift back to the old version for the rest of the programme. After the first spectra were obtained, the improvement in efficiency was so evident that it was decided to go on with it for the whole run.

The ESO grating no. 15 was used together with the f/8 collimator and f/1.9 blue camera of the B & C spectrograph. This combination gives a dispersion of 170 Å/mm and a resolution (FWHM) around 10 Å. This dispersion is quite appropriate to study the distribution and rms velocities of galaxies, for which it is necessary to keep rms errors on cz to less than 50 km/sec. We plan to measure eventually the redshifts using cross-correlation with template spectra (generally of a bright galaxy or a K-type star): this technique permits to reach rms errors on z between 1/25 and 1/10 of the nominal resolution, depending on the S/N ratio of the spectrum. This corresponds in our case to errors in cz between 25 and 60 km/sec.

The OPTOPUS starplates were prepared in Garching in June 1988. The galaxy magnitude limited samples were extracted from a subset of the Edinburgh-Durham Southern Galaxy Catalogue (EDSGC) under completion in Edinburgh (Heydon-Dumbleton et al., 1989), kindly provided by the authors. We observed three areas of 1, 3 and 0.2 square degrees around the South Galactic Pole, all at the same declination and with right ascensions around 22 h, 00 h and 03 h, respectively. The largest region is centred on the rich cluster Klemola 44. The exposure times were usually of 60 minutes divided into two exposures for optimal cosmic-ray elimination. Three or four fibres were used during each exposure to monitor the sky spectrum, while a shorter sky exposure was observed right after each object exposure, offsetting the telescope 1 minute north. In Figure 2a, b we present two partly reduced spectra of faint galaxies in the field of Klemola 44. The sky has not yet been subtracted but its contribution in these spectra is mainly confined to the emission lines. An estimate of the accuracy with which the sky can be subtracted will have to wait for a complete reduction of our data.

The average S/N ratio in the blue-visual continuum of the spectra is around 25: with such a value the rms error on the redshift cross-correlation measurement is expected to be better than 30 km/sec. Therefore it appears that OPTOPUS with the new prototype head is already a well suited instrument for redshift surveys down to at least bj = 19–19.5.

These magnitudes are integral values for the entire galaxies which extend beyond the finite aperture of the fibres. The real fluxes collected by OPTOPUS depend on the surface brightness distribution of the objects. For point-like sources like QSOs it will certainly be possible to reach fainter limits. If we consider also that a further improvement (of the order of 10%) will come from the introduction of the F/6 collimator, we can foresee that the updated version of the OPTOPUS facility will really be one of the most efficient facilities of this kind.

It is also interesting to relate about the "mechanical" efficiency of the system, i.e. the rate of fields observable per night. We observed with 25 independent starplates during 5 actual nights of observations. This can be considered as an upper limit, as the level of technical support to this test run was particularly qualified.

A normal changeover of the starplate takes around 30 minutes. A complete exposure run of a starplate, including mounting, alignment, calibrations, flats, 30 min sky exposure and 1 h scientific exposure, takes around 130 minutes.

An OPTOPUS run at La Silla is a demanding task because of the many operations the observer is involved in: the checking of the starplates, the mounting of them in the special adaptor, the positioning of the fibres in the holes, the alignment on the field in the sky and the monitoring of the resulting CCD spectra.

All these operations have to be done accurately but quickly if you want to maximize your observing time. At times the work becomes frantic and the observer is usually exhausted at the end of a run. However, the effort is well rewarded, if one considers that we collected some 700 galaxy spectra in 5 nights! A similar number of spectra with single-object spectroscopy would have required around 50 nights!

In conclusion, it can be said that the test run with the new OPTOPUS prototype head has been very successful. First, it has shown that the partial modifications introduced in the instrument so far have already improved its efficiency. On the other hand, it has also clearly demonstrated that a large-scale survey of galaxy redshifts down to magnitudes as faint as 19 is possible, not only in the dreams of cosmologists, but is really feasible now, with the instruments we already have.

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Optics and Grisms of EFOSC 2

In the *Messenger* No. 52 the construction of a second EFOSC for the 2.2-m telescope was announced. Mechanically, EFOSC2 is virtually a copy of EFOSC but comparison of the optical data (see Table 1) shows considerable differences which for some programmes will make EFOSC2 the preferred instrument, even if it is mounted on a smaller telescope.

The optics were completed by the end of 1988 and measured in the ESO optical laboratory. The transmission of the optics is shown in Figure 1. Compared with EFOSC, the transmission has been improved by a reduction in the

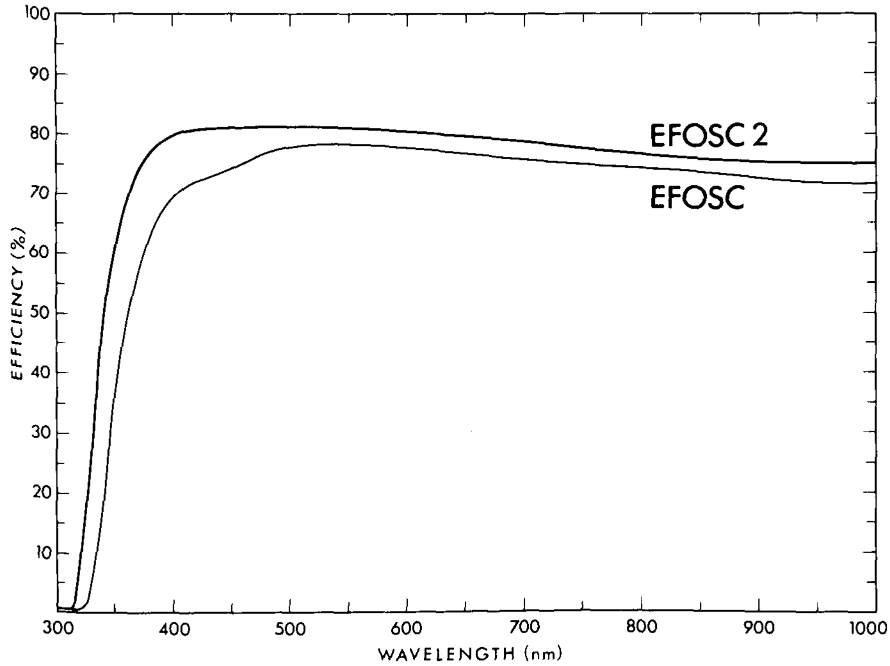


Figure 1: *Measured transmission of the optics of EFOSC and EFOSC2.*

TABLE 1: *Comparison of EFOSC and EFOSC2 optical data.*

		EFOSC/3.6-m	EFOSC2/2.2-m
Camera field (mm)		10 × 15	25 × 25 max.
Field size (arcmin.)		3.6 × 5.8	8 × 8 max.
Wavelength range (Å)		3600–10000	3300 × 10000
Camera focal length (mm)		103	195
Plate scale at CCD (µm/arcsec)		45	52
Dispersion (Å/mm)	grism	up to 120	up to 70
	echelle	55	28
Resolution with 1″ slit		up to 2200	up to 3500

TABLE 2: *Current EFOSC2 grisms.*

Grism #	Dis-persion (Å/mm)	Central wavelength (Å)	Wavelength range with TH 1024 × 1024 (Å)	Blaze wavelength (Å)	Blaze abs. efficiency (%)
1	450	4800	3300– 7000	4500	82
2	490	7000	5500–10000	6700	83
3	114	4390	3300– 5800	4000	71
4	124	5620	4100– 7200	4700	76
5	149	7090	5200– 9000	6800	73
6	153	5760	3800– 7700	5100	77

number of lens groups from 6 to 5, a careful selection of glass melts and optical cements used for the production of the optics and by shifting the reflection minimum of the single-layer MgF2 antireflection coating more to the UV. The polychromatic image quality is excellent everywhere in the 25 × 25 mm field; 80 per cent of the light is concentrated in a circle with a diameter of 20 µm (0.″4).

An initial set of grisms has also been completed; their properties are summarized in Table 2. Grisms with higher dispersion and probably also an echelle will be added when the final detector format is known.

In the second half of 1989, EFOSC2 will be used at the NTT for tests. Some scientific work will also be possible, although, because the instrument parameters were optimized for the 2.2-m, EFOSC2 tends to oversample stellar images. On the NTT the scale at the detector is 115 µm/arcsec which yields a field of 2.′9 × 2.′9 with the Thomson 1024 × 1024 chip. With grism # 3 the slit-limited resolution is 13 Å at 4400 Å with a 1″ slit.

After EMMI has been installed and tested on the NTT, EFOSC2 will be moved to the 2.2-m where it will become generally available in the course of 1990.

H. DEKKER, ESO

MIDAS Memo

ESO Image Processing Group

1. Application Developments

Now that system developments in the portable version of MIDAS have stabilized, activities in the area of applications have resumed.

The echelle package is being upgraded to minimize the number of parameters controlling the reduction sequence, and to correct some known deficiencies of the current version. The new package will also be optimized to process data from other instruments like EFOSC and Echelec.

A new package for the reduction of long-slit spectra is now being tested. This package will replace the IPCS context of the old MIDAS version.

In the portable version of MIDAS the implementation of the ROMAFOT crowded field photometry package has been completed for DEC/VMS systems. Currently an upgrade is in progress to port the package to UNIX systems. This upgrade mainly involves the complete implementation of the MIDAS table file system and is expected to be released with the 89 MAY release (see below).

Also in the portable version, the upgrade of the INVENTORY package was finalized. The documentation of the package has been updated accordingly.

A new file system has been implemented in the plot package. In the new release, MIDAS plot information will be contained in only one plotfile. This plotfile is created by the major PLOT commands and will have the name of the frame, table, keyword or descriptor that is plotted. The file extension is ".PLT". Subsequent OVERPLOT commands will append the plot file with the new plot instructions. The SHOW/PLOT command shows the user the name of the current plotfile. MIDAS will allow one version of a plot file: an old plot file with the same name as a newly created one will be deleted. In the SEND/PLOT command, as the second parameter, one can specify which plotfile is to be sent to the graphics device.

2. Data Analysis Workshop

The next Data Analysis Workshop will be held April 18–20, 1989, in the ESO headquarters. Its form will change significantly in the sense that the main emphasis will be placed on astronomical applications rather than on system related software. The first day and a half will be devoted to applications for a specific area, while the last day will be used for MIDAS and ST-ECF sessions.

This year the special topic will be analysis of two dimensional direct images including stellar/surface photometry, search for objects and classification. There will be the possibility of presenting short papers during the workshop and we encourage you to contact us if you wish to give a contribution or just participate. We expect that proceedings of the scientific sessions will be published. Our aim is to create a forum for discussions of different methods and algorithms used in image processing.

3. Portable MIDAS

The first official release of the portable MIDAS, 88NOV, was made with some delay due to verifications of the VMS installation procedure. This first version does not yet include all applications and especially only supported Gould-De-Anza IP 8500 and X-window version 10.4 display systems. It is expected that these deficiencies will be resolved in the 89MAY release which will contain the basic display software for X-window version 11 being adopted as the standard for MIDAS. From the 89MAY release the portable MIDAS will be the *only* official version of MIDAS for both UNIX and DEC/VMS systems.

4. Access to Astronomical Catalogues and Databases

A new version (2.2) of STARCAT is now available; it is accessible from the ESO computer or remotely through networks. Here are some new features of this version:

- astronomical catalogues can be queried by a target radius and position. The position may be specified in many coordinate systems (equatorial at any equinox, galactic, supergalactic, ecliptic);
- J2000 coordinates are computed and listed for every catalogue;
- the result of any query can be stored as a MIDAS table, or as a plain ASCII file;
- remote connections now include IUE-Vilspa, SIMBAD, and EXOSAT (ESTEC) but are only available for local ESO users.

About 30 astronomical catalogues are available on-line, with complete on-line documentation. Among the most recently incorporated ones are for example the new version (1988) of Abell's catalogue of clusters of galaxies, and the most recent version of the catalogue of White Dwarfs (McCook and Sion, 1987).

The same STARCAT interface will be used for the future catalogue of the ESO Archive.

5. Measuring Machine Facility

The central computer of the Measuring Machine Facility is being replaced by a Stellar GS-1000 system. The decision was made after extensive MIDAS benchmarks giving it the best price/performance. The system will be able to analyse the scans of full Schmidt plates which the upgraded OPTRONICS machine is expected to perform later this year. The Stellar GS-1000 system runs a UNIX-like operating system and has an X-window system version 11 for display. It will run MIDAS for reductions of measuring machine data and be connected to the central computers through Ethernet using TCP/IP protocols.

6. AIPS-MIDAS Agreement

An increasing number of astronomers are using observations in several wavelength regions (e.g., optical, infrared, and radio) in their research. In general, different data reduction software packages are used for the different wavelength regions. Also different software packages have different capabilities, strengths, and weaknesses. It is therefore important to ease the transfer of data between image processing systems. As a first step in this direction, AIPS and MIDAS have agreed to write FITS files on disk with identicial specifications. This will enable users of these systems to exchange data files much faster via disk instead of passing through a magnetic tape. AIPS already conforms to the agreement while MIDAS will implement it as of the 89MAY release.

The agreement specifies that FITS disk files have a record size of 2880 bytes, which is the standard FITS logical record length. There shall be no "extra" bytes in a record, such as those used to specify variable lengths on some systems. In this way, FITS disk files may be passed between different operating systems through networks with no ambiguity. The use of a 2880-byte record implies that reading programmes are not required to reblock the data into logical records, although packages such as AIPS and MIDAS can be expected to have that capability in future.

7. MIDAS Hot-Line Service

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

- EARN: MIDAS@DGAESO51
- SPAN: ESOMC1::MIDAS
- Tlx.: 52828222 eso d, attn.: MIDAS HOT-LINE
- Fax.: +49-89-3202362, attn.: MIDAS HOT-LINE
- Tel.: +49-89-32006-456

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

Institutes which would like to use the MIDAS system should submit a MIDAS Request Form to the Image Processing Group. This form can be obtained through the HOT-LINE service.

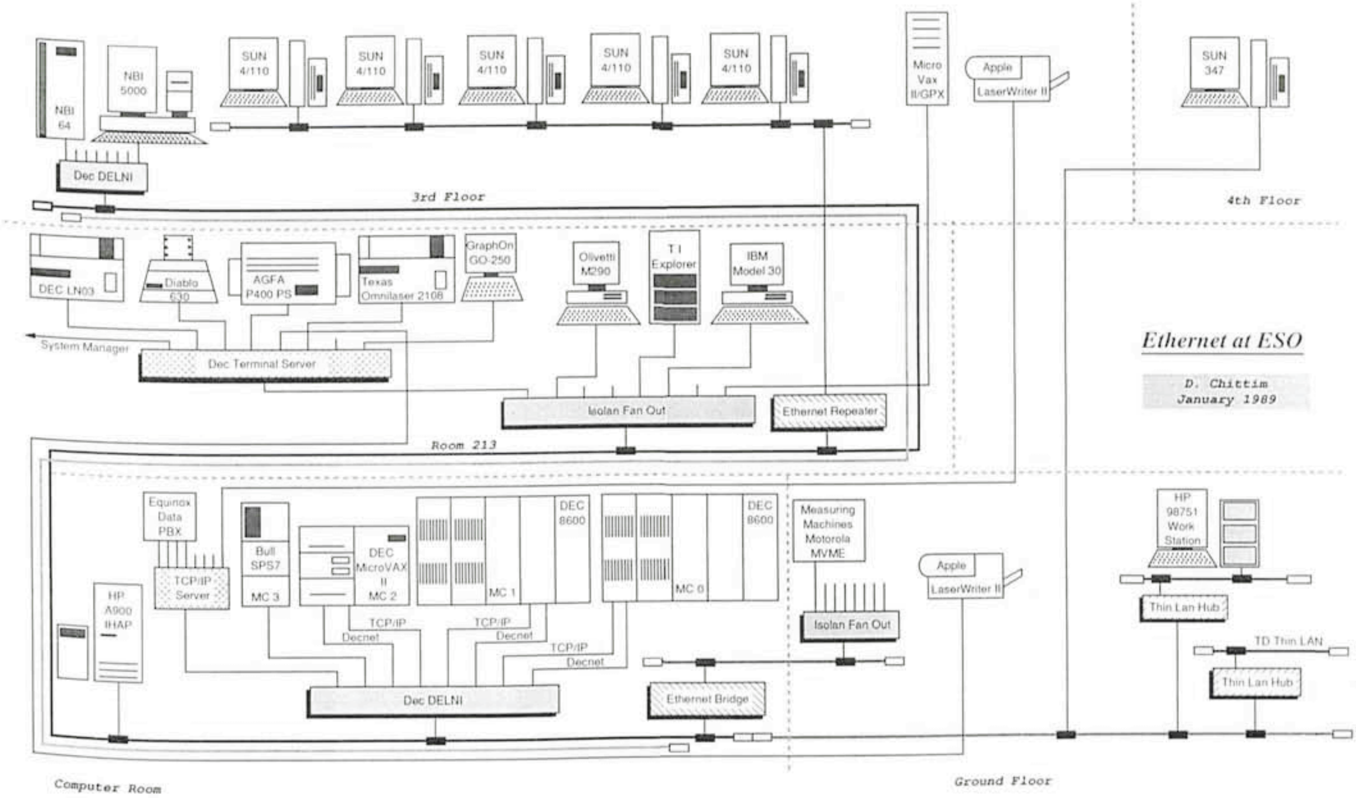
Ethernet at ESO Headquarters

D. CHITTIM, Benney Electronics, ESO

Ethernet is a cable used with associated software packages for connecting computer equipment throughout a building. It has the advantage that equipment can be connected along its length at almost any point. Due to the high data transmission speeds involved, ethernet is most suitable for computer-to-computer communications although terminals can be connected onto it if necessary.

Since the initial installation of ethernet at the ESO Headquarters two years ago, the system has grown steadily. There are now only a few areas of the building which are not close to the network. The system consists of both "Thick Ethernet", which uses an expensive co-ax cable which is almost immune to electrical interference and a thinner cable which is more susceptible to interference but cheaper (hence it's nickname "Cheapernet").

– The main ethernet cable can be five



hundred metres long but may be extended by using a "repeater".

– Each device may be no more than fifty metres from the cable.

– Each device or "node" on the network has a unique address. When data is transmitted it is preceded by the address to which is has to be sent. Each device checks the address and will take action only if the data is for that particular device.

– The small black rectangles shown along the length of the cables are Medium Attachment Units (MAU). These pierce the outher shield of the cable and make contact with the inner conductor. (In the case of "cheapernet" this is done with plugs and sockets).

– Equipment can be connected directly to a MAU or through a "fan out" unit. The latter can either be a DEC DELNI box or an "Isolan" equivalent; both, however, perform the function of splitting the connection eight ways.

– The terminal servers provide eight serial (RS 232) interfaces directly onto ethernet. One supports the TCP/IP protocol, the other supports DECNET.

– The "ethernet repeater" serves mainly as a connection between two ethernet cable segments whose ends are inaccessible Networks connected by a repeater and can be considered to be a single unit. It can also provide an interface between a thick ethernet and a "cheapernet".

– The "ethernet bridge" is similar to a repeater, but it can translate one protocol into another. It is also used to separate a network carrying relatively little traffic from a heavily used one.

– A thin lan hub gives the possibility of connecting a thick ethernet cable to up to four thin ethernet cables.

– Both ends of every cable must be terminated with 50 ohms.

– Two cables to the Vaxes are required at the moment, one is used for the interface supporting the TCP/IP protocol, the other is used for Decnet communications. An increasing number of devices on the market now support TCP/IP and only these will be purchased in future.

– The Technical Division (TD) "cheapernet" has many devices connected to it including HP computers, test devices and VME chassis.

Changes to the configuration are made quite frequently, and it is possible that this diagram will be slightly incorrect by the time it is published, but if sufficient interest is shown I will produce updated diagrams from time to time.

My thanks go to Preben Grosbøl and Charlie Ounnas for their constructive comments.

EARTH AT NIGHT

In the caption to the reproduction **Earth at Night** (see *The Messenger* No. 54, p. 15) there was unfortunately no mention that the reproduction was made from a wall chart of Hansen Planetarium.

Earth at Night (23″ × 35″) is available from Hansen Publications, 1098 South 200 West, Salt Lake City, Utah 84101 (FAX-801-538-2249). Price $ 6.00 + $ 1.50 shipping. Wholesale pricing available on request.

NEW ESO PROCEEDINGS AVAILABLE

The Proceedings of the ESO Conference on

Very Large Telescopes and their Instrumentation

held from 21 to 24 March 1988 in Garching, were published in late 1988. The Proceedings, which contain a total of 1334 pages, are divided into two volumes and are sold at a price of DM 95.–. This price includes packing and postage (surface mail) and has to be prepaid.

Payments have to be made to the ESO bank account 2102002 with Commerzbank München or by cheque, addressed to the attention of
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Please do not forget to indicate your full address and the title of the Proceedings.

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

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EUROPEAN
SOUTHERN OBSERVATORY
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München
Fed. Rep. of Germany
Tel. (089) 32006-0
Telex 5-28282-0 eo d
Telefax: (089) 3202362
Bitnet address: IPS@DGAESO51

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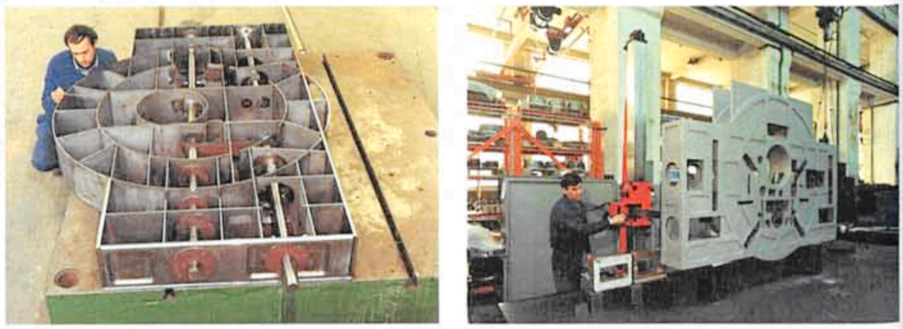

A Slice of Swiss Cheese Made Out of Steel . . .

is suggestive of the main supporting structure of the EMMI spectrograph/imager for the NTT shown in these two photographs taken at two phases of the manufacturing at the De Pretto-Escher Wyss factory in Schio, Italy. The left-hand picture, taken before welding of the covering plate, shows the inner structure with the complex net of ribs to increase the rigidity. The long poles were inserted temporarily to align the apertures. The right-hand picture shows the welded, cleaned piece mounted on a measuring machine for the check of the dimensions. The openings correspond to the main optical components to be inserted: collimators, filter and grism wheels, folding mirrors, etc.

The dimensions of EMMI's main structure are 240 cm in length, 160 in height and 28 only in depth; the weight is about 800 kg.

The structure will arrive at ESO in February. Mounting of the different functions (now being integrated and tested in Garching) on the main body and testing of the overall instrument will take place within the summer of this year.

S. D'ODORICO, ESO

Contents