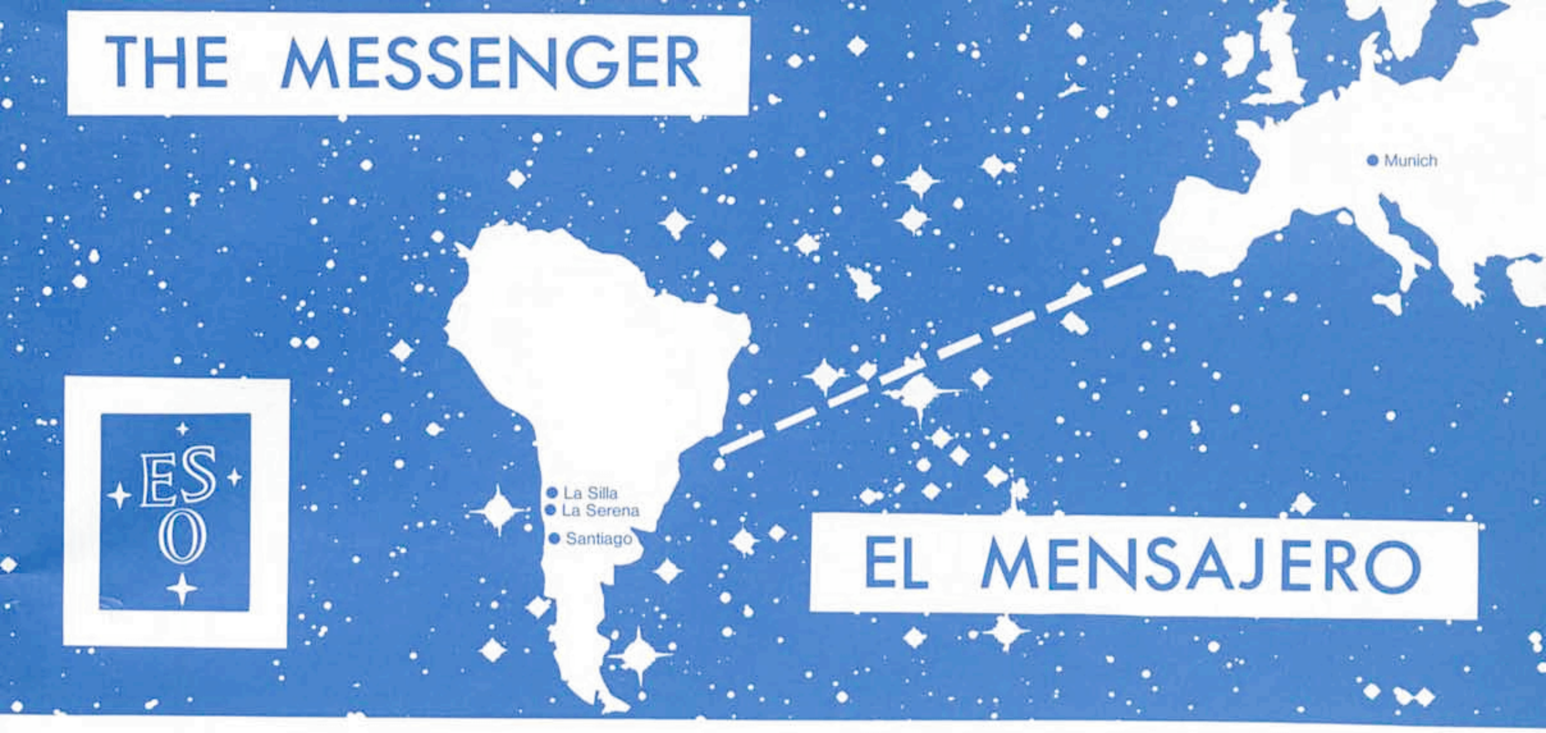


No. 27 – March 1982

Switzerland, Member of ESO . . .

On March 1, 1982, the Federal Council of Switzerland submitted its signed ESO membership document to the French Foreign Ministry (where the ESO documents are kept). With this act Switzerland's ESO membership becomes effective.

This brings to a happy end a complex development which began sixteen years ago, when the Swiss Council for Science Policy recommended that Switzerland should build its own observatory on Gornergrat above Zermatt. When it was realized that this project posed several unsurmountable problems, Swiss astronomers joined forces to work toward Switzerland's becoming a member of ESO. The momentum in this direction grew through the subsequent recommendation of the Swiss Council of Science Policy (1972) and the erection of the Geneva telescope on La Silla (approved by the ESO Council in 1975, and reluctantly again in 1977).

In 1979, direct talks between Swiss government representatives and the Director-General of ESO, as well as contacts between the Italian and Swiss governments culminated in the acceptance by the ESO Council of Switzerland and Italy as new member countries (March 1980).

The driving forces within Switzerland became more and more the Federal Office for Education and Science and the Foreign Ministry. The latter drew up a message to Parliament, which was approved by the Federal Council in December 1980, and which was adopted by the two Chambers, without an opposing vote, in June and September, respectively, of the following year. After a three-month referendum period, which was not used, the Federal Council put its final signature on the ESO document on February 3, 1982.

Switzerland will pay an entrance fee of about 5 million Swiss francs and an annual contribution of about 2 million Swiss francs. It is planned to use the Swiss entrance fee together with the Italian one for the construction of a new telescope on La Silla to meet the increased demand on the already heavily loaded telescopes.

The Federal Council has named Dr. Peter Creola from the Foreign Ministry and Prof. Marcel Golay from the Geneva Observatory as Delegates to the ESO Council, with Mr. C. Peter from the Federal Office for Education and Science as an advisor. The ESO Council has appointed Prof. G. A. Tammann of the Basel Observatory into the Scientific/Technical Committee. The Swiss members of the Finance Committee, the Observing Programmes Committee, and the User's Committee are still to be named.

Felix, faustum, fortunatumque sit! G. A. T.

. . . and Italy will Follow Soon

At the moment of going to press we are informed that the Italian Parliament on March 2, 1982 definitely approved the adhesion of Italy to ESO. Italy will become a member of ESO as soon as the document of adhesion is deposited with the French Ministry of Foreign Affairs. We welcome this imminent happy event.

The ESO Scientific and Technical Committee

P. Léna, Observatoire de Meudon, Chairman of the STC

Since 1978, the structure of ESO involves a Scientific and Technical Committee (STC) which advises the Council on scientific and technical matters. This committee meets twice a year, usually at Garching; its members are nominated by the Council and their term is 4 years. The STC has 10 members, who are as evenly distributed as possible among member countries, although indeed mainly chosen for their scientific abilities. The chairman is invited to attend Council meetings and to report to the members.

In the three past years, the STC has essentially dealt with prospective activities, a role fairly similar in this respect to the one played within the European Space Agency by the Astronomy Working Group. Important decisions, such as to implement two new telescopes (3.5 m NTT and 2.2 m) at La Silla, or to house the European Coordinating Facility of the Space Telescope, were taken by the Council. Given the growing complexity of astronomy with respect to instruments as well as to telescopes, the STC should relay the wishes, needs and various competences of the European community: e. g. for the NTT project, the main options such as telescope design, focal plane configuration, mode of operation, instrumentation, optimization with respect to the 3.6 m use are currently discussed.

Another task of the STC is to follow the progress of ESO built-in instrumentation. Given the long lead-time of such projects—even worse in the past two years due to the move to Garching—the work here is very prospective indeed, and is usually substantiated by workshops. To propose such meetings at European scale, in close cooperation with the ESO staff, is an initiative often taken by STC members who, here also, may channel wishes and needs of the community (a few examples in the past years: Abundance Determination for Stars, Two-Dimensional Photometry, Infrared Astronomy . . .). Among instruments, let us mention the new IRSPEC cryogenic spectrograph born at the first ESO infrared workshop held in Utö (Sweden) in 1978. It will only be in one or two years that the STC will be able to resume a new development phase, once the current set of instruments under construction is completed. The purchase of expensive items, such as array detectors, computers . . . is also being discussed by the STC who has to approve it. Another prospective and important subject in the past two years has been the preliminary study for the Very Large Telescope (VLT): the matter is important as it is clearly illustrated by the successive conferences (Geneva 1976, Tucson 1980, Garching 1981, Tucson 1982) being held and by the very broad range of options under discussion. It is clear that ESO, with the backing of almost the whole Europe, can play there a significant role. Apart from the full support given by the STC to the Garching Conference, the matter is discussed regularly: Among other crucial issues which will need a continuing debate, is the spatial interferometry and coherence capability of such a large venture. Given the growing costs of astronomical projects, the variety of options (visible, IR, radio, space), it becomes difficult to make sound choices in a context of economic difficulties. The STC should be the right place to reflect the will and opinions of European astronomers.

Apart from STC members' personal experience, the day-to-day life of ESO, especially at La Silla, is less reflected in the STC concerns, leaving this heavy responsibility to the Director-General advised by the Users Committee and the Observing Programmes Committee. The situation might be different if some STC meetings could occur at La Silla or if the director at La Silla could attend STC meetings, a less expensive proposal I made at the last Council meeting.

As emphasized in this brief report, I believe that the STC is already and should be in the future a place of confrontation of ideas and options, even if they appear sometimes as very unorthodox, as the debate on whether ESO should build a mm radio telescope at La Silla, use concrete spherical mounts for the NTT or operate telescopes in Chile in a completely remote manner.

Social Activity in the Outer Atmosphere of La Silla

Sonia Rodríguez-Larraín, ESO, La Silla

Who would believe that there exists another form of life—a social life—in this dark nebula of El Norte Chico? One would immediately assume that in an environment where noise, lights, wine and other types of pollution have been banned deliberately, the swinging species could not evolve in their party-going and mirth. That the sole survivors could only be those vague, unworldly non-drinkers, whose only concern is to generate work and publish it.

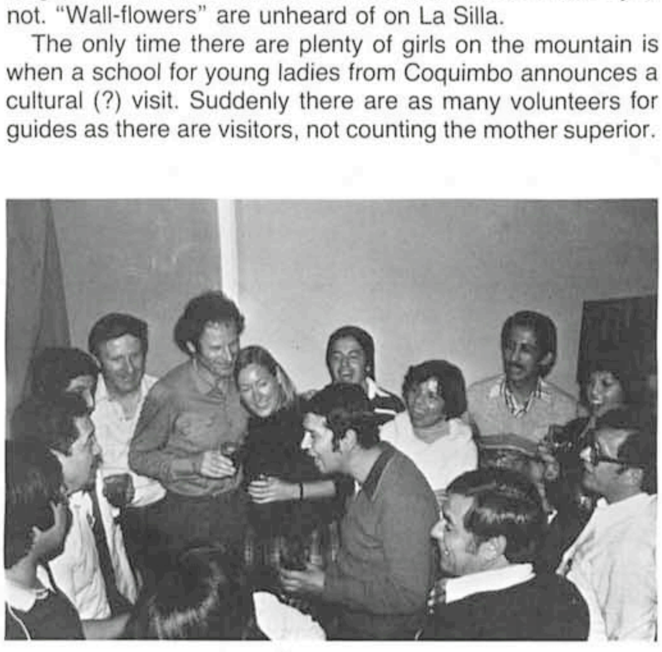
And yet... wrong. The will to enjoy life's more mundane side is not in quiescence for all in this Observatory. The fittest have managed to survive.

The first sign that not all is as prosaic as one would tend to believe in these austere surroundings is the pass-word: "the Bar is open". Certainly those words are not lacking in poetic beauty. Surely that is what is meant by "preparing for the night ahead".

The Bar is a tradition that has survived despite the fact that it is frequented by very few steadies and plenty of new-comers. Any reason is good enough to open the Bar: going on home-leave, getting a new contract, getting a new hair-cut . . .

And while on the subject of traditions and new-comers, it is a Chilean custom that within a month's time of being hired, the new employee has to *pagar el piso* and invite his new colleagues to show what a great pal he is going to turn out to be. These social gatherings normally take place at the beginning of a *turno* since provisions start running low as the days go by. Good music, great dancers, plenty of provisions. It's all there, except for the fact that La Silla is rather short on girls. Let's admit it, there are only half a dozen and all are not always on the mountain at the same time. Yet if you look at it from another angle, this handicap has its advantages. No girl can possibly feel she is left out, or that she is not popular enough. She is absolutely guaranteed, at every party, that she will not miss a single dance. Not a chance. Whether she wants it that way or not. "Wall-flowers" are unheard of on La Silla.

The only time there are plenty of girls on the mountain is when a school for young ladies from Coquimbo announces a cultural (?) visit. Suddenly there are as many volunteers for guides as there are visitors, not counting the mother superior.



"Si vas para Chile" . . .

If at tea-time too much joking and giggling are heard from one table it can only mean that the guide has digressed from the passionate topic of astronomy and has launched into more personal matters with the young ladies. *Un amigo* will usually bring him back to inner space by telling him in a loud voice: "Your wife just phoned, she will be at your mother-in-law's with the children this afternoon." The room is filled with disappointed groans and giggles reach maximum peak. "Oh Death, where is thy sting?"

Incidentally, there is a Drama Group on the mountain and they are most enthousiastic about their personal production of *"Il Barbiere di La Silla"*. The actors, all extremely talented buffoons, adapt their lines with very local terminology as they go along, sometimes producing such hysterical situations that rehearsals have to be stopped until everyone pulls himself together again. At this pace, opening night will not probably be before Christmas 198? but, then, there is no real hurry.

With all this conviviality, and the starry nights and the moon shining so bright, romance is bound to put in an appearance from time to time, and so it does. Several couples have met while working on the mountain and actually owe their married bliss to La Silla. The first marriages date as far back as when they were dynamiting the site to construct the 3.6-m. In this romantic setting, a young and dashing Dutch constructor fell passionately in love with a delicate desert flower who'd come to work on the standard materials catalogue. They were married almost instantly. Soon afterwards a galant French mechanics technician from St.-Chamond declared his love to a pretty, young secretary and was immediately accepted; they were also promptly married and off they moved to Instanbul.

In fact, since the times of site-hunting, twelve unpremeditating internationals, whose only motive for coming to Chile was a contract with ESO, have already walked down the aisle with their Chilean brides or are on the verge of signing this more permanent type of contract. Some have not made it yet, but they don't lose hope. Evidently, the forces of the stars do cast a tantalizing spell over the more assailable benedicks from abroad.

But even for those who are always in a mental fog when it comes to romancing, La Silla is a great place to meet people and make friends, particularly so for the more shy types who have a hard time communicating with others. At meal times people are just bound to meet and talk. For the super-shy who wish to be around people but avoid the talking, we recommend the jogging team. This team is a silent group who rush about the Observatory at hypersonic speed in the early hours, while the more sedentary are just getting into, or out of, bed.

All Departments on La Silla have their Baby-Football teams to be proud of. Each team plays with five mighty "cracks" who look very professional in their spotless uniforms out on the concrete field. All the teams have their fans and cheer-leaders, so considerable thought goes into choosing the appropriate names that will symbolize them with vehemence. Hence, we have the "Come Fierros" (Lead-Chewers) from the Astroworkshop; the "Super H.P.". (Super Horse-Power) from Construction and Maintenance; the "Troncales" (old tree trunks too heavy to move) from the Warehouse and Maintenance, the "OVNIs" (UFOs) from Administration; the "P.P.Q.P." from Electronics (better not translate this one); the "Condores" from the Hotel and Kitchen Staff and "Astronomía" from Astronomy.

The first team was founded 15 years ago and since then the football season has been the main recreative event on La Silla. Unfortunately for want of a well-lit indoor gym, the season is very short. Games are only played after work and they rely on day-light only. The first game is played on October 1st when daylight is prolonged by one hour. Each team works hard to enter the championship, win it and take possession of the cup that is awarded. This much coveted trophy is usually donated by a prominent staff member or an ESO supplier; such is the case of the famous "Dr. Muller Cup", which had to be won three consecutive times before the winning team could keep it. The *Club Deportivo* is the public relations manager and makes sure the press know all about the tournament events. T.V. La Serena has been at La Silla for the closing games of two seasons now.

The Volley-Ball team was recently born at a pic-nic in El Beño water hole. This is La Silla's own "national park" just 15 minutes drive on the road to Pelícano. The occasion was due to many Garching visitors being on the site and this, naturally, called for some special celebration. So written invitations were issued and, after work, the Sunday cold-buffet dinner was transferred to El Beño. The Volley-Ball net was set up and the game was well on its way even before everyone had arrived. Others, less sports-oriented, attached a casette player to the battery of a car and there was music for those who wanted to dance amid the stones and lizards. The general comment afterwards was unanimous: We should have picnics more often.

Still, there are times when not everybody can leave the mountain, so at Christmas and New Year the families of those on duty are invited to come and spend the holidays on La Silla. Meal-times are full of childish chatter—which is a welcome change from the scientific chatter normally going on—the consumption of ice-cream really soars up and, for two days, the soft-drink machine works non-stop. It is said that everyone should enter the New Year in a happy state, so the no-alcohol ("ley-seca") restriction is un-officially countermanded that evening; and as long as there is no more car driving once the party goes into proper motion, ESO will, obligingly, turn all eyes to the telescopes.

So we find that the efforts to sustain a social life in these adverse conditions are not completely futile. Apparently, the fittest could thrive in a black hole given a chance. It is only on those weekends—which seem to drag on forever—when the morale is at its lowest ebb, that the fittest begin to explore their capacities for endurance and ask themselves: "Why do I feel like going down today?"

Tentative Time-table of Council Sessions and Committee Meetings in 1982

May 4	Users Committee
May 5	Scientific and Technical Committee
May 6–7	Finance Committee
May 7	Committee of Council
May 24–25	Observing Programmes Committee
May 26	Council
November 9	Scientific and Technical Committee
Nov. 10–11	Finance Committee
November 12	Committee of Council
Nov. 30–Dec. 1	Observing Programmes Committee
December 2–3	Council

New Telephone Numbers for ESO-Chile

Please note that the telephone numbers for ESO in Chile have changed. The new numbers are:

La Silla Observatory: Santiago 88757
La Serena 213832
Office Santiago: 2285006
Office La Serena: 212882

Contracting Members of Double Stars

Peter Lindroos, Stockholm Observatory

Introduction

Stars which are so young that they are still contracting and have not yet reached the main sequence are called pre-main-sequence stars or pms stars. Observationally it is possible to distinguish between several categories of pms stars representing different kinds of stars and phases of evolution. An important and very well observed (though not well understood) group of such stars are the T-Tauri stars. They are generally found close to the interstellar clouds in which they were born, and compared to normal older stars they exhibit several peculiarities such as: irregular light variations, strong emission lines, high lithium abundance and excess emission both at ultraviolet and infrared wavelengths. If one determines the luminosities and surface temperatures for T-Tauri stars and plots them in an HR-diagram (such as Fig. 1) one finds that they occupy a region well above the main sequence. This location coincides with theoretical evolutionary tracks for contracting stars with masses of about 1 solar mass, calculated by Iben. Iben's models which are the ones which best agree with the latest observations of pms stars also show that the T-Tauri are younger than a few million years. Because their masses appear to be about that of the sun we identify the T-Tauri stars as the progenitors of solar-type stars.

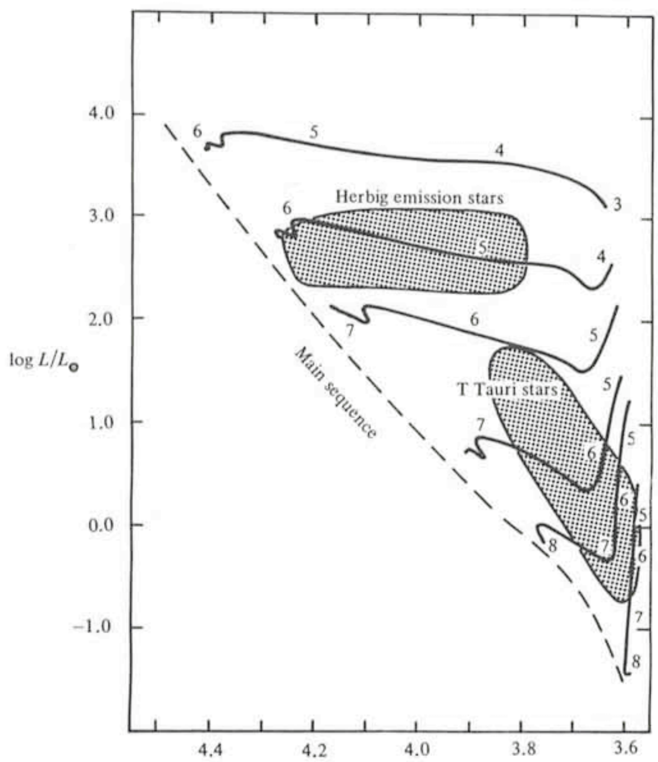


Fig. 1: *Evolutionary tracks in the HR diagram for theoretical models of stars contracting towards the ZAMS calculated by Iben. From bottom to top the tracks are for models with masses of 0.5, 1, 1.5, 3, 5 and 9 solar masses. Numbers along the tracks indicate the logarithm of the age at that point. The shaded areas show the location of two types of pre-main-sequence stars, the high-mass Herbig emission stars and the low-mass T-Tauri stars. (From Frontiers of Astrophysics, Harvard University Press.)*

The mass and age for pms stars can only be determined as above by comparing with the theoretical models, and the uncertainties in the derived values for individual stars are large. The reasons for this are several: the distances to these stars are not well known, so the luminosities are uncertain; the effective temperatures are uncertain; the models themselves are idealized and the position in the HR diagram of the evolutionary tracks and isochrones depend on the chosen chemical composition and mixing length parameter, etc. It is one of the aims of this investigation to test the theoretical isochrones by determining the ages of pms stars in an independent way and circumventing the other difficulties.

The Programme

Since the stars are born in interstellar clouds it is natural that the youngest are found (and searched for) in or close to nebulae. Many young stars are also found in the general star field, however. Obvious examples of such stars are hot main-sequence stars of spectral type B, which, as we shall see below, only have lifetimes of a few million to 300 million years. In general we do of course expect even the young field stars to be somewhat older and more evolved than stars associated with nebulae and therefore it is likely that the youngest solar-type stars we find there have already evolved through the T-Tauri phase. If so, the peculiarities by which they are identified as pms stars would be less pronounced or even absent and their discovery very difficult. Nevertheless, the main goal of this programme has been to detect such stars and to investigate their properties.

To achieve this goal a very special type of stars was selected as pms candidates. The candidates are faint secondary components of visual double stars with primary components of spectral type B. The reasons for this choice were the following: The rate of stellar evolution is very sensitive to the mass. The more massive a star is the more rapid its evolution and the shorter its life. A one-solar-mass star spends about 50 million years on its way down to the ZAMS and then stays 10 billion years at the main-sequence. For a nine-solar-mass star the corresponding numbers are 1 million years and 20 million years respectively. The whole life of a massive star can thus be shorter than the contraction time for a low-mass star. From this it is clear that all massive main-sequence stars that are observed on the sky must be of fairly recent origin. Suppose now that a double star is formed with one component (the primary) much more massive than the other (the secondary). If the mass difference is large enough the primary will reach the main-sequence while the secondary is still in the phase of contraction. If the masses differ by more than a factor of about 7 both stars will actually never be simultaneously at the main-sequence because then the primary's lifetime is shorter than the secondary's contraction time. Table 1 shows examples of such pairs and also lifetimes and contraction times for different stellar masses. If we require the primary to be a B-type star on the main sequence the chances are high that the double-star system is so young that a low-mass companion is still contracting or has just reached the ZAMS.

Guided by these considerations, more than 250 visual double stars with B-type primaries were selected for a spectroscopic and photometric survey. Figures 2 and 3 show how the systems are distributed over separation and magnitude difference. To ensure that the secondaries would be solar-type

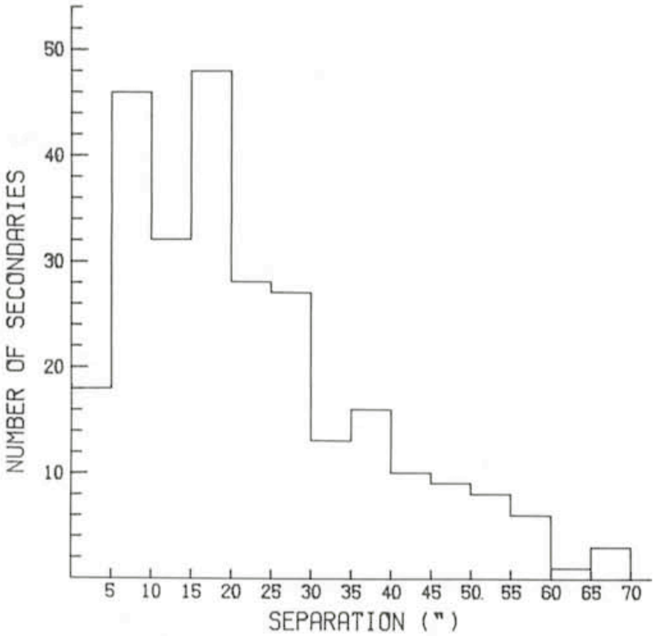


Fig. 2: *The distribution of the components separation. To avoid likely optical systems very few double stars with separations larger than 60" were included.*

stars rather close to the main sequence we also favoured systems with large magnitude differences. Most of the observations have been conducted at ESO, La Silla, with the following telescopes: Danish 50-cm, ESO 50-cm, 1-m and 1.52-m. The author has conducted the photometric part and Dr. Gahm the spectroscopic part of the programme.

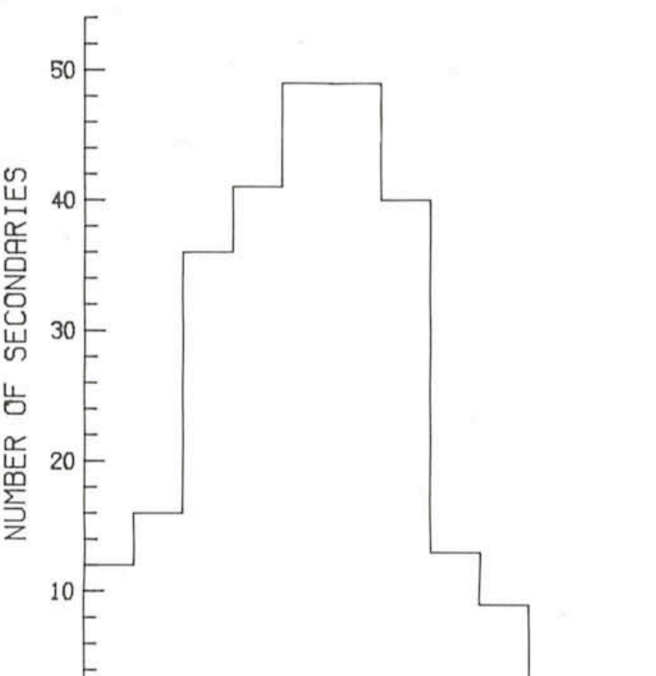


Fig. 3: *The distribution of the components magnitude difference. The small numer of systems with nearly equal brightness is due to the fact that we favoured large magnitude differences in order to find low-mass secondaries.*

The Primaries

As was discussed above, double stars with B-type primaries were selected to ensure that the stars were young. However, B-type stars also offer some other advantages: Many are bright on the sky which makes the observations easy and of high quality. Furthermore, from uvbyβ photometry it is possible to determine several important parameters such as interstellar reddening, effective temperatures and absolute magnitudes. These are in turn used for deriving the distance and age of the star. The primaries are very important in this investigation since it is from them that the distance and age of the secondaries are obtained. To derive the age (and also the mass) of the primary we employed the evolutionary tracks and isochrones calculated recently by Hejlesen for main-sequence stars leaving the ZAMS. From Fig. 4, which shows the positions of our primaries relative to the isochrones, it can be seen that almost all are younger than 200 million years and that many are younger than the contraction times of solar-type stars.

The Secondaries

Double stars are very common phenomena. The sun is actually rather unique in being a single star. Despite this, many of the double stars seen on the sky are optical pairs where two stars just happen to lie along the same line of sight as seen from

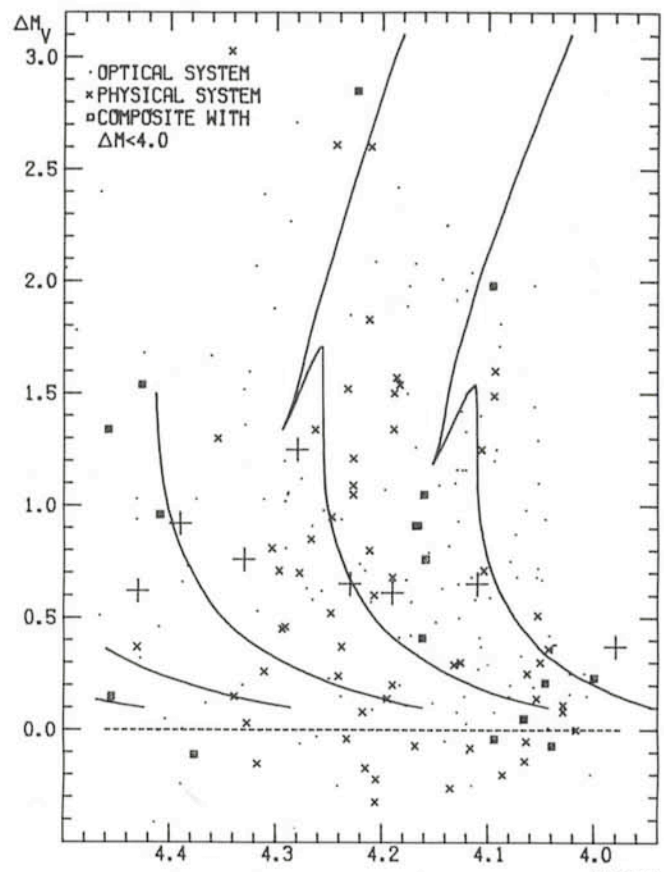


Fig. 4: *The positions of the primaries relative to the isochrones calculated by Hejlesen for model stars leaving the ZAMS. The isochrones are, from left to right, for ages of 1, 3, 10, 32 and 100 million years. The ZAMS is the dashed horizontal line. The horizontal scale is the surface temperature and the vertical scale is the difference in the absolute magnitude between the star and the ZAMS. As a star evolves from the ZAMS its brightness increases while the surface temperature decreases. The large "+" signs indicate the average positions of main-sequence stars.*

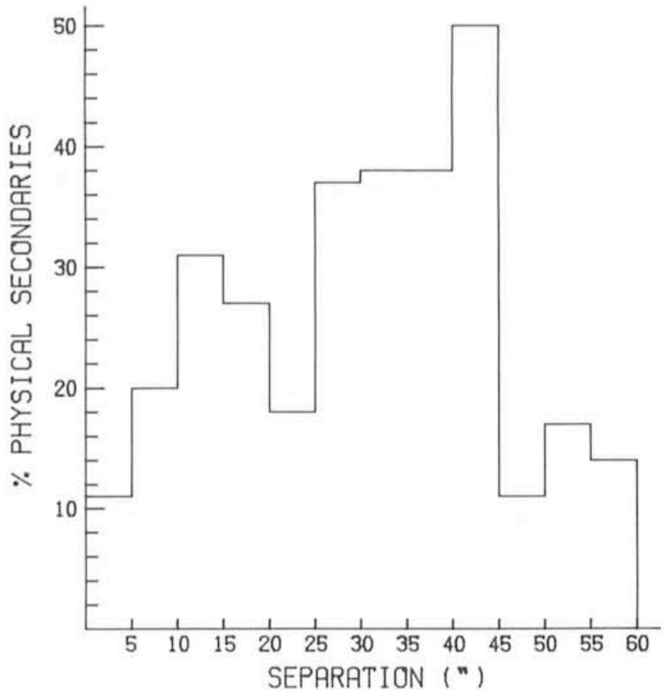


Fig. 5: *The fraction of physical double stars in different intervals of separation. It is surprising that the percentage of physical systems decreases rather than increases towards smaller separation.*

the earth. Optical pairs are of course uninteresting for our investigation and their inclusion could lead to erroneous results. The probability that a double star is optical increases with separation and magnitude difference between the components. In order to exclude systems which very likely are optical we concentrated our study to systems with separations less than 60″. Yet, because of the large magnitude differences many of the systems must be optical and therefore the first step in the analysis of the secondaries was to identify those and reject them from the remaining investigation. To decide if a pair is optical several criteria were used and a system was classified as optical if one of them was fulfilled. The criteria used can be summarized as follows: the components have different radial velocity, they have different interstellar reddening, the secondary is too faint or bright to be at the same distance as the primary.

These criteria proved to be very powerful. Only 70 secondaries or 26 % were retained as physical companions. The majority of them are of spectral types F, G or K, so we succeeded in identifying young low-mass stars. The percentage of physical secondaries in different separation intervals is shown in Fig. 5. It turns out that the fraction of physical pairs is very small not only for the larger separations but also for the smaller ones, say less than 10″. The latter is remarkable since it is naturally expected and also observed for double stars in general that the frequency of physical pairs strongly increases with decreasing separation. This unexpected result may reflect how the true separations for systems like these are distributed. Small apparent separations in general also means small true separations and it therefore appears that systems like ours, i. e. with large mass difference, have large orbits. An intuitive explanation of this is that the massive primary which evolves much more quickly to the ZAMS disturbs the surrounding medium so much that the formation of low-mass companions is prevented within a certain radius. The decline of physical pairs sets in at an apparent separation of about 10″ which at the typical distances of these stars corresponds to a projected separation of a few thousand astronomical units. Support for

Table 1. Double stars for which the primary's lifetime at the main sequence (t_{ms}) equals the secondary's contraction time to the ZAMS.

Primary			Secondary	
Sp	Mass	t_{ms}	Mass	Sp
07	30	4.90×10^6	2.5	B7
09	15	1.04×10^7	2.0	A0
B0.5	9	2.21×10^7	1.3	F0
B2	5	6.68×10^7	0.9	G5
B5	3	2.42×10^8	0.4	M0

this explanation also comes from the distribution of the physical systems over the projected separation, Fig. 6. The number of systems first increases as expected towards smaller separation, then levels off and finally drops at separations below 1,000 A.U.

The projected separation is less than 15,000 A.U. for 90 % of the systems. Statistically this corresponds to an orbit with a semimajor axis of less than 24,000 A.U. The orbits are generally quite large and even for the smaller ones the period of revolution is more than a thousand years and therefore it is unfortunately impossible to derive the masses of the stars by studying the orbital motion.

Contracting Secondaries

The members of a double star are most certainly born at the same time. Therefore the ages that we determined for the primaries also apply to secondaries. By comparing the theoretical contraction time to the ZAMS calculated by Iben for stars of different masses with the ages of our secondaries it was found that 38 were so young that they should not yet have reached the ZAMS. In the HR diagram we expect these contracting stars to fall above the ZAMS and as can be seen in Fig. 7 this is also the case. The typical height above the observed ZAMS for these stars is almost one magnitude compared to only 0.3 magnitude for the older ones. The spectral types for all the contracting secondaries are later than A0 and this means that 70 % of the late-type secondaries are contracting.

The ages and positions in the HR diagram for our stars can be compared with the isochrones calculated by Iben. The result is that all our secondaries more massive than one solar mass are several million years older than predicted by the isochrones. This indicates that the isochrones of the main-sequence models do not agree with those of the pre-main-sequence models. If we believe in the former models (after all main-sequence stars are better understood than pms stars) it means that the currently used contraction times are underestimated. In that case still more of our secondaries could be in the

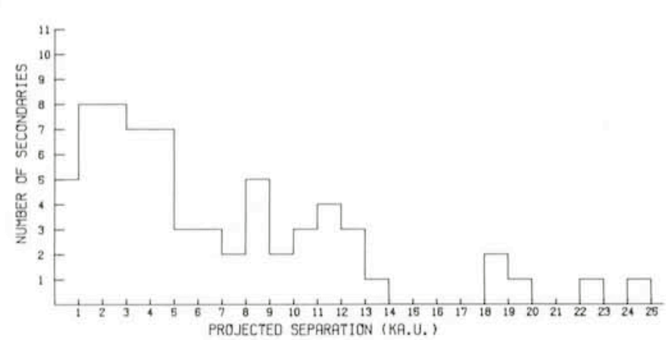


Fig. 6: *The distribution of the projected separations in units of 1,000 A.U.*

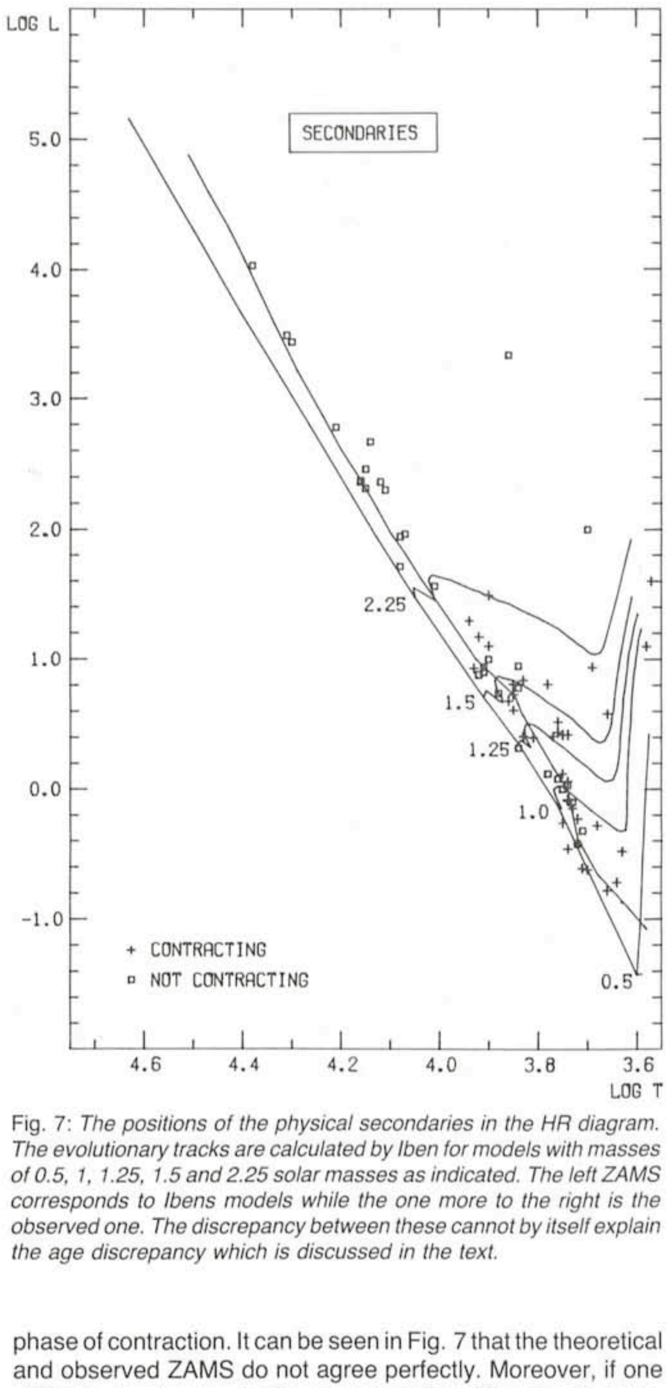


Fig. 7: *The positions of the physical secondaries in the HR diagram. The evolutionary tracks are calculated by Iben for models with masses of 0.5, 1, 1.25, 1.5 and 2.25 solar masses as indicated. The left ZAMS corresponds to Ibens models while the one more to the right is the observed one. The discrepancy between these cannot by itself explain the age discrepancy which is discussed in the text.*

phase of contraction. It can be seen in Fig. 7 that the theoretical and observed ZAMS do not agree perfectly. Moreover, if one shifts the isochrones by the corresponding difference in temperature the discrepancy still remains. As mentioned earlier, these pms star models are idealized, e.g. they do not take into account the effects of rotation while real pms stars are suspected to be fast rotators. It would be interesting to see if the isochrones from more elaborate models agree better with our results.

Peculiarities

Although many of the secondaries fall above the ZAMS they are closer to it and also older and more evolved than typical T-Tauri stars. None of them which have been spectroscopically investigated exhibit any strong T-Tauri characteristics and we conclude that the T-Tauri phase ends several million years before the stars settle on the ZAMS. This is also supported by the infrared results. Practically all of the contracting secondaries were measured in JHKL in order to detect any possible infrared excess emission which is common for T-Tauri stars. The presence of such excess emission is explained by a circumstellar dust cloud which is heated by the stellar radiation. Again, none of the investigated stars show any excess. Their JHKL magnitudes are those of normal stars of the same spectral type. The stars therefore seem to shed their circumstellar material at the end of the T-Tauri phase and they reach the ZAMS as quite normal stars.

Despite the fact that none of the secondaries show any strong pms characteristics, more than 25 % do exhibit some spectroscopic peculiarity. In particular emission lines of Hα and Ca H, K are frequent, and a strong absorption line of lithium at 6707 Å is present in the spectra of several contracting stars. A few stars also have very broad and diffuse spectral lines. All these features are common to pms stars and spectroscopically some of the secondaries resemble T-Tauri stars of the weakest emission class.

The primordial lithium is destroyed by protons while the stars are contracting and therefore the presence of a strong lithium line is important since it demonstrates that the stars are young. Unfortunately only a limited number of secondaries have so far been investigated in the red part of spectrum and it is therefore likely that the number of stars with Hα emission and strong Li absorption is much higher. However, in the material we have, it is interesting to note that all the contracting stars which have a Li line also have Ca H,K emission. This suspected coupling will be further investigated in May 1982 with the ESO 3.6-m telescope.

The first results of this investigation have been published as a thesis (Lindroos, *Stockholm Observatory Report* No. 18, 1981). The whole investigation will be presented in a series of articles in *Astronomy and Astrophysics.*

Visiting Astronomers

(April 1 – October 1, 1982)

Observing time has now been allocated for period 29 (April 1 – October 1, 1982). 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: Israel/de Graauw/van der Stadt, Eichendorf/Krautter, Eichendorf/Reipurth, Léna/Foy/Mariotti/Perrier, Krautter/Vogt/Beuermann/Ritter, Brahic, Kunth/Joubert, Audouze/Dennefeld, Lachieze-Rey/Vigroux.

May: Lachieze-Rey/Vigroux, Campbell/Pritcher, Cayrel G.+R., de Bruyn/van Groningen, Lindros/Gahm, Weigelt, Motch/Ilovaisky/Chevalier, Jörgensen/Norgaard-N., Tarenghi, Pakull.

June: Landini/Oliva/Salinari/Moorwood, Moorwood/Glass, Decanini/Fossat/Grec, Alcaíno, Fusi Pecci/Cacciari/Battistini/Buonanno/Corsi, Rosino/Ortolani, Seitter/Duerbeck, Häfner/Metz, Pedersen/Lewin/van Paradijs, Wargau/Drechsel, van der Hucht/Thé, Koornneef/Westerlund.

July: Koornneef/Westerlund, Nguyen-Q-Rieu/Epchtein, Kreysa/Mezger/Sherwood, Steppe/Witzel/Biermann, Schultz/Sherwood/Biermann/Witzel, Sherwood/Gemünd, Schnur, Fricke/Kollatschny/Biermann/Witzel, Adam, Ardeberg/Nissen, Danks/Wamsteker.

August: Danks/Wamsteker, Engels/Perrier, Chevalier/Ilovaisky/Motch/Hurley/Vedrenne, D'Odorico/Grosbøl/Rosa, Greenberg/Brosch/Grosbøl, Seggewiss/

Breysacher/Azzopardi, Lindblad/Athanassoula/Grosbøl/Jörsäter, de Vegt.

Sept.: Chen/Danziger, Danziger/de Ruiter/Kunth/Lub/Griffith, Arp/Gosset/Surdej/Swings, Azzopardi/Breysacher/Lequeux/Maeder/Westerlund, Cetty-Véron.

1.4-m CAT

April: Habing/Brand/de Vries/de Graauw/Israel/van der Stadt.

May: Dennefeld, Danks/Lambert, Ferlet/Dennefeld, Ferlet/York, van Dishoeck/Habing.

June: van Dishoeck/Habing, Westerlund/Krelowski, Wöhl, Mauron/Querci, Gillet/Querci.

July: Gillet/Querci, Baade, Baade/Pollok, Schnur, Häfner.

August: Häfner, Schultz, Kozok, Schultz, Gerbaldi/Faraggiana/Floquet/van Santvoort.

Sept.: Gerbaldi/Faraggiana/Floquet/van Santvoort, Schultz.

1.5-m Spectrographic Telescope

April: de Loore/Burger/v.d. Heuvel/v. Paradijs, Spaenhauer, Boisson, Wampler, Kunth/Joubert.

May: Kunth/Joubert, Lindblad/Lodén, K., Infante, Jankovics/Appenzeller, Tarenghi, Melnick/Quintana, West/Kumsiachvili.

June: West/Kumsiachvili, Gieseking, Stenholm, Lundström, Perinotto/Purgathofer, Thé/Westerlund, Rahe/Drechsel, Drechsel/Rahe, Wargau/Drechsel, Houziaux.

July: Rahe/Drechsel, Drechsel/Rahe, Wargau/Drechsel, Houziaux, Voigt/Schneider, Voigt, Fricke/Kollatschny/Schallwich/Yorke, Kollatschny/Fricke/Yorke, Quintana, Kohoutek/Pauls, Liseau, Sahade.

August: Schade, von Dessel, Gustafsson/Vieira, Kozok, Lortet/Testor/Heydari-Malayeri, Koornneef/Maurice/Prévot.

Sept.: Alloin/Pelat, Nottale/Pelat, Véron, Koester/Weidemann.

1-m Photometric Telescope

April: Gammelgaard/Kristensen, Eichendorf, Krautter, Léna/Foy/Mariotti/Perrier, Krautter, Krautter/Vogt/Beuermann/Ritter, Brahic, Wielebinski/Beck/Schnur, Sterken/de Loore.

May: Sterken/de Loore, Hahn/Lagerkvist/Rickmann, de Jong/Willems, Alcaíno, Liller, Schneider/Maitzen/Catalano.

June: Schneider/Maitzen/Catalano, Lundström, Westerlund/Thé/de Jong, Leandersson, Thé/Westerlund, van der Hucht/Thé, Epchtein/Gomez/Lortet/Pitault.

July: Epchtein/Gomez/Lortet/Pitault, Nguyen-Q-Rieu/Epchtein, Bergeat/Lunel, Chini, Adam, Battistini/Cacciari/Fusi Pecci, Engels/Perrier.

August: Engels/Perrier, Leitherer/Wolf, Mattila/Schnur/Fricke/Schallwich, Bues/Rupprecht, Lauberts.

Sept.: Lauberts, Moreno, Chen/Danziger, Koester/Weidemann, Arp/Gosset/Surdej/Swings.

50-cm ESO Photometric Telescope

April: Divan/Zorec, Moreno/Carrasco, Wielebinski/Beck/Schnur, Hahn/Lagerkvist/Rickmann.

May: Hahn/Lagerkvist/Rickmann, Engber, Westerlund/Thé/de Jong.

June: Westerlund/Thé/de Jong, Leandersson, Thé/Westerlund, Leandersson.

July: Kohoutek/Pauls, Moreno/Carrasco.

August: Mattila/Schallwich/Fricke/Schnur.

Sept.: Debehogne, Moreno/Carrasco.

GPO 40-cm Astrograph

April: Azzopardi/H.-Delplace/Jaschek M.+C.

May: Dettmar/Gieseking.

August: Lagerkvist.

Sept.: Debehogne/Caldeira.

1.5-m Danish Telescope

May: Veillet, Terzan, Motch/Ilovaisky/Chevalier, Blecha/Grenon/Jörgensen, Crane/West/Kruszewski, Jaffe/Kruszewski/Valentijn/West, Jörgensen/N.-Nielsen, Ardeberg.

July: Ardeberg/Nissen, Chevalier/Ilovaisky/Motch/Hurley/Vedrenne, Liseau, Sol, Baade/Eichendorf/Sol/Valentijn.

Sept.: Tarenghi/Cetty-Véron/Véron/Pedersen, Bergeron/Kunth, Danziger/Pedersen, Steppe/Pedersen/Gopal-Krishna, Maurice (CORAVEL Group), Ardeberg.

50-cm Danish Telescope

April: Schober, Vogt/Maitzen.

May: Sterken/van der Linden.

90-cm Dutch Telescope

April: Gathier/Pottasch.

May: Pakull, Thé/Westerlund.

June: Thé/Westerlund.

July: Weiss/Hensberge/Schneider.

Sept.: Schober.

61-cm Bochum Telescope

April: Barbier.

May: Barbier, Terzan.

June: Schneider/Maitzen/Catalano, Barbier.

July: Barbier, Thomsen.

August: Kozok.

Sept.: Kozok.

Applications for Observing Time at La Silla

Period 30

(October 1, 1982 – April 1, 1983)

Please do not forget that your proposals should reach the Section Visiting Astronomers **before April 15, 1982.**

Magellanic Irregular Galaxies and Chemical Evolution of Galaxies

G. Comte, Observatoire de Marseille
J. Lequeux and G. Stasinska, Observatoire de Meudon
L. Vigroux, Section d'Astrophysique, CEN Saclay

Abundance determination provides a way to study the evolution of galaxies. In conjunction with other properties of galaxies, such as the gas mass fraction, the present rate of star formation or the luminosity, they can help to determine the 3 major quantities which govern the chemical evolution of galaxies: the Initial Mass Function (IMF), the past rate of star formation (SFR), and the amount of heavy elements produced at each generation of stars. Possibilities of abundance determinations in external galaxies are rare. Even in the closest galaxy, the Large Magellanic Cloud, stellar spectra are restricted to supergiants whose complex atmospheres prevent us from obtaining accurate abundances. Spectra or colours of the integrated light of clusters, or galaxies themselves, can give some information. However, this integrated light comes from a mixture of stars of different spectral type, luminosity classes and luminosity, its interpretation in terms of abundances is not straightforward (e.g. Tinsley 1980, *Fund. Cosm. Phys.*, **5**, 287). For external galaxies, H II regions provide the most reliable abundances. They are bright enough to be observed in distant galaxies and the emission line intensities are proportional to the abundances of the emitting ions. Two major problems remain in the way to elemental abundances: correction for unseen ions, and the amount of different elements locked in dust grains.

Among different types of galaxies in which H II regions are observed, the Magellanic Irregulars (Fig. 1) seem to be the only ones for which simple chemical evolution models lead to meaningful results. In spiral galaxies the chemical evolution cannot be disconnected from the dynamical evolution. This is obviously shown by the existence of systematic abundance differences between halo and disk stars, as well as by the abundance gradients in the disk of spirals. A purely chemical origin of these gradients is difficult to believe, since most of the models including only chemical evolution have failed to reproduce the observed gradients together with the other radial properties of the galaxies. Moreover such gradients can easily be built by slow radial motion, even of the order of 1–10 km/s (Mayor and Vigroux, 1981, *Astron. & Astrophys.*, **98,** 1). In galaxies such as Irregulars or blue compact ones, the total mass is much smaller than in spirals for example, the rotation curve of the LMC rises only to 70 km/s compared to 300 km/s for a spiral. Therefore, one can expect that the effects linked to dynamical evolution are far less important and can be neglected in a first approximation. However, blue compact galaxies create another problem for chemical evolution models. Their evolution seems to have proceeded only by important bursts of star formation (see Audouze et al., 1980, *The Messenger*, **22,** 1). The number of bursts experienced by these galaxies is very small, of the order of unity. The chemical enrichment depends strongly on the duration, the intensity and, eventually, the periodicity of these bursts, especially for secondary elements.

In Magellanic-type irregulars the star formation occurred more quietly. On the scale of the whole LMC, the SFR is low compared to the one in our Galaxy (Lequeux, 1979, *Astron. & Astrophys.*, **71,** 1). When present, bursts of star formation are local and affect only a fraction of the galaxies. The 30 Doradus complex in the LMC is the most dramatic example of such a burst of star formation. Inspection of the catalogue of bright stars in the LMC (Rousseau et al., *Astron. & Astrophys. Suppl.*, **31,** 243) shows that only ~ 1/10 of the bright supergiants are located in this complex. This number may be underestimated due to some selection effect, crowding or absorption, but in any

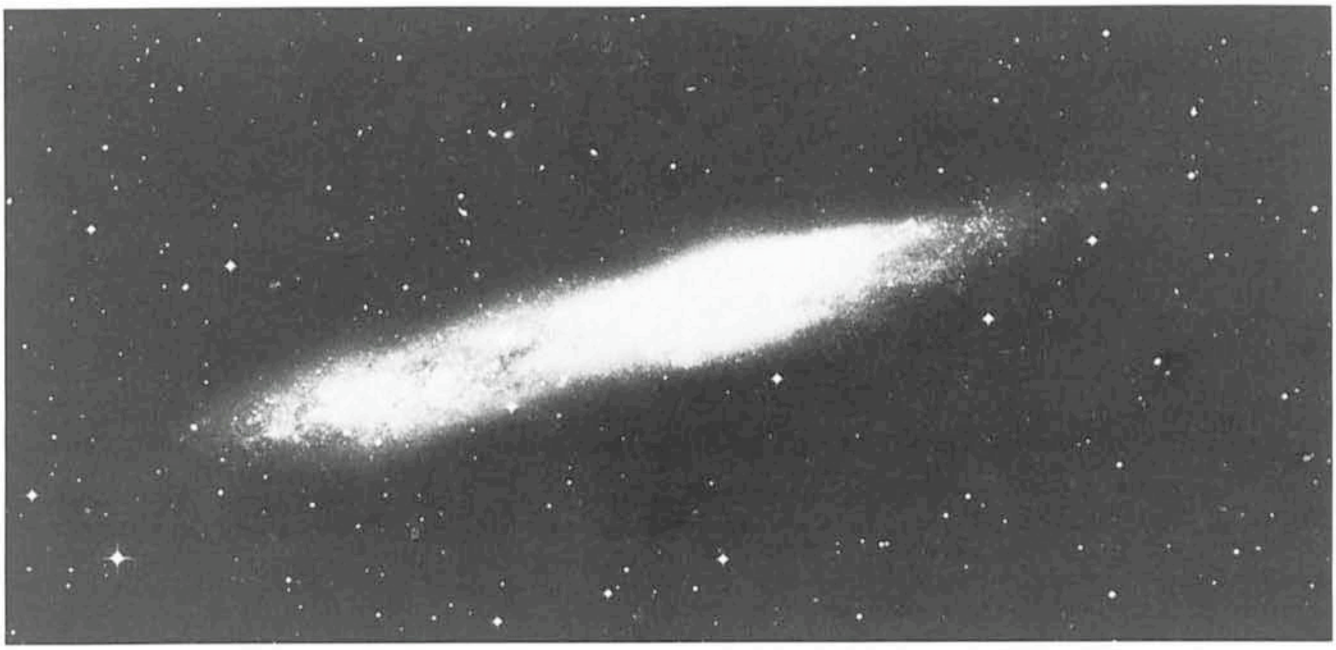


Fig. 1: *NGC 55, a large Magellanic-type galaxy in the Sculptor Group, photographed from the SRC deep J survey with the Anglo-Australian Schmidt telescope. North is at top.*

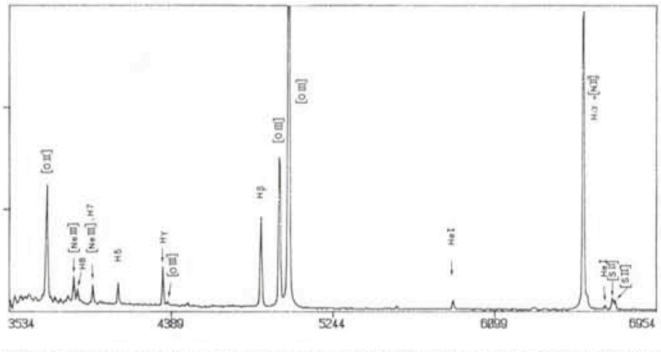


Fig. 2: *Spectrum of an H II region in NGC 55, taken at La Silla with the IDS at the Cassegrain focus of the 3.6-m telescope.*

case the total amount of bright stars recently formed in the 30 Dor complex is less than 1/5 of the stars of the same age formed in the whole LMC. The situation is very different for that in a blue compact galaxy where a complex like 30 Dor would be the galaxy itself. The homogeneity of the abundance distribution in the LMC (Pagel, 1978, *MNRAS*, **183**, 1 p) shows that the different parts of the LMC evolve with more or less the same time scale. These considerations on the LMC indicate that this galaxy and (at least we may hope) those of the same type are the best candidates to disentangle the different problems of chemical evolution.

As previously said, the chemical evolution of a galaxy is ruled by 3 main parameters, the IMF, the SFR, and the stellar heavy element production. It can be shown (e.g. Tinsley, 1980, *Fund. Cosm. Phys.*, **5**, 287) that, at a given stage of evolution determined for example by the amount of gas left in the galaxy, the abundances depend mainly on one quantity, the so-called *yield*. It is the mass of heavy elements produced and ejected in the interstellar medium by a generation of stars divided by the mass of small unproductive stars ($M < 0.8\ M_\odot$) and of remnants of more massive stars. A measurement of abundances and of the gas mass fraction provides a direct determination of this yield. Some attempts have been made to use the observed yield as a probe for stellar evolution theories, in particular, these last years, for mass loss in massive stars (Chiosi and Caimmi, 1979, *Astron. & Astrophys.*, **80**, 234). The higher the mass loss, the smaller is the metal production and the yield. The claim was that the observed yield is compatible only with very high mass loss rate. However, recent observations show that the mass loss is lower in the LMC than in our Galaxy and, more generally, is proportional to the metallicity (Maeder et al., 1981, *Astron. & Astrophys.*, **90**, L17). Then one expects, on the basis of a mass loss effect, a yield higher in the LMC than in our Galaxy. This is the opposite of what is observed. The yield deduced from a sample of Irregulars and compact galaxies is 0.003 ± 0.001 (Pagel and Edmunds, 1981, *Ann. Rev. Astron. & Astrophys.*, **19**, 77) while it is 0.005 ± 0.001 in our Galaxy. This example clearly shows the difficulty to use the yields. In fact, the yield is a combination of 2 quantities, the IMF for the small stars and the heavy element production by massive stars. An apparent variation of the yield from a galaxy to another can be due to variation of one or both of these quantities. But, provided one can determine by some other means the amount of small stars, from a M/L ratio determination for example, the yield could effectively lead to some insight in basic stellar evolution.

The comparison of the abundances of different elements can give other information. If one looks at an element produced only in massive stars ($M > 10\ M_\odot$), such as oxygen, and another produced mainly in lower mass stars ($M < 5\ M_\odot$), such as nitrogen, the ratio of these 2 elements allows an estimation of the proportion of low and high mass stars, that is the slope of the IMF for $M > 1\ M_\odot$ (Alloin et al., 1979, *Astron. & Astrophys.*, **78**, 200). Obviously, this is true only for a continuous star formation process, since in case of bursts the N/O ratio depends also on the ages of the bursts.

Systematic observations of a large sample of Magellanic-type irregular galaxies will lead to a considerable improvement of our understanding of galactic evolution. In order to be fully efficient, these observations must permit us to determine a great number of parameters, such as the abundances of various elements, the total mass, the H I distribution, the stellar continuum and H_α fluxes . . . We have undertaken such a programme of observation. The first step has been the determination of abundances in 10 Magellanic-type irregulars by the measurement of H II region spectra (Fig. 2). They were obtained during two missions at the ESO 3.6-m telescope with the Cassegrain Boller and Chivens spectrograph. These spectra are now nearly reduced. However, additional parameters, in particular the photometry, are still lacking. We hope that the above considerations will prompt astronomers to study more thoroughly these objects which are extremely promising, despite their ugly appearance.

ESO WORKSHOP ON "THE MOST MASSIVE STARS"

The workshop on "The Most Massive Stars" took place in the ESO Headquarters in Garching from November 23–25, 1981. It was attended by 63 participants from 13 countries, and a total of 28 contributions were presented and, sometimes vivaciously, discussed.

The most massive stars were chosen as a subject for the workshop because of their relevance for the evolution of galaxies as a whole. The largest ground-based telescopes and even more, in the near future, the space telescope can study the most massive stars, which happen to be also the most luminous, in the nearby galaxies. We need to understand well the physics and evolution of these stars to interpret correctly the observations, determine their properties and correlate them with those of the galaxies they belong to.

The specific aim of the workshop was to confront people concerned with modelling of massive stars with the most recent observational results in this field. Among the topics which were discussed are the effects of mixing and mass loss on the evolutionary tracks, the H-R diagrams for the brightest stars in the nearby galaxies, the WR stars of Pop I, the evolution of massive binaries, the supermassive object R 136 in 30 Doradus, the initial mass function of massive stars, the use of the luminous stars as distance indicators and the possible role played by very massive objects in a pregalactic phase of the evolution of the universe.

Special attention was devoted to the discussion of the critical areas in the theory of evolution of massive stars and to the uncertainties and selection effects of the observations.

S. D.

Proceedings Now Available!

The Proceedings of the Workshop on the "Most Massive Stars" have just been published. The price of the 364-page volume is DM 50.– (including postage) and has to be prepaid.

If you wish to obtain the volume, please send your cheque to: Financial Services, ESO, Karl-Schwarzschild-Strasse 2, D-8046 Garching bei München, or transmit the amount of DM 50.– to the ESO bank account No. 2102002 with Commerzbank München.

Infrared Instrumentation at ESO

A. F. M. Moorwood, ESO

Introduction

The ESO infrared photometer/spectrophotometer, which was first made available at the 3.6-m telescope towards the end of 1980, has considerably expanded the scope for infrared observations on La Silla and has already led to an enlargement of ESO's active infrared community. Improvements made recently in this system plus the fact that a similar one is to be installed on the 1-m telescope later this year makes it timely to review the status and some of the uses being made of this instrument. In addition, this is a convenient opportunity to report on the progress of the F/35 wobbling secondary and the cooled array spectrometer, both of which will increase further the infrared observing possibilities at the 3.6-m in the future. Before discussing these developments specifically, however, I thought I would begin with a brief introduction to the fundamental considerations which affect infrared instrumentation design and to some of the terminology, which I hope will prove useful to readers who are unfamiliar with this subject.

Basic Considerations and Jargon

The ground-based infrared astronomer faces an analogous situation to that which would be experienced by an optical observer, maliciously scheduled during daytime, in that both the sky and his telescope are perpetually bright in the wavelength region he is trying to observe. This problem is particularly acute in the 3–20 μm region, i.e. around the wavelength of peak emission for room temperature objects, where the background may be orders of magnitude larger than the signal from the astronomical object of interest. Two fundamental aims underlying most infrared system designs therefore are to first minimize the amount of background radiation (and hence also its associated photon shot noise) reaching the detector and then to ensure that the astronomical signal can be discriminated against the background which remains. Under most conditions, the latter requirement can be satisfied by employing an observing technique which combines *sky chopping* and *beam switching* or *nodding*. Chopping involves rotating or oscillating a suitable optical element in the system such that the detector alternately views two areas of sky through the same, cold, defining diaphragm. These are separated by the *chopping amplitude* which, ideally, should be chosen just large enough to avoid overlap of the two beams although larger values may be necessary when observing extended sources. Clearly, if an astronomical object is present in one of the beams it will generate an AC signal at the chopping frequency, typically 10–20 Hz, which can be phase-sensitively detected, digitized, etc. Unfortunately, the fact that the two beams follow slightly different optical paths through the telescope means that the actual signal in practice normally contains an additional component, the *chopping offset*, because the radiation background is not exactly equal in the two beams. Whereas this signal however is independent of the telescope position, at least for small angular movements, the phase of the source signal can be shifted by 180° by moving the object into the other beam. It is possible to cancel the offset therefore by slowly nodding the telescope by an amount equal to the chopping amplitude, thus generating pairs of signals whose difference is simply equal to twice the source signal obtained in a single beam. Providing that the instrumental chopping offset is stable, this technique is extremely effective on a clear sky. The presence of clouds, on the other hand, even thin cirrus which may not be evident to the naked eye, adds an additional non-uniform and varying component of emission which can lead to a sufficiently large increase in the effective system noise to send the infrared observer to bed long before many optical astronomers would give up.

Even on a clear sky, the dominant noise at wavelengths longer than 2 μm is generally the statistical shot noise associated with the background, mentioned already. In order to minimize this, careful design of the instrument cold optics plus efforts aimed at reducing the effective telescope emissivity (such as increasing the focal ratio) are necessary. For point source observations at least, however, the limiting performance ultimately depends on the size of the smallest useable diaphragm which in turn is limited by the seeing and/or the accuracy with which the source can be centred and tracked. In general, therefore, infrared observations tend to be even more at the mercy of both the sky conditions and the telescope control system than those in the visible.

3.6-m IR Photometer/Spectrophotometer

Description. This instrument is intended mainly for conventional photometry, circular variable filter (CVF) spectrophotometry and mapping through diaphragms in the range 3–10″. As anticipated in the design, however, it is also suitable for speckle observations, as described already by C. Perrier in *The Messenger* No. 25 (1981), and has also been used in a slightly non-standard way to observe a stellar occultation by the rings of Uranus (Bouchet, Perrier, Lecacheux and Sicardy, *The Messenger* No. 26, 1981).

Two detector units, one containing a solid N_2 (~ 50 K) cooled InSb detector used in the 1–5 μm region and the other a bolometer, cooled to ≃ 1 K by pumping on liquid He, provide coverage of all the atmospheric windows out to 25 μm. Together, these detectors are equipped with some 14 broad and intermediate width interference filters plus 4 CVF's which cover the 1.5–5.5 μm and 8–14 μm regions at a resolving

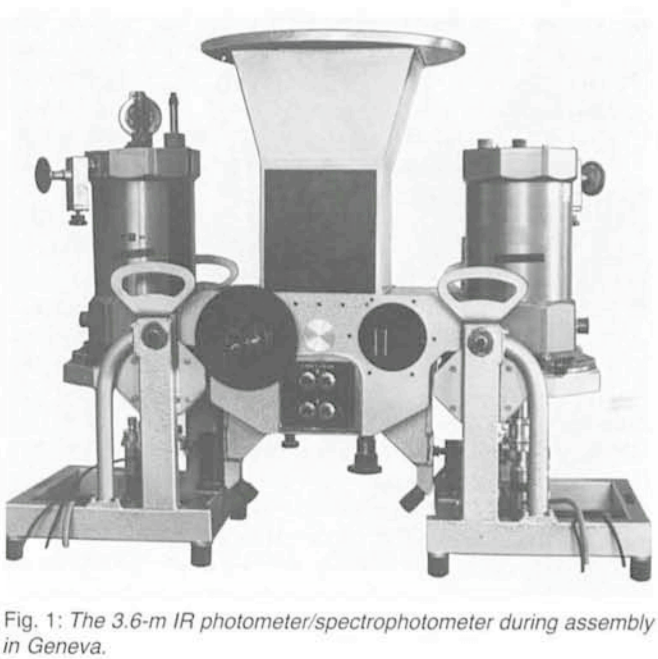


Fig. 1: *The 3.6-m IR photometer/spectrophotometer during assembly in Geneva.*

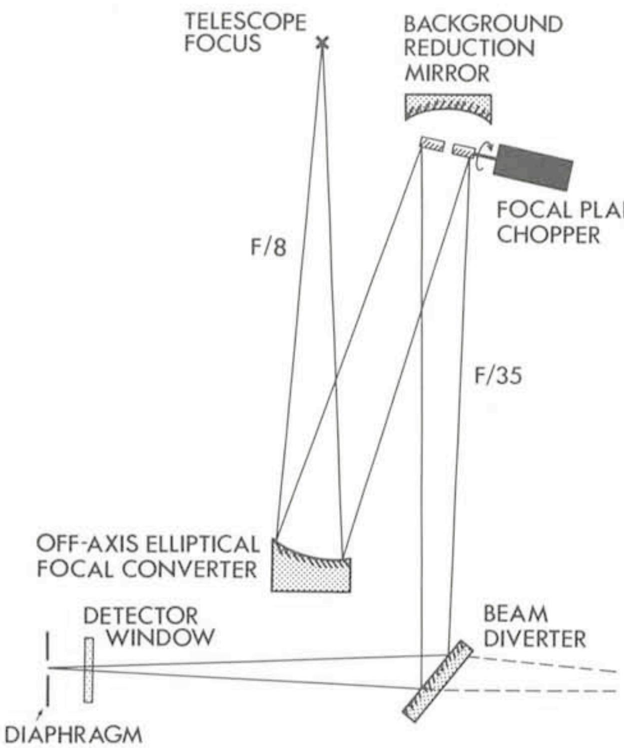


Fig. 2: *Optical schematic of the F/8 mount shown in Fig. 1. In reality the detector beams are perpendicular to the plane of the figure but have been rotated here for clarity.*

power of ≃ 70. (The latter are also multilayer interference filters but deposited on a circular substrate in such a way that the thickness of the layers and hence the transmitted wavelength is a function of angular position along the filter.) Fig. 1 is a photograph of the instrument taken during its assembly in Geneva. Both of the detectors are in fact designed to be used directly at F/35 once the wobbling secondary becomes available at the 3.6-m. In the meantime they are used on the photometer mount shown which contains optics (Fig. 2) to convert the F/8 telescope beam to F/35, provide sky chopping by means of a small wobbling mirror at an intermediate pupil image and reduce the emissivity of the central obscuration. The two cold photometer units are virtually identical. One of them can be seen in Fig. 3 and its optical layout is shown schematically in Fig. 4. The relatively complex off-axis optical arrangement was dictated by space limitations and the need to re-image the pupil at the filter wheel position in order to avoid a dependence of CVF resolution on the diaphragm size.

Except for the beam diverter mirror used, to select the required detector, and the chopper controls, which at present have to be operated manually in the Cassegrain cage, all the instrument functions are controlled via the instrument computer from the control room. The HP *soft key* feature is utilized for selecting the observing mode and various software routines exist for automatic filter sequencing, CVF spectrophotometry and mapping and for computing on-line magnitudes and errors, displaying CVF spectra, etc. The instrument computer also communicates with the telescope computer, thus allowing automatic control of the telescope beam switching and coordinate printouts. Data are output on the line printer and magnetic tape and the CVF and mapping data will, in the future, be produced in FITS format to facilitate off-line reduction.

Performance. Apart from the usual teething problems and a few irritations such as vacuum leaks, common to IR systems, no fundamental problems have been discovered with the instrument concept. The F/8 chopper in particular, which was introduced into the system at a relatively late stage and has a somewhat unconventional design, has exceeded expectations in that it can be operated stably up to amplitudes in excess of 1.5′—large for a focal plane chopper on a telescope of this size. Less satisfactory initially were the detector beam profiles which suffer from the off-axis optics described above. This situation has been transformed however with the provision of new detector units, an InSb with a corrector lens and a set containing specially designed off-axis mirrors, which have now replaced those originally installed. Recent observations with InSb 2 gave reproduceable signals at the 1–2% (p-p) level over three nights. Improved sensitivities (s/n = 1, T = 15 min) of J (1.2 μm) = H (1.65) = 19 mag, K (2.2) = 18 mag, L (3.6) = 13.5 mag (7″5 dia) and N (10) = 8 mag (7″5) have also been

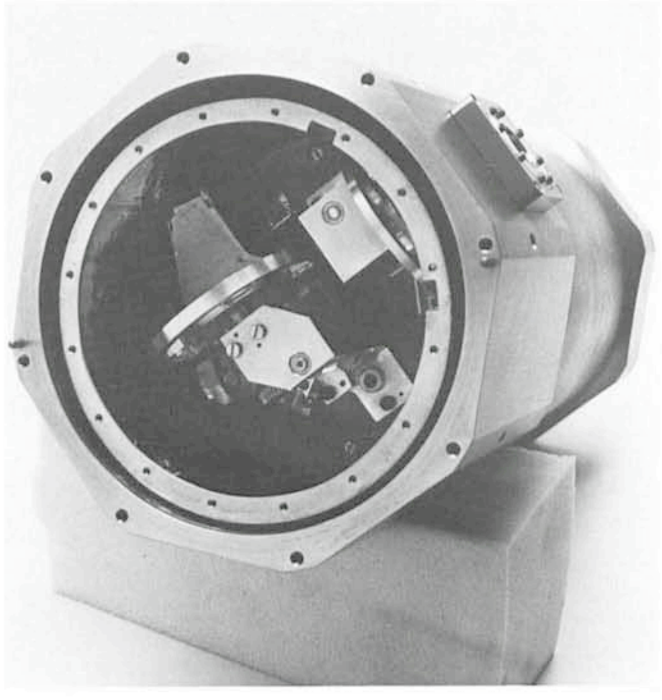


Fig. 3: *One of the detector units with its bottom cryostat cover and radiation shields removed to show the internal construction of the photometer assembly.*

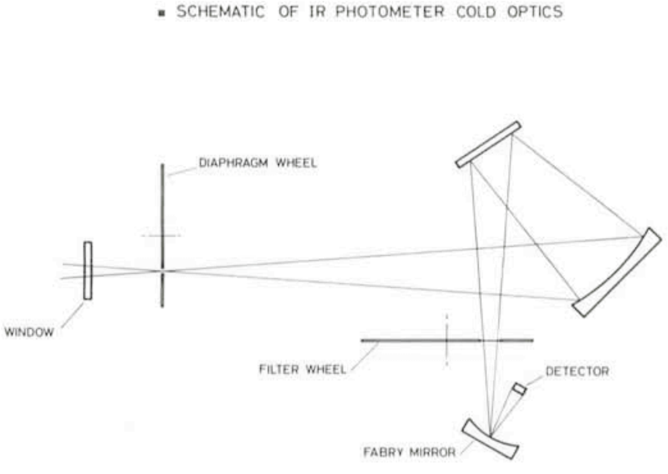


Fig. 4: *Optical layout of the cooled photometer assemblies. The beam folding and off-axis optics are dictated by space limitations and the need to re-image the pupil at the filter wheel position to avoid a dependence of CVF resolution on diaphragm size.*

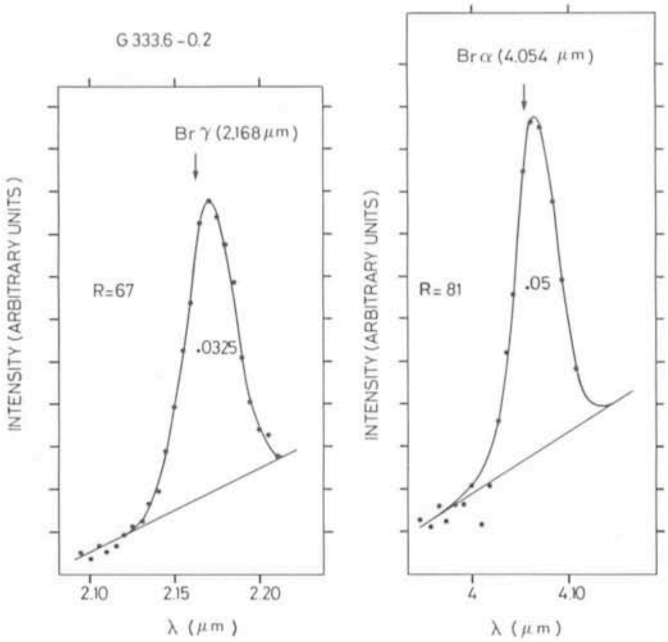


Fig. 5: *CVF scans of the Brγ and Brα hydrogen recombination lines on the H II region G333.6-0.2 made at the full position encoder resolution. The wavelength scale, derived from the laboratory calibration, is correct within about 1 step or 25 % of the filter resolution.*

obtained. Further work on the InSb preamplifier is expected to yield an extra magnitude at J and H while the the F/35 system should result in a gain of ~ 0.5 mag in the longer wavelength, background limited bands.

A large variety of photometric programmes are already in progress ranging from the study of truly infrared dust embedded objects to a wide range of extragalactic sources which are now accessible at the 3.6-m. An idea of the detectability of extragalactic objects can be given by noting that a normal elliptical galaxy at zero redshift has colour indices V-H ≃ V-K ≃ 3. At larger redshifts, near-infrared observations at a given V magnitude become increasingly more favourable due to the fact that the cosmological K corrections are negative. At z = 1 for example, V-H ~ 5 and the detection limits quoted above consequently begin to approach those in the visible.

The background limit at longer wavelengths restricts observations to the brightest normal galaxies but still permits many studies of galaxies exhibiting infrared excesses associated with non-thermal activity or star formation which tend to have V-N = 7–10 mag. CVF spectrophotometry is ideally suited to observations of solid state emission and absorption features. It can additionally however provide useful information on molecular absorption bands (e.g. CO and H_2O in late-type stars) and even emission-line intensities (e.g. H and He recombination lines, H_2). The actual-profile obtained with this type of filter can be seen in the oversampled test scans (Fig. 5) made of the Brγ and Brα H recombination lines on the H II region G333.6–0.2. Extragalactic applications so far at the 3.6-m have included the measurement of redshifted Pα in quasars (Fricke and Kollatschny, *The Messenger* No. 25, 1981) and observations of active galaxy nuclei. Fig. 6 shows a recent spectrum, obtained by the author, of the nucleus of the Seyfert 2 galaxy NGC 7582. In addition to possible molecular bands and the presence of the unidentified 3.3 μm emission feature, believed to be associated with dust, this spectrum reveals a rather different underlying continuum to that expected on the basis of the broad-band photometry.

While further improvements in performance can be expected in the future, I hope that the figures and examples quoted above serve to demonstrate that this instrument is already proving itself to be a useful additon to the 3.6-m instrument zoo.

F/35 Wobbling Secondary

Although sometimes erratically, due to the pressure of other projects, moving country, etc., this system is progressing and passed a critical phase last year when a successfull top ring exchange test was made on La Silla. Users of the 3.6-m will probably have seen the actual infrared top ring and will now appreciate the foresight which went into planning the size of the dome! The wobbling unit itself exists and has wobbled both in Garching and during the test on La Silla. Still remaining however is the construction of a new photometer mount which will have to accommodate an F/35 TV acquisition and guiding system to replace the functions presently provided for in the Cassegrain adaptor at F/8. When completed, hopefully in 1983, the F/35 system will reduce the diameter of the telescope central obscuration from about 1.6 m to 0.7 m and, with the exception of wobbling the primary mirror, provide the optimum method for sky chopping.

ESO 1-m Telescope

This telescope has already been used successfully for many years with the InSb and bolometer infrared photometers developed in Bonn and Groningen respectively. In order mainly to increase its flexibility and achieve better compatibility with the 3.6-m, however, it is now planned in June this year, following the installation of a new RTE computer system, to test the new ESO system which employs identical detector units to those at the 3.6-m and a similar although somewhat more complex photometer mount. One reason for the latter is the inclusion of an offset guiding eyepiece which can be used with either detector. The CVF mode will be new at the 1-m as will the possibility of using different diaphragms and chopper throws

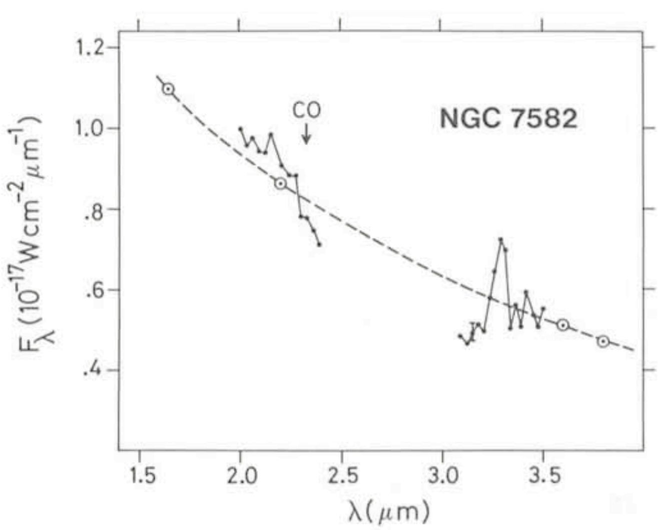


Fig. 6: *CVF spectra from 2 to 2.4 μm and 3.1 to 3.5 μm plus H, K, L, L' photometry of the Seyfert 2 galaxy NGC 7582 obtained by the author with the 3.6-m. Internal accuracy around 2 μm is roughly equal to the size of the plotted points. The structure is attributed to molecular bands associated with the stellar population plus some small residual atmospheric effects. The 3.3 μm feature, unidentified but circumstantially associated with dust, is extremely strong and the true underlying continuum clearly departs from a smooth curve drawn through the photometric points.*

with the InSb detector. For many programmes on extended sources the larger diaphragms (≤ 30") and chopping amplitudes (≤ 4') will compensate to some extent for the smaller telescope aperture compared with the 3.6-m and in some cases may even make this telescope more attractive.

IRSPEC (Infrared Spectrometer)

This is a cooled array spectrometer which is being developed for the 3.6-m telescope where it should provide for observations in the 1–5 μm region at a resolving power of ≃ 3000 through an input slot of up to 3 × 7". The mechanical construction is now in progress and most of the critical assemblies should be delivered within the next 2–3 months. Final completion will depend largely on when we actually receive the 52-element InSb array being produced specially for this instrument and on the difficulties encountered in developing its associated electronics. A more detailed account of this instrument therefore will be reserved for a future *Messenger*.

Acknowledgements

Without wishing to offend the many other ESO staff involved with the projects described here, I feel that special mention should be made of P. Salinari who was responsible for most of the IR photometer design before escaping to Florence, A. van Dijsseldonk who alternately builds and repairs detector units with great enthusiasm in Garching and, on La Silla, D. Hofstadt, F. Gutierrez, J. Roucher plus J. Koornneef and C. Perrier who face the unenviable task of demonstrating to visiting astronomers what has been written here.

ANNOUNCEMENT OF AN ESO WORKSHOP ON

"GROUND-BASED OBSERVATIONS OF HALLEY'S COMET"

to be held in PARIS, 29–30 APRIL 1982

With the aim of stimulating and planning ground-based observations of Halley's comet during its next apparition in 1985–1986, ESO is organizing a workshop entitled "Ground-based Observations of Halley's Comet".

This workshop will take place at the Institut d'Astrophysique de Paris on 29–30 April 1982. It will include both review papers and short contributions with ample time for discussion.

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ESO
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Mass Determination of Massive X-ray Binaries

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Introduction

Massive X-ray binaries consist of a normal component of spectral type O or B which is transferring matter to a compact companion, generally a neutron star, with possibly one exception, Cyg X-1, where the compact component could be a black hole. These compact stars have enormous magnetic fields (of the order of 10^{12} gauss), and extremely large gravities; accreted matter will be accelerated to velocities of half the light velocity, and guided by the field lines to restricted areas near the magnetic poles, the hot spots. These regions acquire in this way temperatures of the order of 10^7 K, and X-rays are generated. The X-rays are transported outwards as beams, and since the compact objects rotate rapidly, X-rays are observed as pulse-shaped beams.

In order to enable a good physical description of compact objects and to derive an equation of state, their masses have to be determined as accurately as possible.

Mass ratios for binary systems can be derived from the radial velocity curves of the two components. In the case of a double-lined spectroscopic binary this is possible from measurements of the amplitude of these variations. For X-ray binaries the optical spectrum of the non compact component leads to the radial velocity curve of this component; from the Doppler delay of the arrival time of the X-ray pulse the radial velocity curve of the compact companion can be derived. Hence when the compact star is a pulsar the system can be treated exactly as a double-lined spectroscopic binary.

Massive X-ray Binaries

A list of massive X-ray binaries with their characteristics is given in Table 1. The table shows the names, spectral types, magnitudes, orbital periods in days, eventual pulse periods in seconds, the optical luminosity and the distance in kpc. As can be seen from the table the best suited candidates for the determination of physical parameters are Vela X-1 (4U 0900-40), 4U 1700-37, SMC X-1, LMC X-4, Cen X-3, Wra 977, 1538-52 and Cyg X-1, since they have short periods and are not too faint. Vela X-1, SMC X-1, Cen X-3, Wra 977 and 1538-52 are pulsars so that in principle the two radial velocity curves can be derived.

The best suited one is Vela X-1, since its magnitude of $6^m_.9$ offers the possibility to acquire high-resolution coudé spectrograms, and moreover it is a pulsar (already discussed by Mauder in *The Messenger* No. 24).

The Case of Vela X-1

Some hundred blue plates were taken by the Amsterdam-Brussels group (Astrophysical Institute, Brussels; Royal Belgian Observatory; Astronomical Institute, Amsterdam) with the 152-cm spectrographic telescope of ESO with reciprocal dispersions of 12 and 20 Å/mm in the wavelength range 3700-4900 Å. The plates were collected between April 1973 and May 1976. From the line positions, heliocentric radial velocities were derived (Van Paradijs et al. 1976, *Nature,* **259,** 547). In

Table 1. Hard spectra binary X-ray sources—Massive X-ray binaries.

Name	Source	Spectral type	m_v	P_{orb} (d)	P_{pulse} (s)	L_x	L_x/L_o	d (kpc)
γ Cas	0053+604					3E33	6E-6	0.3
	0114+650	B0.5IIIe	11.0				1.5E-4	
SMC X-1	0115−737	B0I	13.3	3.89		6E38	1.2	65
X Per	0352+309	09.5(III-V)e	6-6.7		835	1.2E34	1E-4	0.35
LMC X-4	0532−664	08III-V	14	1.4			1	55
HDE 245770	0535+262	09.7IIe	9.1			2E37	0.08	1.3
Vela X-1	0900−403	B0.5Ib	6.9	8.97	283	1.4E36	3E-3	1.4
Cen X-3	1119−603	06.5II-III	13.35	2.087	4.84	4E37	0.05	8
Hen 715	1145−619	B1Ve	9.0		292 297	6E36	0.2	1.5
Wra 977	1223−624	B1Ia	10.8	35	699	1E37	3E-3	2
GX 304-1	1258−613	B6-9e	14.7		272	2.1E36	0.3	2±1
	1538−522	B0I	14.5	3.7	529	4E36	0.01	7±2
HD 153919	1700−377	06.5f	6.6	3.4		3E36	5E-4	1.7
Cyg X-1	1956+350	09.7Iab	8.9	5.6		2E37	2E-2	2.5

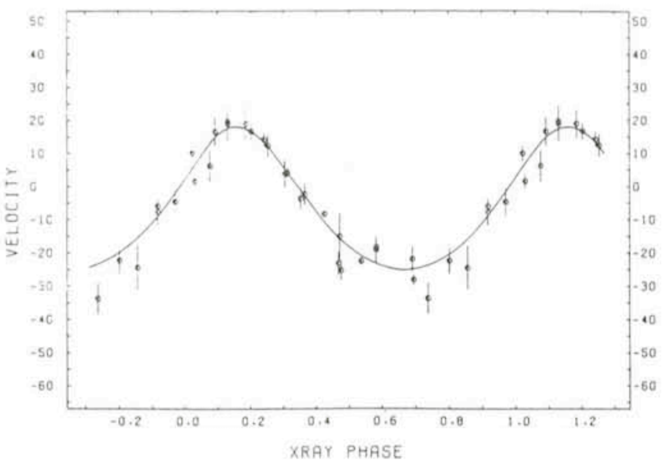

Fig. 1: *Variation of the radial velocity of HD 77581 with X-ray phase as obtained from all lines except the He I lines. Each point represents the average radial velocity for one plate. The error bars denote the mean error of the radial velocity variations. The curve drawn through the points depicts the best fit solution to the data points.*

Fig. 1 the variation of the radial velocity as a function of phase is shown.

The orbital elements we derived are: a period of 8.9681 ± 0.0016 days and an eccentricity of 0.136 ± 0.046. The observed pulse-arrival times given by Rappaport et al. (1976, *Astrophys. J. Letters,* **206,** L 105) were used for the determination of the orbital elements of the compact object: the pulse period is 283 s and the eccentricity 0.096 ± 0.019; a sin i = (32.83 ± 0.45) 10^6 km.

From the orbital elements, using all lines, the masses of the two components can be derived:

$$\frac{M_x}{M_\odot}\sin^3 i = 1.67 \pm 0.12$$

$$\frac{M_{opt}}{M_\odot}\sin^3 i = 20.5 \pm 0.9$$

Adopting a value for $\sin^3 i$ of 0.96, the masses can be estimated as 1.74 $M_\odot$ for the neutron star and 21.3 $M_\odot$ for the optical companion.

Other Massive X-ray Binaries Suited for Radial Velocity Studies

LMC X-4

Electronographic spectra (124 Å/mm) were obtained by Chevalier and Ilovaisky in 1977 (*Astron. Astrophys.* **59,** L 9)

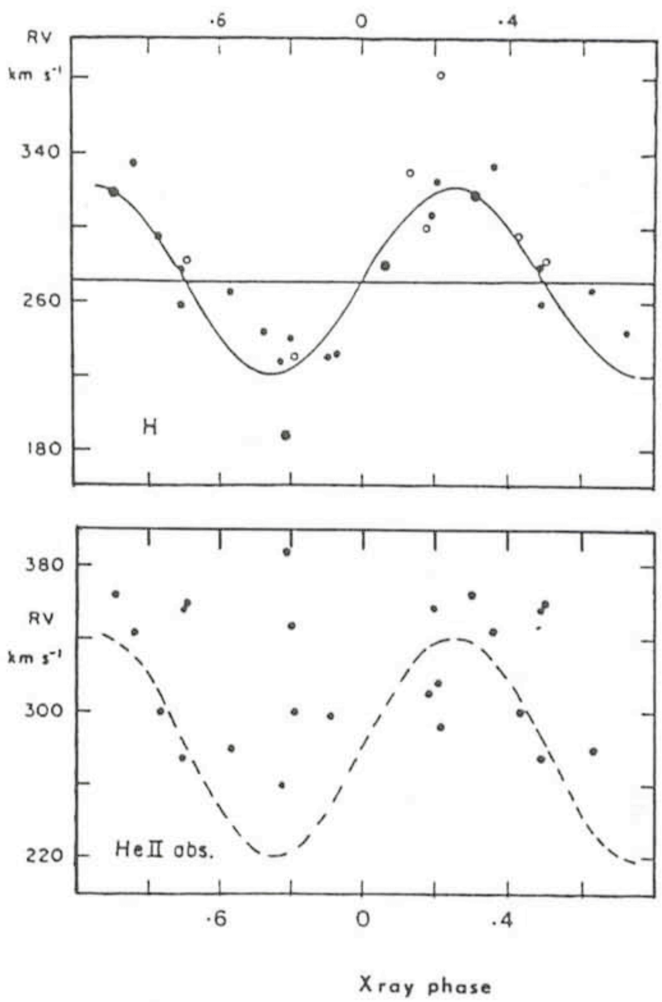

Fig. 2: *LMC X-4. Radial velocities measured from H absorption lines (top) and He II absorption lines (bottom).*

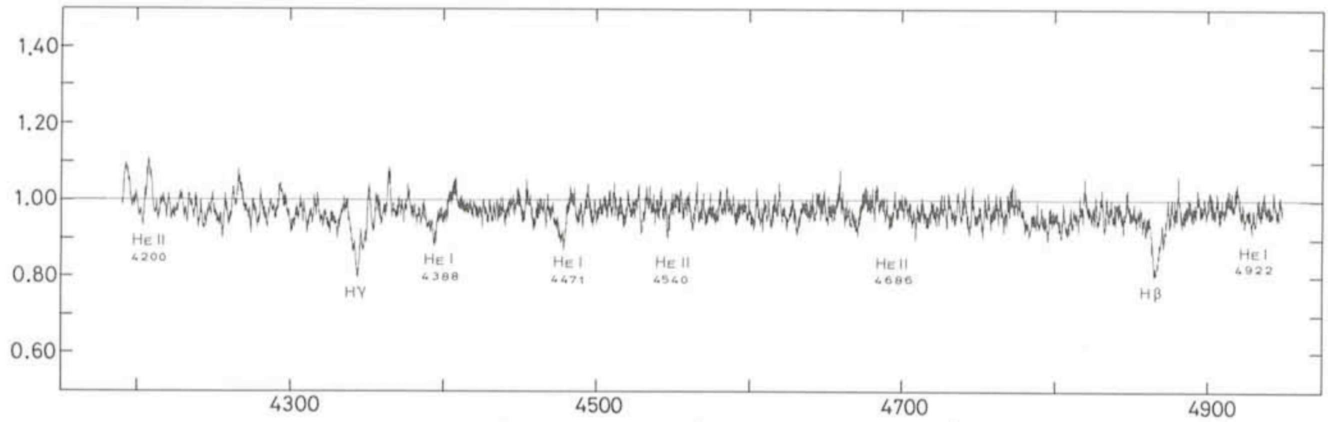

Fig. 3: *Spectrum of LMC X-4 in the blue region, between λλ 4200–5000.*

using the 152-cm ESO reflector. They derived an average radial velocity of the system from all their plates of ~300 km s^{-1} and, as upper limit for the semi-amplitude, they found ~35 km s^{-1} (± 15 km s^{-1}).

Hutchings, Crampton and Cowley (1978, *Astrophys, J.* **225,** 548) obtained a sequence of spectra of LMC X-4 during 1978, and they have succeeded to derive radial velocity curves, however with large spreads (Fig. 2). In February 1981 we took some spectra of this source with the image tube at the 3.6-m ESO telescope, at a reciprocal dispersion of 30 Å/mm in the wavelength range 4000-5000 Å, with the hope to improve the accuracy of the data. Also, at the end of October 1981, we took during two successive nights a sequence of LMC X-4 image-tube spectra at the same telescope. The number of lines suited for radial velocity determinations is satisfactory, and the lines are sufficiently sharp (Fig. 3). The analysis of our material is in progress, and we hope to be able to get improved radial velocity curves.

From the existing material we can already make an estimate of the parameters of the system. At the moment, no study of Doppler variations in the X-ray pulsation period is yet available, but the velocity of the compact star may be obtained from the He II λ 4686 emission line which is formed near this component. The deduced mass ratio is 10. From the X-ray eclipse duration we may determine the inclination angle and then using the third Kepler law and assuming that the luminous component fills its Roche lobe, we derive the distance between the two components ($A = 16\ R_\odot$), the radius of the primary ($R = 10\ R_\odot$) and the masses of both components: 24 $M_\odot$ and 2.4 $M_\odot$. From the spectral type O7 of the primary, its radius, the magnitude and the distance we derive a temperature (log T = 4.54) and a bolometric magnitude of $M_{bol} = -7.9$ which corresponds to $\log L/L_\odot = 5.1$. Using our own evolutionary tracks this leads to a mass of 27 $M_\odot$ for the primary (and 2.7 $M_\odot$ for the neutron star). We note that this system does not require a strong mass loss, unlike other X-ray binaries.

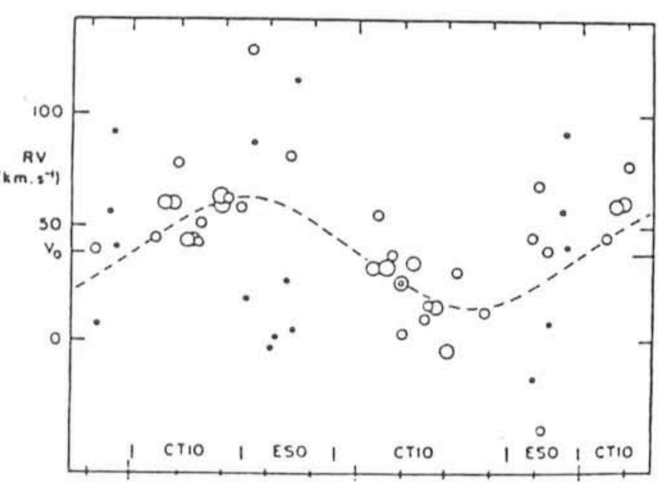

Fig. 4: *Cen X-3. Radial velocities and adopted circular orbit. Size of points indicates weight. Phase bins of CTIO and ESA data indicated (Hutchings et al., 1979, Astrophys. J.* **229,** 1079).

Wra 977 (4U 1223-62)

For this source more than 50 spectra have been collected so far by our group. The collection consists mainly of 62 Å/mm Echelec plates, obtained with the 1.52-m ESO telescope and the Lallemand camera between 1977 and 1981. Our experience with Vela X-1 already taught us that a large collection of plates is necessary to allow a satisfactory analysis. This is even more true in the case of Wra 977 where the orbital period is larger and where it is not possible to obtain plates of the quality of the 12 Å/mm coudé plates (as was our luck with Vela X-1).

The Echelec spectra can yield reliable radial velocities, provided that a careful and rather elaborate reduction procedure is followed. Even then the spectra have to be added by two at least in order to make the lines stand out from the noise. This clearly reduces the effective number of spectra available. Another problem is that we are not sure of the real period (in fact it is one of our main aims to determine it unequivocally), so that we are not sure to have a good phase coverage. Different periods have been proposed. The most likely, suggested from photometric data, is ~35 days. Such a period would be adequately covered by our plates.

4U 1538-52

This X-ray binary is very well suited for radial velocity studies, since it has a short period and is a pulsar. We have taken some spectra with the image tube, at the 3.6-m ESO telescope, with a reciprocal dispersion of 30 Å/mm; they are comparable with the LMC X-4 spectra with respect to the number of lines and their shape. The magnitude also is comparable. The orbital period of the system is short, 3.7 days. The pulse period is 529 s.

Combination of the radial velocity curves in the optical and in the X-ray range will allow to determine the masses of the components.

Cen X-3

This X-ray binary has an orbital period of 2.087 s, is eclipsing—the eclipse time is 0.5 d, the neutron star component is a

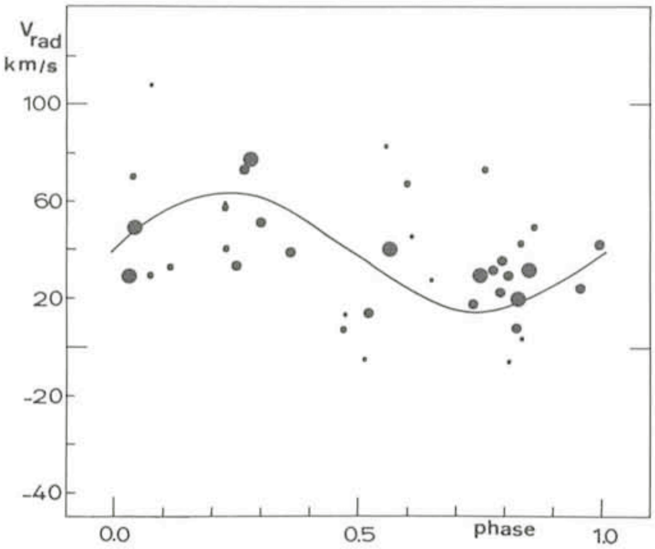

Fig. 5: *Cen X-3. Radial velocity curve derived from lines of Hγ, Hβ, He I 4471, He II 4541, obtained from Echelec and image-tube spectra. Size of points indicates weight. v_o = 39 km s^{-1}; K = 15 km s^{-1}.*

pulsar with a spin-period of 4.8 s. According to these characteristics Cen X-3 should be a marvellous candidate for a detailed analysis. However, the object is rather faint (13^m.6), so that high-resolution spectra cannot be obtained, and the spectrum is not rich in easily visible lines. An estimate of the radial velocities was performed by Hutchings, Cowley, Crampton, van Paradijs and White (1979, *Astrophys. J.* **229,** 1079) from image-tube spectra, 40 Å/mm, obtained at Cerro Tololo and at La Silla (Fig. 4). The amplitude is low, about 24 km s^{-1}.

Observations of this source with Uhuru, Ariel V and COS-B revealed that high and low states occur which can be explained in terms of an accretion disk.

In March 1976 Echelec spectra were obtained by the Observatoire de Meudon, using the 152-cm ESO telescope. The analysis of the ten 62 Å/mm spectra reveals periodic radial velocity variations in the HE II 4686 emission line, with a semi-amplitude of 400 km/s anticorrelated with the radial velocity variations of the Balmer He I and other He II lines.

In March 1981 fifteen image-tube spectra were obtained with the 3.6-m telescope at La Silla (reciprocal dispersion 30 Å/mm, widening 0.75 mm) by the Astrophysical Institute Brussels and the Astronomical Institute Amsterdam. This material was treated (partly at Meudon, partly at Brussels) together with some 20 Echelec plates, collected in 1977, 1978 and 1979, with a reciprocal dispersion of 62 Å/mm.

The radial velocity curve derived from the Hγ, Hβ, He I 4471 and He II 4541 lines is shown in Fig. 5. The analysis confirms the results of Hutchings et al.: v_o = 40 km/s, semi-amplitude = 25 km s^{-1}. The mass ratio is q ~ 18. From the eclipse duration we can derive that i is near 90°. The masses for the optical companion and the compact object are then 18 $M_\odot$ and 1 $M_\odot$ respectively.

Conclusions

The results obtained thus far show that the determination of radial velocity curves leads to reasonable values for the masses of the components of pulsating X-ray binaries. The masses derived in this way seem to agree with the general accepted picture of the evolution of massive close binaries, calculated with rather large mass loss rates, except for LMC X-4. Indeed, their position in the Hertzsprung-Russell diagram corresponds with the masses at our evolutionary tracks for decreasing mass, computed with mass loss rates about a factor 4 larger than the mass loss rates found in normal O-type stars. X-ray systems represent advanced stages of close binary evolution and offer us valuable information on the evolution of massive close binaries. Observations of X-ray sources therefore have to be continued. More specifically, elaborate radial velocity studies using a large amount of spectra for many sources will lead to accurate mass determinations as well for the optical component as for the compact companion; these latter masses are very important for the study of matter at extreme dense conditions.

Observations of the Small Amplitude β Cephei Stars

M. Kubiak, Warsaw University Observatory and Observatorium Hoher List

The reason why stars do sometimes pulsate seems to be satisfactorily explained by the present theory of stellar stability. The small but "irritating" exception is only the group of β Cephei stars: the physical mechanism of their variability remains till today essentially unknown. Observational characteristics of these stars can be summarized as follows: (i) they are located in a rather narrow instability strip on the H-R diagram in the vicinity of effective temperature of about 20,000° or spectral types B1–B2; (ii) periods are of the order of a few (3–6) hours; (iii) in some cases the shape of spectral lines varies with phase, the lines being broad on the descending and narrow on the ascending branch of the radial velocity curve; (iv) radial velocity curves are sometimes asymmetric or even discontinuous, particularly for the stars with large amplitudes; (v) maximum light occurs near the phase when the descending branch of the radial velocity curve crosses the mean velocity; (vi) in some of these stars two or more close frequencies are excited; in two cases triplets of equally spaced frequencies are observed.

All these features (except the first one) find more or less satisfactory explanations if we assume that β Cephei stars undergo non-radial oscillations. Fully admissible from the physical point of view, non-radial oscillations differ from the well-known radial pulsations in this respect that the elements of the star surface are subject to both radial and horizontal displacements. The surface of the star can be envisaged as being in a state of wavy motion, the waves being standing or propagating. The character of the motion (or the mode of oscillation) is fully described by two integer numbers l and m which, roughly speaking, give for a rotating star the number of nodes between the poles and the number of crests and valleys on the equator, respectively. Opposite signs of the same m denote similar waves propagating in opposite directions.

The complicated velocity field on the surface in interplay with general rotation of the star gives rise to characteristic profile variation during the cycle. For any (l, m) mode and phase, the shape of the profile can be computed numerically by summing

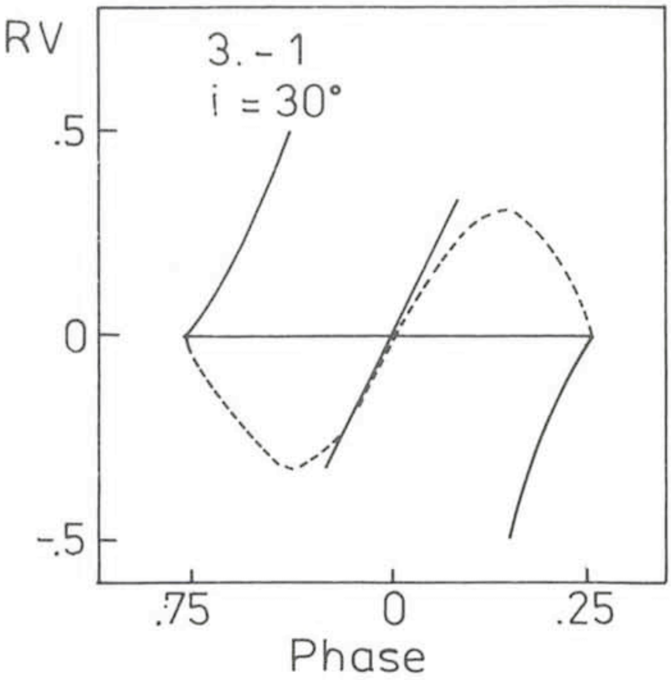

Fig. 1: *Radial velocity curve calculated for the mode (3, −1) and aspect angle 30°. The full line corresponds to the case where the line produced in the stellar atmosphere is infinitely narrow. The broken line represents the more realistic case of the line having intrinsic Gaussian shape. The vertical scale is arbitrary.*

up the contributions to the radial velocity coming from all points on the visible disk. Free parameters are: amplitude of velocity variations on the surface and aspect angle between the axis of rotation and the direction toward the observer. The immediate result of profile calculations is the observed radial velocity curve. The light variations can easily be found analytically; in the limits of linear approximations, they are sinusoidal for all modes, with the observed amplitude depending in a known way on the aspect angle.

Without going further into details, it is intuitively clear that the observed effects of non-radial oscillations must depend on the order l of the mode. For large l, when many waves are seen simultaneously, the changes of physical parameters across the disk will be "averaged" and the net effect will be small. In practice we do not expect to observe modes with l greater than, say, four. In other words, stars with strong light and radial velocity variations may rather—if at all—be identified with low l modes. In fact, essentially all results of mode identification based on observations of profile and radial velocity variations lead to the conclusion that in large amplitude stars, running waves corresponding to l equal 1 and 2 are most probably excited. The validity of this method of mode diagnostic is however restricted by two facts: firstly, β Cephei stars with large amplitude are scarce, and, secondly, the large amplitude of variations makes the presence of non-linear effects possible, which makes the unambiguous interpretation of the observed profiles more difficult.

Positive identification of modes in a large number of objects is of particular importance if we want to answer not only the question of how do these stars pulsate, but also why they are doing so? Among many ingenious mechanisms of β Cephei pulsation proposed till now, the most promising and simple seems to be the Stellingwerf's mechanism connected with some peculiarities in the opacity of stellar envelopes (see e.g. Dziembowski and Kubiak 1981, *Acta Astronomica,* **31,** 153). If this mechanism is indeed the right one, then no particular modes should be privileged, and modes with l from zero (pure radial pulsation) up to about 10 should be almost equally possible. The excitation of high l modes is hardly predicted by other mechanisms.

It follows from what was said above that the chance of finding high l modes is greater among the stars with small amplitudes. In such cases, however, we may not expect much information from profile or radial velocity variation. Fortunately, the high l modes are in a sense more "peculiar" than the low l ones. As an example, Fig. 1 shows the radial velocity curve for the 3, −1) mode observed at aspect angle 30°. Full lines represent the variations which would be observed if the intrinsic width of the lines produced in the atmosphere were infinitely small. The broken line is the same curve but obtained from lines having Gaussian shape. It can be seen that in both cases the phase relation between light (which has maximum at zero phase) and radial velocity variations should be opposite. This is only an example and more extensive calculations may reveal other interesting features of other modes.

Having in mind the possible importance of small amplitude β Cephei stars, Dr. W. Seggewiss and I included in our programme of simultaneous spectroscopic and photoelectric observations of β Cephei stars two small amplitude objects: ν and β Centauri. Thanks to the courtesy of the European Southern Observatory we had to our disposal the 1.52 m

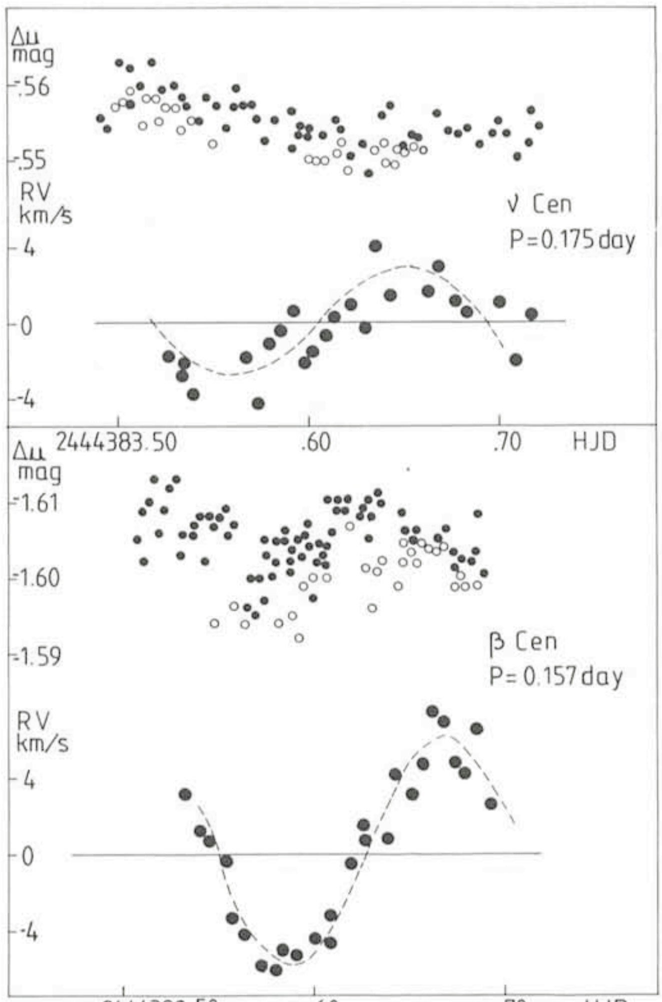

Fig. 2: *Light and radial velocity curves of ν and β Cen. Open circles denote photoelectric observations made on other nights and reduced to the night of simultaneous spectral and photoelectric observations. Only relative values are given.*

spectrographic and 0.5 m Danish telescopes at La Silla. The 12.3 Å/mm coudé plates of ν Cen were reduced at the ESO Data Reduction Centre in Garching, and the 3.3 Å/mm plates of β Cen were measured with the oscilloscope setting comparator at the Hoher List Observatory. Photoelectric observations were carried out with the aid of simultaneous four-channel uvby photometer. The results of these observations are shown in Fig. 2.

The radial velocity curves, in spite of their small amplitudes, are well defined and do not show any peculiarities. The accuracy of observations seems to be sufficient for determining both the moments of particular phases and the amplitudes (about 3 km/s for ν Cen and 6 km/s for β Cen). Points denote velocities actually observed, the broken line is a sinusoid fitted by eye to the observations. Both objects are bright, so the exposure times were typically 2–3 min.

The high brightness of the stars complicates somewhat the photoelectric observations. Fortunately for ν Cen a good comparison star exists, so the variability in the u-band with an amplitude of about 0.004 mag could be detected. The reality of the changes is confirmed by the observations made four nights later (open circles). Observations of β Cen were more difficult and are certainly less accurate. This star (one of the brightest in the sky) could be observed only with appropriate shielding of telescope aperture. The only reasonable comparison is α Cen differing largely in position and spectral type. Nonetheless, observations from two nights (dots and open circles), though not of excellent quality, strongly suggest the variability in the u-band with an amplitude of approximately 0.005 mag. (As was to be expected no trace of variability of these stars could be found in the B and V bands.)

Nevertheless, inspection of Fig. 2 immediately shows the different behaviour of the two stars. Phase relation between light and radial velocity in the case of ν Cen obeys the general rule that in β Cephei stars the maximum of brightness occurs at the descending branch of the radial velocity. In this respect the behaviour of β Cen seems to be opposite: maximum of brightness—if real—corresponds clearly to the middle of the ascending branch.

It would be premature at the moment to draw any firm conclusion about the mode excited in β Cen from the direct comparison with Fig. 1. It seems clear, however, that observations of small amplitude β Cephei stars, although troublesome, are worth being done and may really contribute to our understanding of these objects.

The Galactic Abundance Gradient

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S. R. Pottasch, Kapteyn Astronomical Institute, Groningen

Introduction

The study of chemical abundances and their variation from one galaxy to another or within individual galaxies is of fundamental importance for our understanding of the evolution of galaxies. The abundances of heavy elements in the interstellar medium provide a fossil record of the enrichment which has taken place due to nucleosynthesis in successive generations of stars. Gradients of heavy element abundances with distance from the galactic centre are predicted by models in which the rate of star formation varies across the galactic disk, and by dynamical collapse models of galactic evolution which involve fresh infall of primordial gas onto the disk over long periods of time. Different models predict different abundance gradients (in slope and shape), and abundance measurements give constraints on these models (see Pagel and Edmunds, 1981, *Ann. Rev. Astron. Astrophys.* **19,** 77, for a recent review).

H II regions provide the most accessible probe of current interstellar abundances. In computing abundances from line intensity ratios, an accurate knowledge of the electron temperature is essential: a 40 per cent change in the temperature can change the abundance by an order of magnitude. Optically, temperatures can only be measured for the brightest and hottest H II regions, and this severely limits the number of H II regions for which "absolute" abundances can be determined.

Radio recombination lines can be used to obtain accurate electron temperatures for a much larger number of galactic H II regions. They are strongest when the temperature-sensitive optical lines are weakest, i.e. at low temperatures. In addition they can readily be detected from relatively faint or heavily reddened H II regions. Thus the radio and optical methods are truly complementary. By carefully choosing the radio recombination lines to be observed in accordance with the emission measures of the H II regions, non-LTE corrections can be kept down to a few per cent, and uncertainties in the resulting temperatures are then limited only by observational factors, typically 5-10 per cent.

We have combined radio and optical spectroscopic observations of a large number of galactic H II regions in a novel approach to the determination of abundances and their distribution across the galactic disk. Accurate temperatures have been measured for 67 H II regions located between 3.5 and 13.7 kpc from the galactic centre; optical spectra have been obtained for 32 of these H II regions, bringing the total number of galactic H II regions with known (absolute) abundances from 18 to 43.

Some Preliminary Results

The radio observations were made using the 210-foot radio telescope at Parkes in Australia. Sample spectra, showing the 109α lines of hydrogen and helium, and the 137β line of hydrogen, are given in Fig. 1. These lines arise from transitions in the extreme outer parts of the atoms: the 109α line is due to a $n = 110 \rightarrow 109$ transition (n = principal quantum number), and the 137β line is due to a $n = 139 \rightarrow 137$ transition. Of special interest in Fig. 1 is the narrowness of some of these lines, proving that some H II regions have electron temperatures below 5,000 K ($\simeq$ 15 km s^{-1}).

Optical spectra were obtained using the Image Dissector Scanner (IDS) and the Image Photon Counting System (IPCS) on the ESO 3.6-m telescope, and with the IPCS at the Anglo-Australian Telescope. Fig. 2 shows a representative selection of these spectra. Variations in excitation conditions, temperature, and abundances are revealed by changes in the [O III]/Hβ

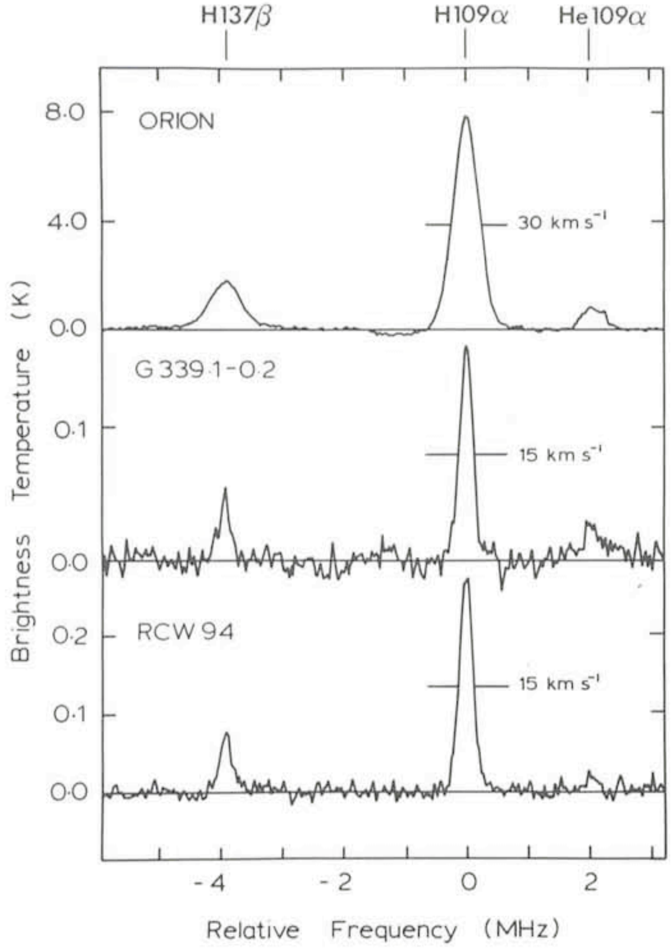

Fig. 1: *Radio spectra of three galactic H II regions at 5 GHz, showing recombination lines of hydrogen and helium. Note particularly the narrowness of the lines from G 339.1-0.2 and RCW 94, proof that their electron temperatures are less than 5,000 K.*

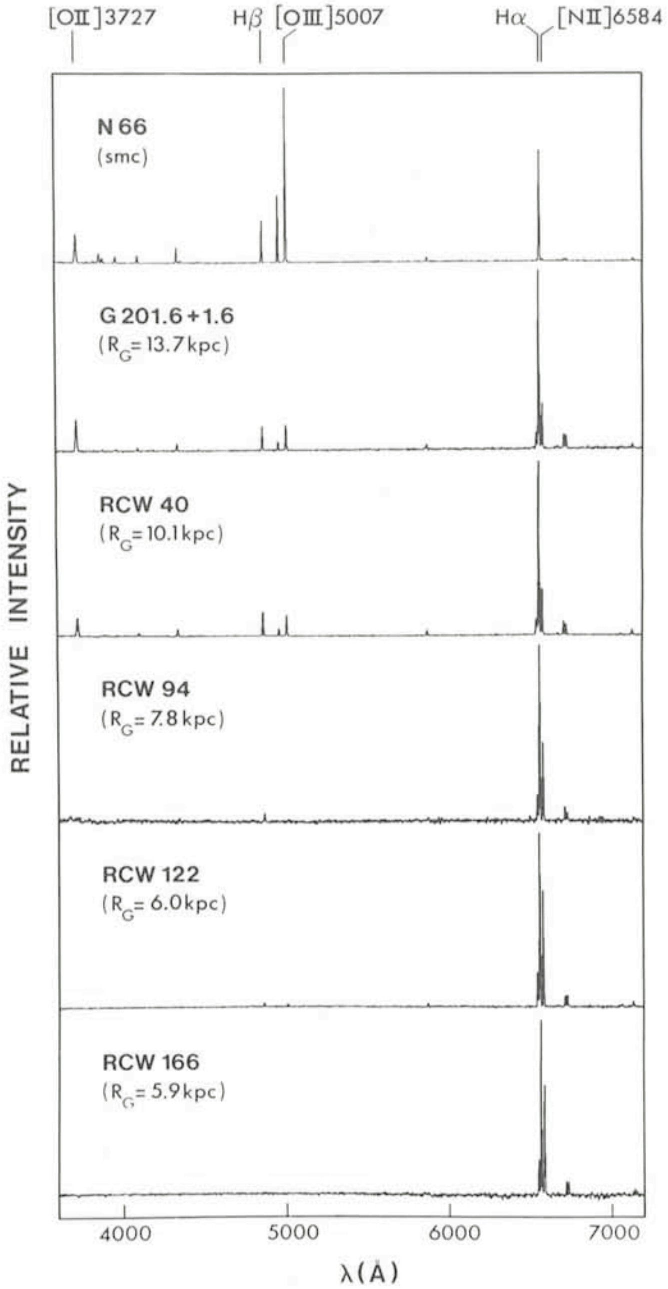

Fig. 2: *Optical spectra of six representative H II regions, showing the wide range of excitation and reddening found in the sample.*

and [N II]/Hα ratios. The strong reddening evident in the bottom three spectra highlights the difficulty in finding candidates for optical observations in the important region within 7 kpc of the galactic centre.

The radio-determined electron temperatures, corrected for the small deviations from LTE, were applied to these optical spectra to compute abundances. At this point an additional uncertainty enters, related to possible stratification effects within each H II region: the temperatures of the O^+, O^{++}, N^+, and H^+ zones may differ significantly from each other. Photoionization models (such as those by Stasinska, 1980, *Astron. Astrophys.* **84,** 320) suggest that such differences can be important especially below 7,000-8,000 K. Thus the derivation of abundances from optical spectra using radio temperatures is to some extent model-dependent, and the uncertainty is greatest at low temperatures (and therefore in the inner regions of the galaxy).

Fig. 3 shows the electron temperatures (from the radio data), the He^+/H^+ ratios (from radio and optical data), and preliminary oxygen and nitrogen abundances (from the radio temperatures, the optical spectra, and one set of models), plotted against galactocentric distance. Gradients are clearly present in T_e, O/H, and N/H, but not in He^+/H^+.

The T_e and O/H gradients are mutually consistent, on the assumption that oxygen is the prime coolant in H II regions. On the other hand, the range of temperatures at a fixed R_G is due in large part to the range of effective temperatures of the exciting stars and to the range of densities of the H II regions: most of this spread is real, and not due to observational error.

The absence of any significant gradient in He^+/H^+ may be due to two effects which roughly balance each other. The total helium abundance may increase with metallicity, i.e. towards the galactic centre, due to helium production in stars. On the other hand the increasing metallicity may reduce the relative number of helium-ionizing photons, and therefore the He^+/H^+ ratio, due to line blanketing in the stellar atmospheres.

Finally, the similarity of the oxygen and nitrogen abundance gradients is surprising, because these are thought to be primary and secondary nucleosynthesis products respectively. Primary elements have ^1H or ^4He as their direct progenitors, whereas secondary species are formed by subsequent processing of a primary element. Thus, the abundance of a secondary element should increase as the square of the abundance of its primary progenitor. Most metals do vary in lockstep with oxygen, as expected for primary elements. The fact that the nitrogen abundance gradient is not much steeper suggests that much of the nitrogen may also be of primary origin. A further puzzle arises in the fact that several isotopic ratios ($^{18}O/^{17}O$, $C/^{13}C$, $S/^{34}S$, $N/^{15}N$, etc.), measured at millimeter wavelengths, are constant to a high degree over the plane of the galaxy, in apparent contradiction to the marked gradients in O/H, S/H, etc. (Wannier, 1980, *Ann. Rev. Astron. Astrophys.* **18,** 399). These facts seem to call for a revision of our ideas about nucleosynthesis.

It is thought that the disk of our galaxy formed gradually, with infall of primordial gas extending over a long period. The main evidence for this is the shortage of old stars in the disk with low abundances. These infall models share the prediction that the abundance gradient should flatten off in the inner regions of the disk (Tinsley and Larson, 1978, *Astrophys. J.* **221,** 554; Chiosi, 1980, *Astron. Astrophys.* **83,** 206). There is no evidence for this in Fig. 3, but there are a number of ways out of this dilemma, such as postulating infall of metal-enriched gas from stars in the galactic bulge. There are clearly many free parameters in such models, but an increasing array of observational data will hopefully provide the constraints necessary to ultimately distinguish the actual evolutionary scenario.

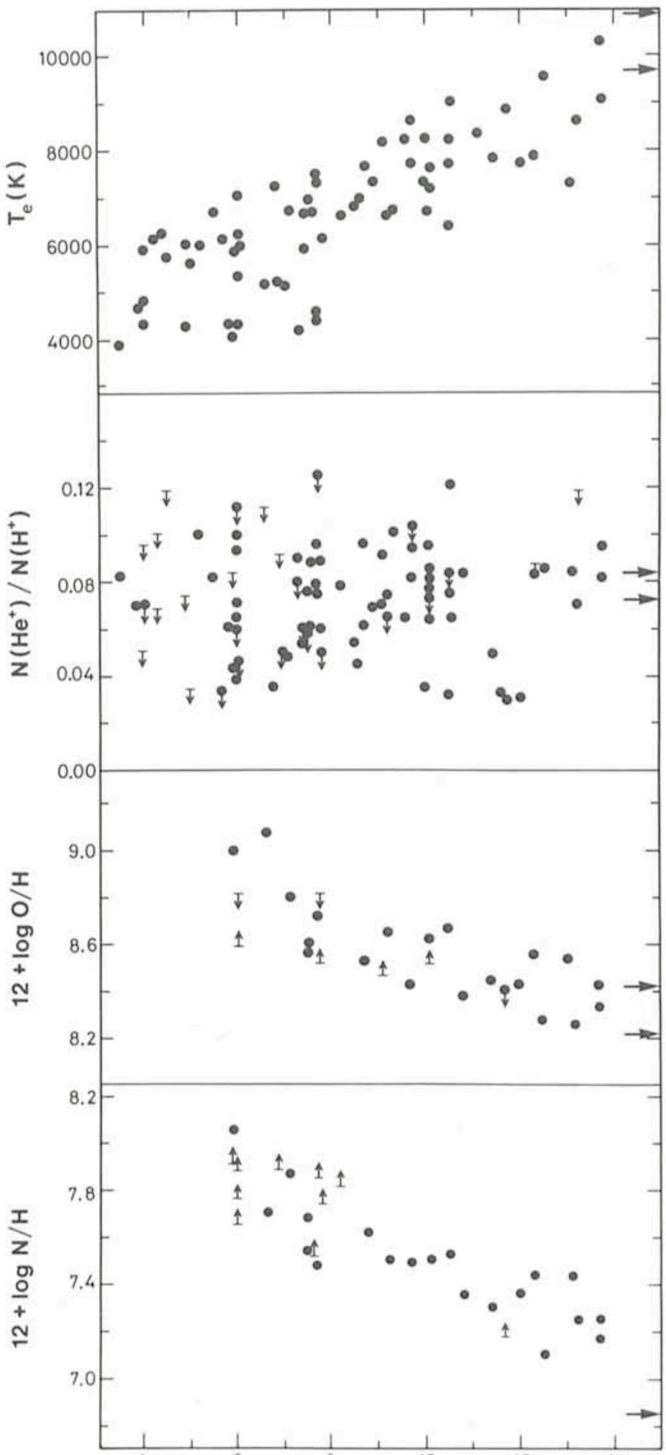

Fig. 3: *Variations of electron temperature and preliminary abundance ratios He^+/H^+, O/H, and N/H, as a function of distance from the galactic centre. Arrows to the right indicate values for the LMC (30 Doradus) and SMC (N66).*

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177. J. Breysacher, A.F.J. Moffat and V.S. Niemela: Wolf-Rayet Stars in the Magellanic Clouds. II. The Peculiar Eclipsing Binary HD 5980 in the SMC. *Astrophysical Journal.* December 1981.
178. E. Athanassoula, A. Bosma, M. Crézé and M.P. Schwarz: On the Sizes of Rings and Lenses in Disk Galaxies. *Astronomy and Astrophysics.* December 1981.
179. I.S. Glass, A.F.M. Moorwood and W. Eichendorf: Mid-Infrared Observations of Seyfert 1 and Narrow-Line X-ray Galaxies. *Astronomy and Astrophysics.* December 1981.
180. S. D'Odorico and M. Rosa: Wolf-Rayet Stars Associated to Giant Regions of Star Formation. IAU Symposium 99 on Wolf-Rayet Stars. December 1981.
181. J. Materne, G. Chincarini, M. Tarenghi and U. Hopp: Optical Investigations of Two X-ray Clusters of Galaxies: 0430.6-6133 and 0626.7-5426. *Astronomy and Astrophysics.* January 1982.
182. M. Rosa and S. D'Odorico: Wolf-Rayet Stars in Extragalactic H II Regions: II. NGC 604—A Giant H II Region Dominated by many Wolf-Rayet Stars. *Astronomy and Astrophysics.* January 1982.
183. W. Bijleveld and E.A. Valentijn: Radio and X-ray Observations of the Abell 2241 Galaxy Clusters. *Astronomy and Astrophysics.* January 1982.
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186. G. Setti and L. Woltjer: The Origin of the X- and γ-ray Backgrounds. To be published in the Proceedings of the Vatican Study Week on "Cosmology and Fundamental Physics", Rome, Sept. 28–Oct. 2, 1981. February 1982.
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188. R.M. West and H.E. Schuster: The ESO Quick Blue Survey and ESO (B) Atlas. *Astronomy and Astrophysics,* Suppl. February 1982.
189. W. Eichendorf, A. Heck, B. Caccin, G. Russo and C. Sollazzo: UV, Optical and IR Observations of the Cepheid R. Muscae. *Astronomy and Astrophysics.* February 1982.
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Extremely Metal-poor Subdwarfs

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Introduction

The formation of our Galaxy and its evolution from an extended spherical halo to a highly flattened spiral disk can be convincingly documented by observing cool dwarf stars that have remained essentially unevolved since they formed billions of years ago. Model predictions of nucleosynthesis in stars, starting from a zerometal primordial composition, combined with a theoretical outline of the galactic collapse, have led to a coarse description of the history of our Galaxy, in which the oldest stars are extremely metal-poor and have highly eccentric galactic orbits with relatively small orbital angular momenta as compared with young disk stars.

Although the photometric and spectroscopic observations obtained in the last two decades have been found consistent with theoretical predictions, there still remain many open questions regarding the detailed kinematical and chemical evolution of the pre-disk stage of our Galaxy:

(a) What were the physical conditions in the interstellar gas out of which the stars formed during the galactic collapse phase? We know that the initially chaotic gas motions have settled towards a fairly regular rotation pattern, with a minimum dispersion in galactic orbital velocities.

(b) Was there a similar decay of random gas motions on a smaller scale, possibly related to the binary formation rate? Comparative observational evidence concerning the frequency of binaries among disk and halo stars rather seems to contradict such an assumption.

(c) How reliable are the current models describing the nucleosynthesis of heavy elements? Recently published abundance analyses of halo stars fail to confirm the even-odd effects predicted from purely explosive carbon, oxygen and silicon burning.

While it is certainly necessary to improve the methods used to interpret the available spectroscopic information, it seems indispensable to carry out new observations by taking advantage of fast modern detectors. Here, we present a preliminary report on the results of our programme which is designed to obtain radial velocities and element abundances of metal-poor subdwarfs. Since there are so few subdwarfs in the solar neighbourhood, we have aimed at reaching FG-type dwarfs fainter than $V \cong 8$, corresponding to distances $\gtrsim 50$ pc.

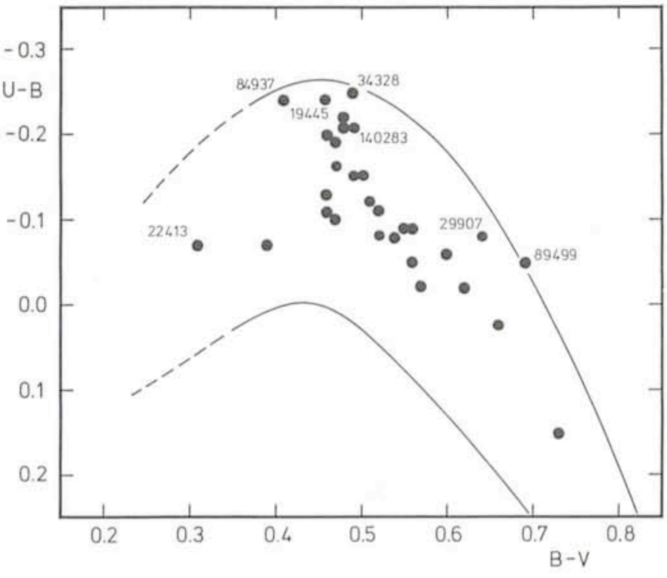


Fig. 1: *Two-colour diagram showing metal-poor subdwarfs observed at the ESO 1.5-m and MPIA 2.2-m telescopes. The lower curve is the Hyades main sequence. The upper curve represents the locus of stars with zero-metal content. Selected subdwarfs are labelled by their HD numbers.*

Observations

Due to the faintness of halo subdwarfs the limited observing time requires some kind of compromise concerning the selection of objects and spectral resolution. Accordingly, our observing programme was split in two parts: Low-resolution (40 Å/mm) spectra were obtained on IIIa-J emulsion with the B+C Cassegrain spectrograph at the ESO 1.5-m telescope. The stars on this list were selected according to their ultraviolet excess, δ (U-B) > 0.10, which was estimated to represent an upper limit of ~ ⅓ of the solar metal abundance. The low-resolution spectra were intended to measure radial velocities and to provide an improved estimate of the metal content. For the second part of the programme the apparently most metal-poor subdwarfs were observed with the echelle spectrograph and the Lallemand electronographic camera at the Coudé focus of the ESO 1.5-m telescope. The observations covered the blue spectral region from 3900 to 4400 Å, with a resolution of 150 mÅ, and the limiting magnitude for a 3-h exposure was B ~ 10. Additional spectra have been obtained directly with the f/3 camera at the Coudé focus of the MPIA 2.2-m telescope on the Calar Alto in Spain. These spectra are currently used to determine abundances of individual elements. All stars observed so far are presented in a two-colour diagram in Fig. 1, where the lower curve shows the Hyades main sequence, and the upper curve represents the positions of subdwarfs with zero-metal content. Some of the more interesting objects are labelled by their HD numbers.

The reduction of the echelle spectra is relatively simple, provided that a two-dimensional microphotometer and a computer with graphic interaction facilities are available.

It turns out that the quality of the reduced echelle spectra is comparable with that of conventional coudé spectra. No significant loss of resolution is encountered and, under favourable conditions, it is possible to measure line strengths down to ~ 10 mÅ.

Results

(1) Kinematic Properties of the Subdwarfs

All the low-resolution spectra were measured with the MPIA Grant comparator, and mean radial velocities were derived combining our results with radial velocity data found in the literature. Unfortunately, reliable trigonometric parallaxes are known only for a few stars, and most of the parallaxes at present have to be estimated from photometry. The resulting kinematic properties of our metal-poor dwarfs are displayed in Fig. 2, where orbital velocity components in the direction of galactic rotation, V′, are plotted as a function of metal abundance. This diagram is similar to the well-known h vs. δ(U-B) diagram of Eggen, Lynden-Bell and Sandage (1962, *Astrophys. J.* **136,** 748). It shows that only about half of the stars belong to the halo population. According to its colours, HD 22413 is possibly a blue straggler. However its parallax and orbital velocity are highly uncertain. Three of the halo sub-

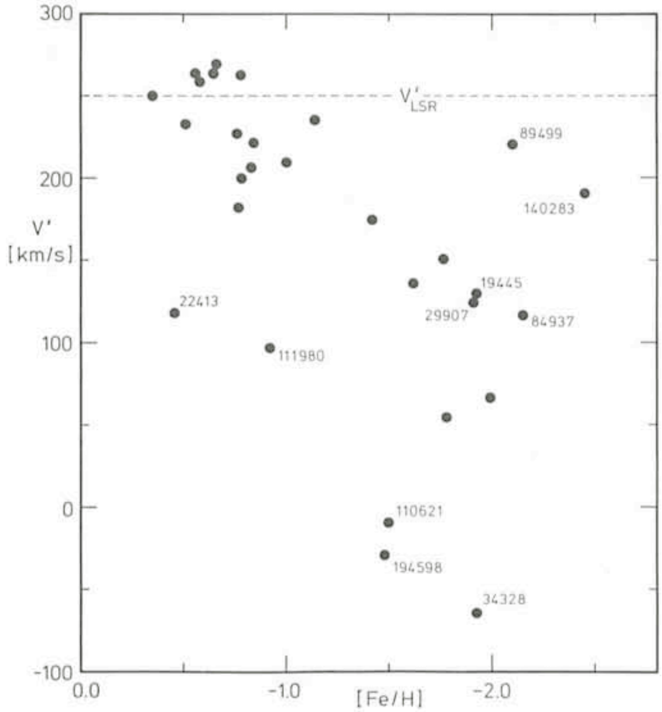


Fig. 2: *Galactic orbital velocities in the direction of galactic rotation for metal-poor subdwarfs as a function of [Fe/H], the logarithmic iron to hydrogen abundance ratio relative to the solar value.*

dwarfs, HD 34328, HD 110621 and HD 194598, move on retrograde galactic orbits.

HD 29907 turns out to have a total orbital velocity of ~ 400 km/s, which is near the local escape velocity of our Galaxy. Accordingly, this subdwarf belongs to the handful of kinematically extreme field stars (including BD+21°607, CD–29°2277, G238–30, G64–12, HD 134439/40, and possibly G21–33), which are known to impose important constraints on the modelling of our Galaxy. The adopted parallax for HD 29907 is a maximum value based on the position of the corresponding metal-poor main sequence.

Fig. 2 also illustrates that the rapid metal enrichment during the collapse phase of our Galaxy was accompanied by an increase in kinematic motions and a simultaneous decrease in the dispersion of orbital velocities and angular momenta. Tinsley and Larson (1978, *Astrophys. J.* **221,** 554) have proposed that the observed age dependence of the velocity dispersion of old stars was produced by a gradual decay with time of large-scale interstellar turbulent motions. If a similar decay with galactic evolution of small-scale turbulent motions took place, one might expect the frequency of binaries among halo stars to be *higher* than among disk stars, since the formation of binaries is supposed to depend on the state of local turbulence in the protostellar gas (Huang and Wade, 1966, *Astrophys. J.* **143,** 146). In fact, our observations appear to support this hypothesis. Comparison of our radial velocities with measurements of other authors reveals a scatter of radial velocity data shown in Fig. 3, where we have plotted the external probable error for a single plate, $\sigma(V_r)$. For stars like HD 89499, HD 29907, BD–3°2525 and HD 34328, radial velocity measurements differing by more than 20 km/s and up to 60 km/s indicate that these subdwarfs are probably spectroscopic binaries.

This result disagrees with empirical investigations of Abt and Levy (1969, *Astron. J.* **74,** 908) and Crampton and Hartwick (1972, *Astron. J.* **77,** 590), who found that at least short-period (spectroscopic) binaries seem to be *rare* among halo stars. On the other hand, a reinvestigation of the binary frequency among stars listed in the Nearby Star Catalogue reveals no deficiency of short-period binaries among high-velocity stars, provided that stars of sufficiently faint magnitudes ($V > 7$) are compared. In view of these contradictory results a more systematic approach to detect high-velocity spectroscopic binaries would be extremely valuable.

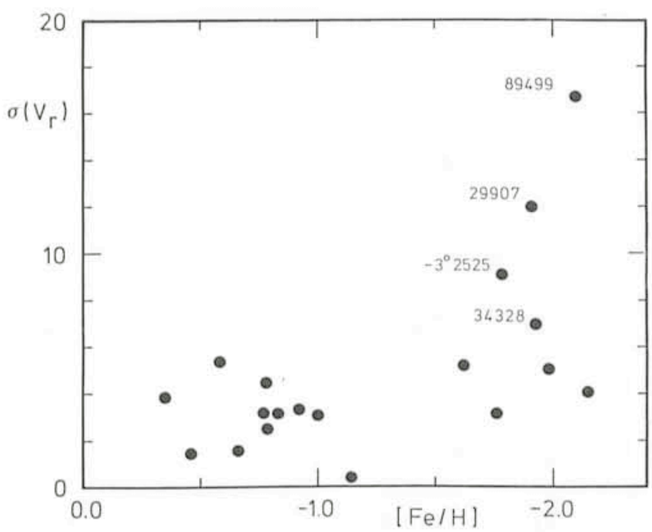


Fig. 3: *External probable error of radial velocities measured from a single plate as a function of metal abundance, including published radial velocities. Note the high fraction of possible spectroscopic binaries among the halo subdwarfs.*

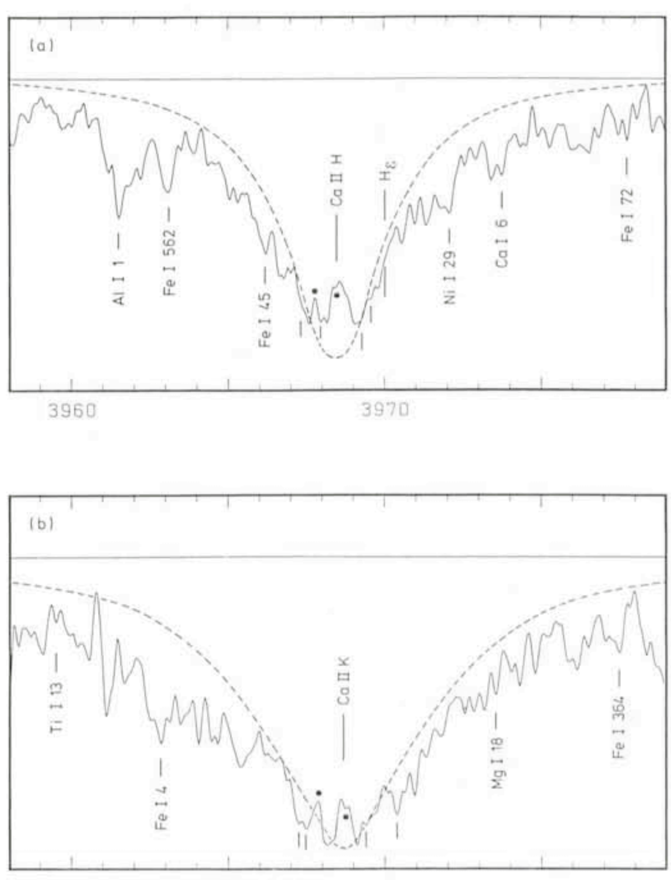


Fig. 4: *Echelle tracings of the Ca II H and K lines in HD 89499. The central emission cores are clearly visible.*

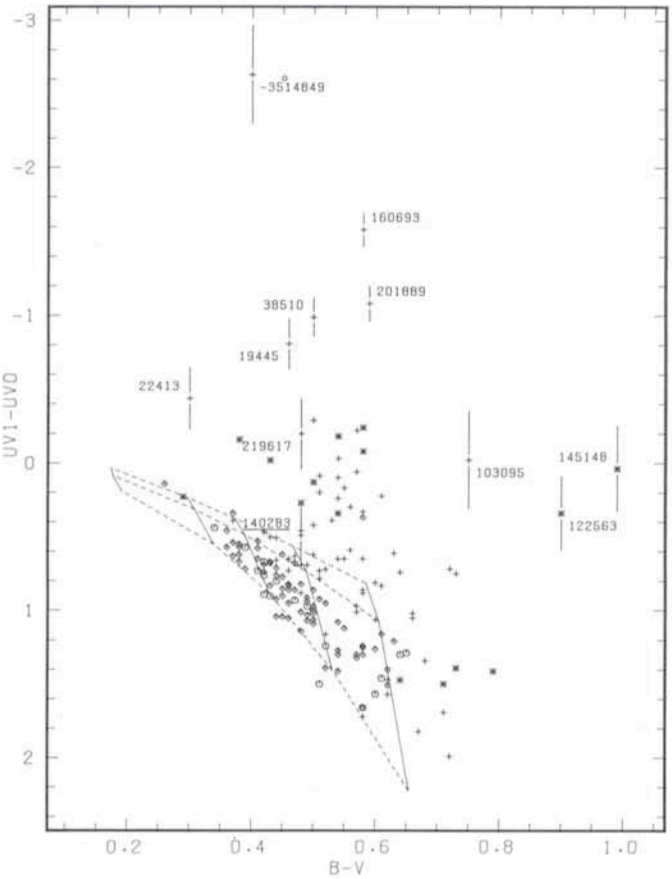


Fig. 5: *Two-colour diagram for late-type stars including all the stars in the lists of Abt and Levy (1976,* Astrophys. J. Suppl. **30,** *273, mostly population I) and Carney (1979,* A Catalogue of Field Population II Stars*), for which UV magnitudes have been measured from the TD-1 satellite. UV0 and UV1 refer to ~ 300 Å wide passbands centered on 2740 and 2365 Å, respectively. The model grid taken from Kurucz (1979) shows solid lines of constant temperature (starting with 5500 K on the right) and dashed curves of constant metal abundance (1, 0.1 and 0.01 solar from the bottom). Crosses are population II dwarfs, asterisks are population II giants or subgiants. Diamonds and circles refer to population I dwarfs and giants, respectively. Bars denote the observational errors.*

(2) Metal Abundances

Since detailed spectroscopic abundance analyses of the high-resolution observations will be published in a separate paper, we will give only a short summary of the results. According to model atmosphere analyses, iron abundances for 6 of the halo subdwarfs range from [Fe/H] = –1.3 to –2,2, generally in fair agreement with photometric predictions based on δ(U-B) or dm_1(b-y). Within the expected error limits, using solar oscillator strengths and damping parameter in differential analyses relative to the Sun, *none* of the heavy elements observed is overdeficient with respect to iron. In particular, the striking agreement in metal deficiency of odd-Z elements like ^{27}Al, ^{51}V, ^{55}Mn and ^{59}Co with ^{56}Fe definitely rules out purely explosive carbon and silicon burning in supernovae without assuming an appreciable increase of the neutron excess, η, prior to the ignition. According to Arnett (1971, *Astrophys. J.* **166,** 153), this could be achieved in a preceding stage of hydrostatic thermonuclear reactions.

Our results do not confirm the mild overdeficiency of the s-process elements Sr, Y and Zr for [Fe/H] < –1.5, found by Spite and Spite (1978, *Astron. Astrophys.* **67,** 23). However, except for the Sr II resonance lines which are strongly blended, the measured equivalent widths are very uncertain. The predicted ageing effect of s-process elements can be more readily detected by analyzing the strong Ba II lines, which are outside the spectral region we observed. For two of the subdwarfs it was possible to measure the Eu II 4129.7 line, and the corresponding abundances of the r-process element Eu are in agreement with those obtained for iron.

(3) The Peculiar Subdwarf HD 89499

The ultraviolet excess of HD 89499 is larger than that predicted for a star with zero-metal content (cf. Fig. 1). Recent photometry, combined with previously observed colours, indicates variations of Δ(U-B) ≅ 0.10 and Δ(B-V) ≅ 0.07. The echelle spectrum of this V = 8.7 mag star shows fairly broad lines with half widths 15 to 20 km/s in excess of instrumental resolution. Part of its spectrum is reproduced in Fig. 4, clearly displaying the relatively strong *emission cores* of the Ca II H and K lines. Model atmosphere analysis yields T_{eff} = 5300 K, log g = 4.25, and a fairly uniform metal deficiency of ~ 1/100 solar. Radial velocity measurements range from +6 km/s to –30 km/s and –85 km/s. Thus, there is no doubt that HD 89499 is a short-period spectroscopic binary. The Ca II line emission cores and the excessive metal line widths fit to a close binary model in which orbital and rotational velocities are coupled by tidal interaction.

(4) Satellite UV Excesses

In addition to the problems mentioned in the introduction, the ultraviolet stellar fluxes measured from the TD–1 satellite have confronted us with a surprising result: some of the metal-poor stars have UV excesses of 1 to 3 magnitudes. In Fig. 5 we have plotted a two-colour diagram in which the magnitudes UVO and UV1 refer to ~ 300 Å wide passbands centered on 2740 Å and 2365 Å, respectively. The excess is determined with respect to "normal" colours as synthesized from the grid of model atmospheres published by Kurucz (1979, *Astrophys. J. Suppl.* **40,** 1). The observed δ(UV1-UVO) by far exceed the probable uncertainties inherent to theoretical model atmospheres. While a satisfactory explanation of these strange and probably important observations has to be deferred until satellite observations with higher resolution become available, we may articulate our ignorance in a few comments:

(a) Although a moderate excess in UV1-UVO has been observed for a few population I stars, the overwhelming majority belongs to a metal-poor population (cf. Fig. 5).

(b) All the stars with excessive satellite UV fluxes also show considerable U-B excesses. However, the correlation of δ(UV1-UVO) with δ(U-B) or δm_1 is merely marginal. For instance, the colours of HD 140283, one of the most metal-poor stars known today, fit perfectly to what is expected from spectrum synthesis, whereas HD 19445, the "standard" halo subdwarf, has an excess of more than 1 mag.

(c) The observed δ(UV1-UVO) neither correlate with δc_1 (b-y), which rules out any explanation based on gravity effects. Moreover, model atmosphere computations predict a difference in UV1-UVO of less than 0.2 mag, when comparing dwarfs and giants.

(d) Except for CD –35°14849, all stars in Fig. 5 have UVO magnitudes quite in agreement with model predictions. The UVO and UV1 passbands are separated by the 2500 Å absorption edge of Mg I. However, the assumption of a peculiar Mg/Fe ratio is in contradiction to abundances derived from visual spectra of HD 19445 and HD 140283. In both passbands, the dominant source of line blanketing are low-excitation lines of Fe II, while UVO also contains the Mg II resonance lines. Thus, among very metal-poor stars, no combination of element abundances can plausibly explain the order of magnitude differences observed in the UV1 passband.

Unless the reported observations are completely unreliable, our arguments suggest an explanation outside the conventional limits of single stars.

Conclusions

The external evidence for radial velocity variability among metal-poor stars presented above, which is at variance with previous observations, would seem to deserve a more extended systematic approach, preferably with a fast radial velocity spectrometer like the CORAVEL. Whereas the results of our abundance analyses definitely rule out the possibility of producing heavy elements by purely explosive carbon and silicon burning, more observational efforts must be dedicated to the nucleosynthesis of r- and s-process elements. In order to measure reliably the equivalent widths of faint rare earth lines, a resolution of 50 to 80 mÅ and a signal-to-noise ratio of 50 to 100 would be necessary. Unfortunately, at present, these specifications cannot be attained for halo subdwarfs. HD 89499 has emerged to be the first subdwarf observed to have a close companion. Its Ca II line emission cores as well as the large satellite UV excesses observed for some metal-poor stars strongly recommend further observations in the ultraviolet.

Our report would not be complete without mentioning the support of the ESO technical staff and night assistants, who helped to ensure a successful observing run.

Faint Satellites of Outer Planets

Ch. Veillet, CERGA, Grasse

Introduction

In astronomy, as in other matters, the charm of novelty is one of the important factors that govern the choice of the observations. How many objects saw suddenly many eyes or kinds of detectors looking at them, before finding again, some months or years later, their sidereal quietness! . . . However, it is often after a long time of regular observations that they confide a (small) part of their secrets. The faint satellites of planets don't transgress this fortunately approximative rule. The deficiency in observations during many consecutive years makes the determination of their motion very difficult, and it is often too late to make up for lost time. We shall try to illustrate this fact in the next lines using the observations of the systems of Saturn, Uranus and Neptune we made in April 1981 on the Danish-ESO 1.5-m reflector.

Saturn

Except for sparse observations (like those by J. D. Mulholland with the 2.1-m reflector at McDonald Observatory, USA), the vicinity of Saturn has been poorly observed in order to look for faint satellites inside the orbits of the inner satellites. All the energies have been devoted to the rings. Suddenly, during the passage of the Earth through Saturn ring plane in 1979–80, and probably strongly incited by the Voyager flyby, the astronomers discovered many objects orbiting between the rings and Dione, i.e. at less than 45 arcseconds from the edge of the rings. If some of them are only visible while the rings are seen edge-on, the others can be observed even with an open ring, as is the case for Dione B (moving on Dione orbit) and for other bodies the observations of which remained unlinked up to our work.

The focal length and aperture of the Danish-ESO 1.5-m reflector are well suitable for a search for faint objects near a planet: Only a few minutes are necessary to record objects at magnitude 17–18 and the scale permits a good determination of the positions on the plates. You can see on Fig. 1 Dione B and a satellite moving on Thetys orbit which has been identified during an observing run at this telescope. A differential guiding has been used to follow the motion of Saturn during the exposures (less than 8 minutes) and a mask with eight circular apertures in the arms of the secondary mirror support vanes has been set at the front of the instrument in order to avoid the diffraction cross around the overexposed image of the planet which unfortunately would have been in the direction of the ring plane!).

The plates have been measured on a Zeiss measuring machine. The well-known satellites (Saturn II to VI) permitted to determine the parameters of the field around Saturn (scale, orientation, coordinates of the centre of the planet). Then the positions of the studied bodies could be obtained, and a least squares programme determines the best angular separation from Dione (or Thetys) which fits each observation. Fig. 2 shows the results obtained for the Thetys L_5 object. Its libration motion appears clearly, but the determination of its period is impossible: This satellite has not been observed at another epoch in 1981. . . .

Eight quasi-consecutive nights provided a series of positions of three faint satellites on the L_4 Lagrangian point of Saturn-Dione (Dione B) and the L_4 and L_5 points of Saturn-Thetys. This series has allowed the determination of an accurate position of the L_4 and L_5 Thetys objects, and thus to establish unambiguously the existence of one satellite at each of these points. We have also discovered a periodic variation of Dione B which can be explained by an eccentricity of about 0.012, five times the value found for Dione. An interesting point can be made after these observations: The facility in recording these objects (photographic plates at the Cassegrain focus of a reflector. . .) even with an open ring suggests the examination of old plates taken in equivalent conditions in order to get other positions or to affirm they were not present at a given epoch (for more information, cf. Ch. Veillet (1981, *Astron. Astrophys.* **102,** L5-L7). Some months later Voyager 2 observed both the Thetys objects as small rocks (50–60 km . . .).

Uranus

Going on with our trip among the planets, we stop near Uranus, planetary system forsaken by the observers for a long time. We find only a few observations from Miranda discovery in 1948 till the detection of the rings in 1977. The motion of Ariel, Umbriel, Titania and Oberon, the four "old" satellites, is quite well determined. But it is not so with the "youngest"! More than half of the available positions of this faint satellite up to 1977 cover the year following the discovery! However, an accurate determination of the motion of Miranda would permit a better knowledge of the gravitational parameters of the Uranian system: The mean motions of Ariel, Umbriel and Miranda

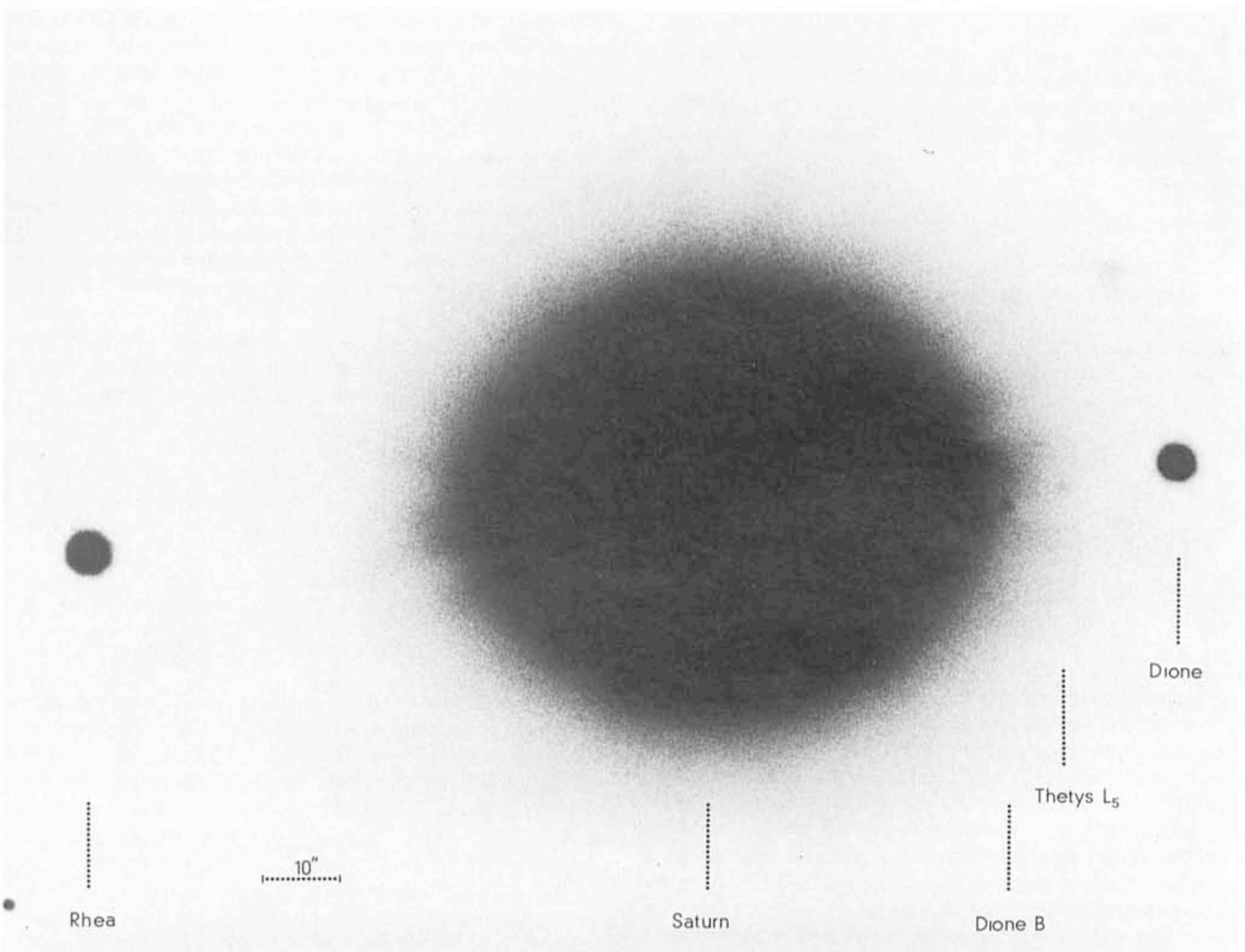


Fig. 1: *Dione B, moving on Dione's orbit, and Thetys L_5 object, moving on Thetys' orbit. 1981, Apr. 12, 03^h44^m UT, 8 mn exp. on III a-J plate. Voyager 2 observations give 50–60 km for their diameter.*

present a Laplacian near-commensurability which enhances the mutual gravitational effects and makes them observable. The only unknown parameter of the perturbations on the longitude of Miranda due to this near-commensurability is the mass product of Ariel and Umbriel. Thus we have a means to determine masses in the system of Uranus. At this time, it is the only one!

We initiated the programme of observations of Miranda at Pic-du-Midi in 1976 with the collaboration of Guy Ratier. It began to provide us with useful positions of this satellite in the 1977 Uranus opposition. The observational conditions were not the best ones: Uranus had a declination of less than –16° and its zenith distance was at least 60° . . . We used a prism near the focal plane of the 1-m reflector to remove the effect of the atmospheric dispersion, too large for an accurate measurement at this zenith distance. The magnitude of Miranda is about 16.5 (and 6 for Uranus) and its period is 1.4 day. An exposure time longer than 6 minutes is not consistent with a good image because of the fast motion of this satellite with respect to the planet. The brightness of Uranus and its proximity of Miranda—between 6 and 8 arcseconds from the planetary edge—make a good seeing during the observations absolutely necessary. Moreover, this proximity constraints us to work with a sufficient focal length. These observational requirements were gathered on the Pic-du-Midi 1-m reflector on which regular observations of Miranda have been made on the 1977–78–79 Uranus oppositions. The 70 new positions of Miranda thus obtained (C. Veillet and G. Ratier [1980], *Astron. Astroph.* **89,** 342) made possible the search of the gravitational effect of Ariel and Umbriel on Miranda theoretically predicted by Greenberg (1976. *Icarus* **29,** 427). A complete determination of the orbit of Miranda provided us with a value of the mass product of Ariel and Umbriel $\mu_2\mu_3 = (1.10\pm0.25)\times10^{-10}$ (expressed in units of mass of the planet) by including this parameter in the calculation as an independent unknown.

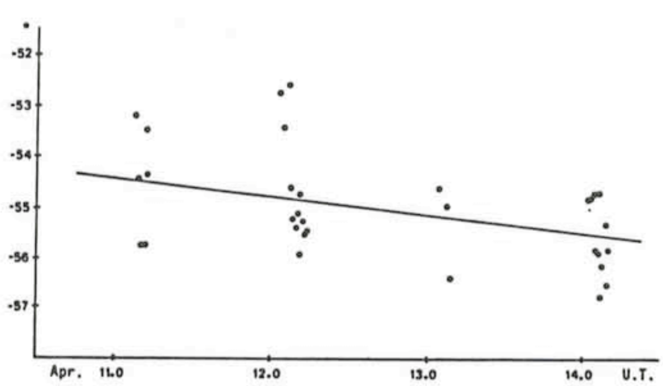


Fig. 2: *Angular separation of Thetys L_5 object from Thetys during the observing run. The slope is found to be $(-0^\circ\!.38 \pm 0^\circ\!.15)$/day.*

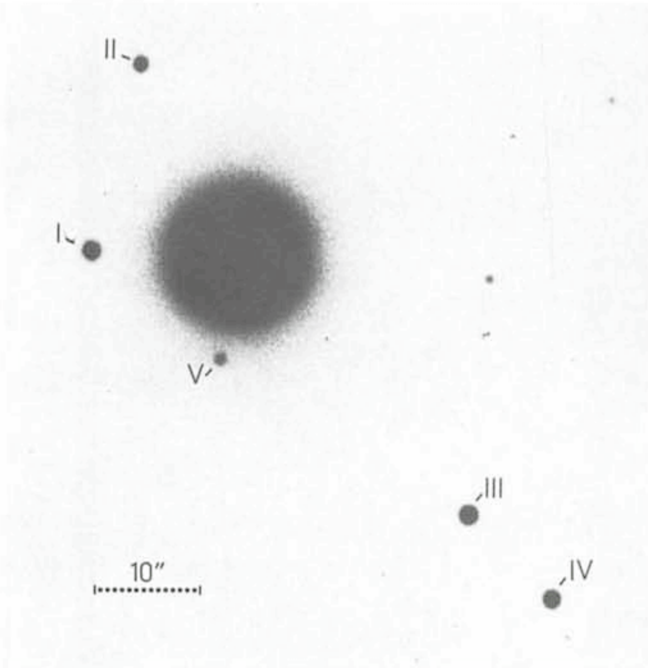


Fig. 3: *Uranus and its five satellites. I = Ariel – II = Umbriel – III = Titania – IV = Oberon – V = Miranda. 1981, 06, 07ʰ39ᵐ UT, 4 mn exp. on III a-J plate.*

In order to get a more accurate determination of the nodal and apsidal precession period, as well as a smaller error on the value of the mass product of Ariel and Umbriel, we decided to extend the observations on the Danish-ESO 1.5-m reflector. Its aperture and focal length are very suitable indeed for such a work and the La Silla location offers Uranus at the zenith to the observer! A first observing run by Guy Ratier in 1980 gave only a few plates of Miranda on half a night. The other nights were under wind and rain. . . However these observations were good enough to incite us to come again. It was lucky for us that we did: I obtained on eight nights from April 6 to 14 1988 about 80 positions of Miranda, more than in three years at Pic-du-Midi!

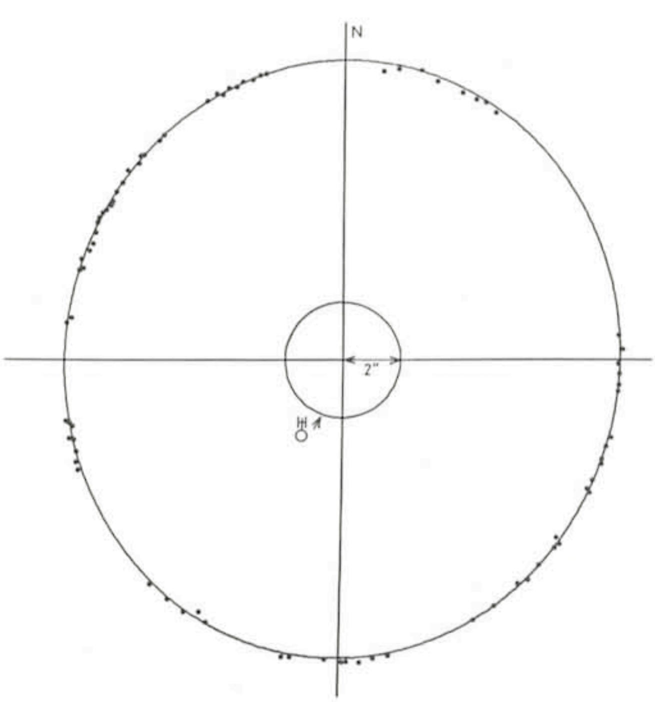


Fig. 4: *Observed positions of Miranda on the sky during the observing run (1981, April 6–14). The standard deviation of the 81 residuals in apparent distance from the plotted ellipse is 0.081 arcsecond.*

Fig. 3 shows a print of a typical plate obtained at La Silla. The diffraction cross is avoided in the same way as for the Saturn plates: Too often Miranda has the bad idea to be just behind one of their arms at the epoch of observation! Four minutes were sufficient to record this satellite well separated from the overexposed image of the planet. Measurements on a Zeiss measuring machine and a reduction using the four other satellites to determine the parameters of the field give the position of Miranda with respect to Uranus (too big on the plate to be measured directly). Fig. 4 shows the results of the 1981 observations. The pair Uranus-Miranda is seen as a double star with a separation between 8 and 10 arcseconds, and a magnitude difference about 10 between them. The high interest of these observations is that for the first time the apparent orbit of Miranda is "frozen", ruling out both nodal and apsidal precessions the periods of which are too long (18 and 16 years) to be taken into account on a week. The best ellipse fitting the observed positions is plotted on Fig. 4. Their parameters will permit an accurate determination of the inclination and longitude of the node on the equator of Uranus, assumed to be the orbital plane of Ariel and Umbriel. It will be possible to propose a set of new orbital parameters and to improve the value of the mass product of Ariel and Umbriel. The calculations are not yet achieved and will be published in the next few weeks.

Neptune

We shall end our visit of the outer planets with Neptune, an unfortunate body which has not filled the first pages of the astronomical news for more than 30 years. It was at the time of the discovery of Nereid in 1949 by Kuiper, a very faint (mg = 19) and eccentric (e = 0.756) object orbiting around its planet with a period of about 360 days. No rings up to now, no spacecraft in the next few years . . . and no published positions of Nereid since 1969! Van Biesbroeck and Kuiper have provided all available positions and their distribution is shown on Fig. 5. It is only in 1974 that Rose (*Astron. J.* **79,** 489) used these data to determine the elements of a Keplerian orbit. One year later, Mignard studied an analytical theory of the motion of this satellite including the perturbations due to the gravitational effect of the Sun on a very eccentric orbit (F. Mignard [1975], *Astron. Astrophys.* **43,** 359). But he didn't try to link this theory to the observations. In order to determine the mean elements of Mignard's work and to check the validity of this theoretical orbit, we initiated in 1981 a programme of observation of Nereid

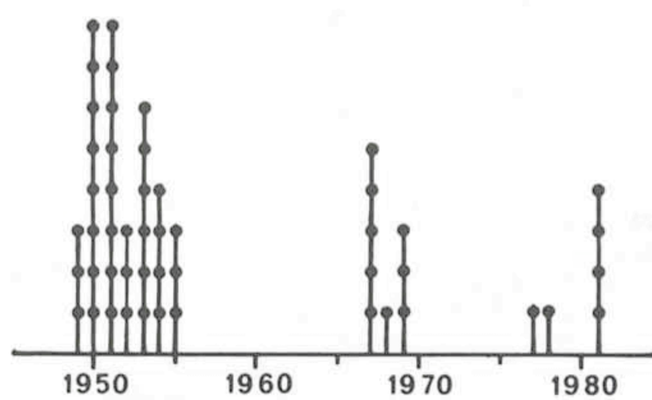
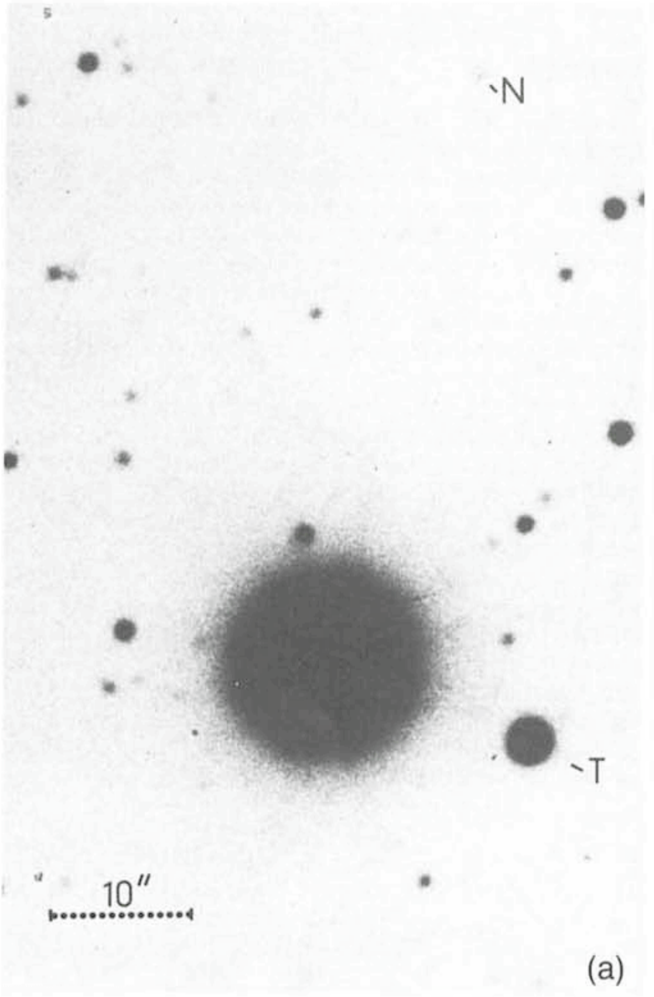


Fig. 5: *Plot of the number of Nereid observations (50) versus time. Each dot is one position.*



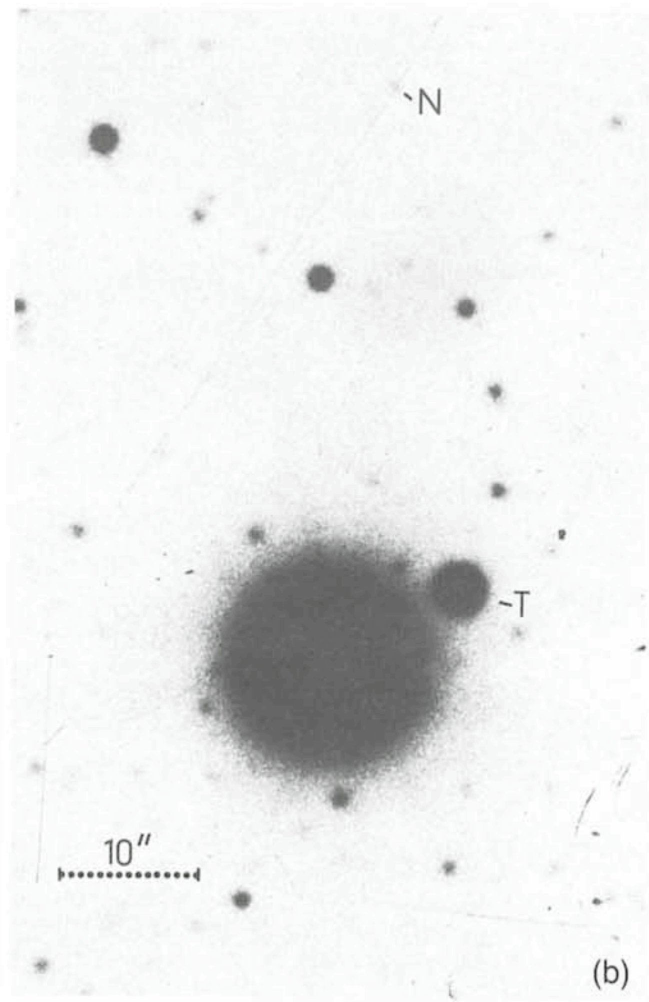


Fig. 6: *Neptune, Triton (T) and Nereid (N). (a) 1981, Apr. 06, 08h 40m UT; (b) 1981, Apr. 11, 08h 40m UT – 40 mn, exp. on III a-J plate. North is up.*

which provided us with four accurate positions. We still used the Danish-ESO 1.5-m reflector. Exposure times of 20 and 40 minutes permitted to record images of Nereid good enough to be measured. Fig. 6 shows prints of two plates taken on two different nights. The motion of Nereid relative to the planet is clearly seen (about 1.8″/day at this epoch).

All the plates have been measured and reduced on an Optronics at ESO (Garching). From a Schmidt plate taken approximatively at the same time for this purpose and reduced with the reference stars of Perth 70, about 15 stars are measured and their coordinates determined. The reduction of the plate showing Nereid is made using these secondary stars. The position of Nereid is available by direct measurement with a sufficient accuracy (0.1 arcsecond) because of the circular image of the planet and the circular circles on the reticle of the Optronics.

Six years after his first paper, Mignard published a second one (F. Mignard [1981], *Astron. J.* **86,** 1728) in August 1981 in which he determined the mean elements of his theory but only by using the old observations (1949–69). Thus our work was no more devoted to a first determination of mean elements, but to a check of the previous orbits and a redetermination of their parameters by adding our new observations. Fig. 7 shows the mean value and standard deviation of the residuals on both the rectangular apparent coordinates of Nereid derived from the previous and the new orbits. The improvement obtained with the new determinations is apparent. The mean elements of the new determination, as well as current osculating elements for the present epoch, will soon be available (a paper has been submitted for publication in *Astronomy and Astrophysics).* The mass of Neptune inferred from the new disturbed orbit is $m^{-1} = 19383 \pm 110$, in good agreement with the values found with other techniques and a good improvement to Neptune masses derived from the previous orbits. However, the residuals of the 1981 plates present systematic errors and it is impossible to

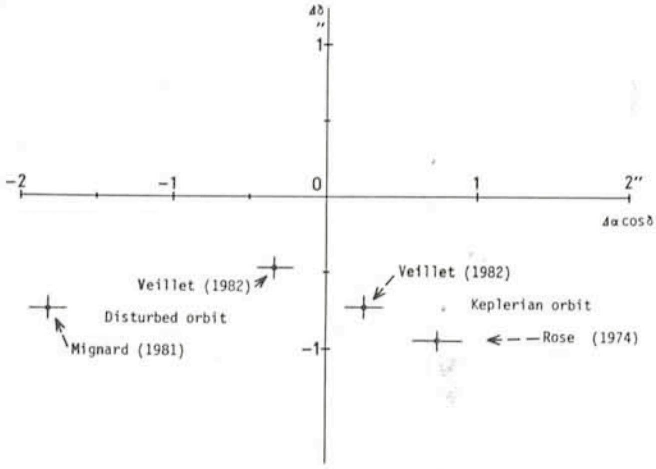


Fig. 7: *Mean value and standard deviation of the residuals in the rectangular apparent coordinates of Nereid from the previous and new orbits for the 1981 observations.*

rule them out. The weight of the old observations, the quality of which is not as good as the new ones, is too important. The standard deviation of the residuals is more than 1 arcsecond after complete calculation and it is difficult to choose which old plate has to be removed without seeing it. . . . The only solution is to get more plates of Nereid in order to increase the number of recent good positions. Observations are planned at both ESO and CFH observatories in 1982. Potential observers are also required: For such a work, it is important to diversify the source of available data.

Conclusion

This observing run at La Silla for studying the motion of faint satellites of outer planets has been very fruitful. We have obtained many results showing that both the site and the instrument are well suitable for accurate astrometric observations of faint objects. It would be very useful to get more positions of the satellites moving on the orbits of Thetys and Dione in order to precise their libration motion. The observations of the Uranian and Neptunian system have also to be carried on to reach a better accuracy in the determination of the orbital elements of their satellites. We plan to make again such a work with the Danish-ESO 1.5-m reflector in May and to extend the programme to the CFH 3.6-m reflector in March this year (1982).

PERSONNEL MOVEMENTS

STAFF

Arrivals

Europe

UNDEN, Christiane (B), Secretary, 8.2.1982

Departures

Europe

JANSSON, Jill (S), Secretary, 30.4.1982

FELLOWS

Arrivals

Europe

PERRIER, Christian (F), 15.2.1982 (transfer from Chile)
KOTANYI, Christopher (B), 15.2.1982
ROSA, Michael (D), 1.3.1982

ASSOCIATES

Chile

BEZANGER, Christian (F), Coopérant, 20.1.1982
DUFLOT, Christophe (F), Coopérant, 20.1.1982

EXPERIENCES WITH THE 40-MM MCMULLAN CAMERA AT THE 3.6-M TELESCOPE

Absolute B,V Photometry of cD Galaxies

Edwin Valentijn, ESO

The ESO 40-mm electronographic McMullan camera was delivered for general use at the 3.6-m telescope in April 1980 and has been used since then at regular intervals. A description of the camera, which can be mounted on both triplet correctors of the 3.6-m telescope, has been given in the *Messenger* No. 17.

The McMullan Camera Compared to the CCD

In 2-dimensional photometry the McMullan camera is a unique instrument, since it combines a relatively large field of view (12′ diameter at the 3.6-m telescope) with a relatively high sensitivity (detected quantum efficiency [DQE] ~10–20%). Therefore, the camera is a sort of intermediate system between the normal photographic plate (DQE ~2%, field diameter 1° at the 3.6-m) and the CCDs (DQE 40–90%, field 4′ × 2.5′). If one expresses the data rate of the cameras in terms of field of view and sensitivity, then the 40-mm McMullan camera has a 2.5 times higher rate compared to the present ESO CCD. The new ESO 80-mm McMullan camera, which will be installed in the near future, will exceed the CCD data rate by a factor of 10. The electronographic camera is UV sensitive, in contrast to the CCDs which are red sensitive. Another advantage of the electronographic camera is its supposed linear response, i.e. the density (D) on the plate relates linearly to the intensity of the exposed light: $m = C - 2.5 \log D$, m is the magnitude of the object and the so-called zeropoint (C), is a constant representing the total sensitivity of the camera plus telescope. For a proper working tube it was found that the gain of the system does not change (< 0.5%) over periods of a few nights. This property is important for doing absolute photometry and is better than the CCDs which can have much faster gain variations. A major drawback of the McMullan camera was that the only available nuclear emulsions from Ilford (uncoated high speed G5, and fine grain L4) were actually not manufactured for astronomy. These plates showed a lot of artifacts and non-uniformities. Besides this, it is very difficult to keep the large 3.6-m dome free of dust, which leads to dust particles on the filters, entrance window and mica window of the camera. I suspect that this was one of the main reasons why the 3.6-m McMullan camera was never taken seriously enough and only a few observers have tried the system. As a result they had to work with an untested system which came straight from the factory and ran into all sorts of instrumental troubles which occurred during their observing run. Most of these problems could have been avoided if more test time had been devoted to the instrument. Thus, the more or less bad reputation of the 3.6-m McMullan camera became self-fulfilling, in contrast to the electronographic camera used on the Danish 1.5-m telescope, where substantial testing has been done and the camera is often used with much more satisfaction. In a recent run, I have tested a new Kodak nuclear emulsion (fine grain SO-647) which was actually developed for astronomical specifications. The Kodak plates are supercoated and were found to be almost free of artifacts and very uniform. The introduction of this much more satisfactory emulsion makes the electronographic camera an up-to-the-mark instrument, unique in 2-dimensional astronomy because of its high data rate. One profits the most from the typical McMullan camera characteristics in doing 2-dimensional photometry of 2′–8′ sized objects.

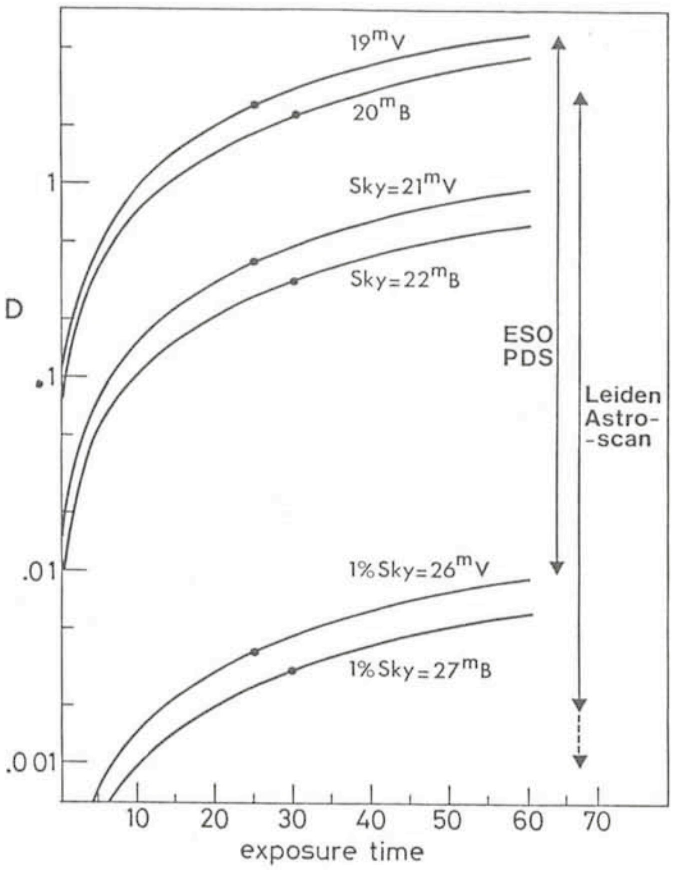


Fig. 1: *Relation between the actual relative density on Ilford L4 plates and exposure time using the 40-mm McMullan camera at the 3.6-m telescope (quantum efficiency in B is 20 %, in V 12 %) for different surface brightness levels. The measurable and reproducible density ranges of the ESO PDS and the Leiden Astroscan microdensitometers are also indicated. The points indicate optimal exposure times (25 min V, 30 min B) for observing galaxies, when plates are scanned with the Astroscan.*

The Programme

I have carried out a programme measuring the very low surface brightness haloes of cD galaxies in clusters, which have angular dimensions in this range. It was my intention to obtain absolute photometry of ~30 cD galaxies (all known to have extended X-ray haloes) in a homogeneous way and down to very low light intensities. In four observing runs, 10 nights of 3.6-m telescope time were allocated to this project and essentially due to the above-mentioned reasons 5.7 nights were lost because of instrumental problems and another 3 nights due to bad weather conditions. In the remaining 1.3 night both the Ilford L4 and G5 and the Kodak emulsions were tested and absolute B and V photometry of 10 cD galaxies was obtained down to surface brightness levels ranging from 25 to 28 magnitude or 2.5 to 0.5% of the night sky brightness. This shows how fast and effective one can collect data with the McMullan camera when it is properly working.

Calibration

Since I wanted to obtain absolute photometry it was necessary to determine the total sensitivity (zeropoint) of the system. It was decided to use two different techniques: (i) plates were taken of photoelectric sequence stars, (ii) the sky brightness was recorded during the observations at the Dutch 90-cm telescope by M. Pakull.

Fig. 1 shows the relative density recorded on L4 plates, as a function of the exposure time. The Ilford G5 emulsions are 4 times faster but have a larger grain and worse non-uniformities. The Kodak fine grain SO-647 is slightly slower than L4. The reproducible delta density ranges of the Leiden Astroscan and the ESO PDS microdensitometers are also indicated. It can be seen that optimal results for elliptical galaxy photometry can be obtained in 25 min V and 30 min B exposure time, when the plates are scanned with the Astroscan. If non-uniformities of both the plates and the sky were not the restricting factor in 2-dimensional photometry, then one could with a high speed emulsion obtain measurable delta densities at the 1‰ sky levels after 20 min (V) and 30 min (B) exposure time. Another reason for using the Astroscan is its known (Swaans, Ph.D. Thesis, Leiden) linear response, allowing us to check the linearity (zeropoint independent of D) of the electronographic system. Fig. 2 shows the zeropoints derived in both the B and V band from our two calibration techniques as a function of the actual density on the L4 plates of the considered object (sky or star).

All four independent measurements (Sky and Stars in B and V) show a similar and significant deviation from linearity of $0\overset{m}{.}45$ per 1D (1 magnitude difference over a 8^{m} range). It is very interesting that the short exposure (low density) sky measurements relate to the longer sky exposures in the same way as the stars do. This proves that the non-linearity in the system originates in the emulsion, since the sky had always more or less the same intensity. If the tube were the cause of the non-linear response, it would not give an exposure time dependent zeropoint for a similar intenstiy. C.S. Petersen (Copenhagen Observatory report) found a similar non-linearity in his G5 exposures but could not trace the origin (PDS, emulsion or tube). The Ilford G5 has probably the same non-linearity as the L4 type. Results for the Kodak emulsion will be available in the near future. Once the non-linearity of the system is known, it is easy to correct for it.

Flat Fielding and Removing of Artifacts

The main restricting factor in 2-dimensional low surface brightness photometry is the sky subtraction, which, in practice, means that one wants to obtain a flat and uniform background. The S-20 cathode in the McMullan camera, however, has a smoothly varying gain (~25%) over its area. One usually corrects for this by taking exposures of a uniformly illuminated part of the dome and subsequently divides the original images of the objects by this flat field image. However, then, every artifact and the noise in the flat field is reproduced in the image of the object. In order to avoid these problems, a refined technique (L. Swaan's programmes installed at the Max-Planck Amdahl computer) has been used to optimize the flat field by combining different exposures. First the bad pixels

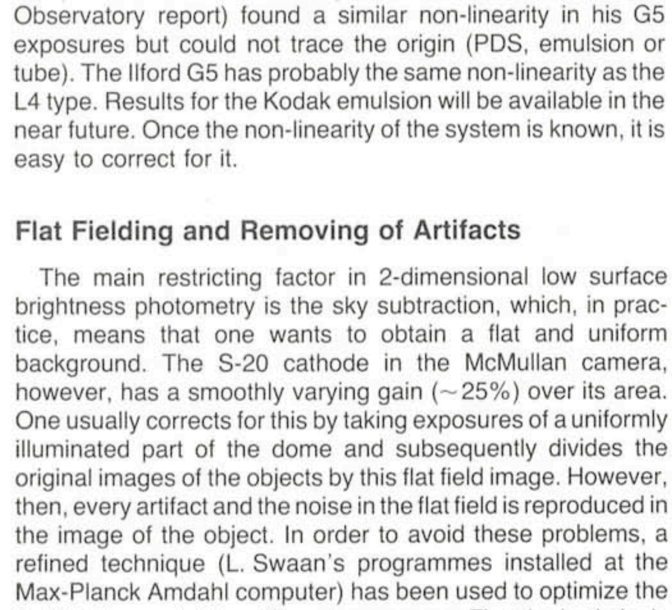


Fig. 2: Zeropoint levels determined with two independent techniques in both B and V versus the actual density of the calibrators (sky and stars) on the plates. The straight line fits represent the found non-linearity of the L4 nuclear emulsion.

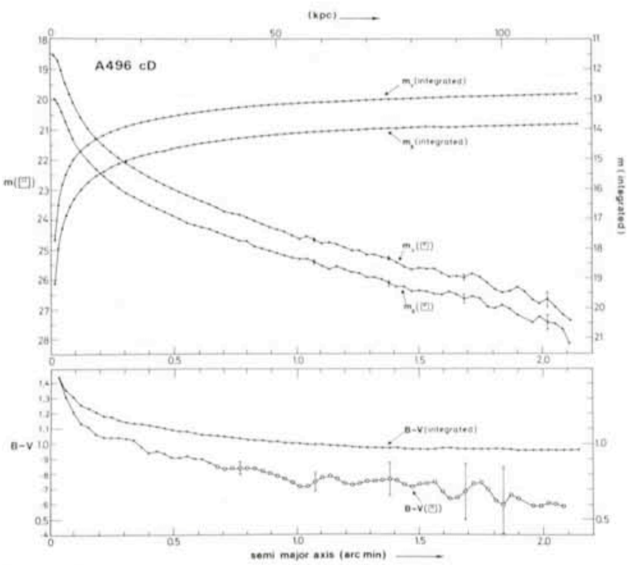


Fig. 3: *Absolute, differential and integral luminosity and colour profiles (sampled in ellipses) of the cD galaxy in the cluster Abell 496. Open circles are smoothed points, all filled circles are independently measured points (the separation between the points corresponds approximately to the FWHM seeing). The error bars indicate the estimated systematic uncertainties due to large-scale plate non-uniformities.*

in the flat fields were filtered (upper limit, lower limit, second derivative limit) and then the four flat field exposures were combined, skipping those pixels which deviated too much from the mean ratio in intensity of the different images. Finally, the resultant image was convolved with a Gaussian.

Results

The images of the cD galaxies were filtered in a similar way, cleaned from stars in the IHAP system and divided by the flat field. As a next step the final images of the cD galaxies were fed to a computer programme fitting ellipses at different isophotal levels surveying for isophotal twisting, asymmetries and ellipticity. In most cases no isophotal twisting larger than 5° or asymmetries were found, but most programme galaxies showed a significant decrease in eccentricity with increasing radii. So, the elliptically shaped cD galaxies showed a much rounder outer halo. Once the ellipse parameters of the galaxies were determined, they were used in a photometry programme to determine the radial luminosity profiles sampled in ellipses. Fig. 3 shows an example of the results of one programme galaxy. The halo of this cD galaxy has been traced out to a distance of 115 kpc (H_0 = 50 km s^{-1} Mpc^{-1}) from the galaxy centre and down to 0.5 % of the intensity of the night sky. The B-V profile shows a very red (B-V = $1\overset{m}{.}4$) nucleus and a very significant colour gradient out to a distance (semi-major axis) of 50 kpc from the galaxy centre (B-V = $0\overset{m}{.}8$). In the outer halo an additional $0\overset{m}{.}2$ colour gradient is observed, which is of low significance because of possible systematic effects due to plate non-uniformities. These results were obtained on a L4 plate. The Kodak plates have a more uniform response and will give smaller systematic errors.

The observed pronounced colour gradient is an interesting result which has implications on the stellar evolution and the presence of interstellar matter in cD galaxies. In the other galaxies of the sample similar gradients have been found. All the cD's of this programme are found to have extended X-ray haloes with the Einstein Observatory. The combination of these optical and X-ray data poses intriguing questions which will be discussed elsewhere.

Letter to the Editor

In my article "The Large Scale Structure of the Universe" published in the *Messenger* No. 26, December 1981, the statement: "However, this evidence was based on a sample of ten galaxies only. The first confirmation of this result was obtained by Tifft and Gregory (1976, *Astrophys. J.* **205,** 696) from the study of a larger sample", was added by the Editor of the Journal without consulting the author. The statement is incorrect and misleading. It misinterprets the work by Chincarini and Martins and does not reflect my knowledge of the work published by various authors and the sequence of events which led to some early estimates of the distribution of galaxies.

Guido Chincarini

ALGUNOS RESUMENES

Suiza, país miembro de la ESO

El día 1° de marzo de 1982 el Consejo Federal de Suiza hizo entrega del documento que lo atestigua como país miembro de la ESO debidamente firmado al Minsterio de Relaciones Exteriores Francés (donde se guardan los documentos de la ESO), y desde entonces ESO cuenta así con siete estados miembros.

Actividad social en la atmosfera exterior de La Silla

Sonia Rodríguez-Larraín, ESO-La Silla

¿ A quien se le ocurriría pensar que existe otra forma de vida – una vida social – en esta nebulosa oscura del Norte Chico? Se creería que al eliminar deliberadamente todo lo que es ruido, luz, vino y otros tipos de polucíon, automáticamente desaparecerían las especies buenas para pasarlo bien y que solamente sobrevivirían aquellos abstemios extraterrestres cuya única preocupación en esta vida es generar trabajo y publicarlo.

Y sin embargo . . . no es así. No todos estan en estado de coma en este Observatorio. Las especies mas fuertes han sobrevivido!

La primera pauta de que aquí no todo es tan prosaico como se imagina, son las palabras mágicas y poéticas: "el Bar está abierto". Por supuesto, a eso se refieren cuando hablan de "prepararse para la noche". La tradición del Bar se inició hace muchos años y para frecuentarlo cualquier razón es buena, un viaje al extranjero, un contrato nuevo, un corte de pelo nuevo, etc.

Hablando de tradiciones, es costumbre chilena que un recién llegado "pague el piso". Esta costumbre da paso a muchas reuniones sociales las que de preferencia se hacen a principio de turno, cuando aún hay provisiones. Habiendo buena música, eximios bailarines y hartas provisiones que más se puede pedir? Bueno, es cierto que hay pocas mujeres, mejor dicho hay sólo unas seis y no todas están siempre en el Cerro. Por lo tanto hay que hacer cola para bailar, pero esto también tiene un lado bueno. Ninguna mujer en La Silla se puede quejar de estar planchando, el éxito en la pista está asegurado, le guste o no bailar.

Las raras ocasiones en que hay muchas chiquillas en La Silla, es cuando un Líceo de Niñas de Coquimbo decide hacer una visita cultural (?) a La Silla. De repente aparecen tantos guías voluntarios como hay visitantes (sin contar a la madre superiora). Si a la hora del té hay muchas risas coquetas en una mesa, es porque el guía se ha desvíado del apasionado tema de astronomía y ha incursionado en tópicos mas personales. Entonces no falta el amigo que se le acerque y le diga: "Tu señora llamó dice que está donde tu suegra con los niños" (¡ Bajen el telón !)

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 seven countries: Belgium, Denmark, France, the Federal Republic of Germany, the Netherlands, Sweden and Switzerland. It now operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where twelve telescopes with apertures up to 3.6 m are presently in operation. The astronomical observations on La Silla are carried out by visiting astronomers – mainly from the member countries – and, to some extent, by ESO staff astronomers, often in collaboration with the former.
The ESO Headquarters in Europe are located in Garching, near Munich.
ESO has about 120 international staff members in Europe and Chile and about 150 local staff members in Santiago and on La Silla. In addition, there are a number of fellows and scientific associates.

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Con esas noches tan llenas de estrellas y esa luna que brilla tan resplandeciente se diría que el amor toca a la portería de Pelícano, y así es. Muchas parejas se conocieron en el trabajo y muchos de ellos deben su dicha de casados a La Silla. Los primeros matrimonios datan desde cuando estaba en construcción el 3.60. Hasta la fecha, doce incautos funcionarios internacionales cuya razón de estar en Chile era un contraco con la ESO, se encuentran ya casado con mujeres chilenas o están a punto de firmar ese tipo de contrato mas permanente.

La Silla es el lugar indicado para conocer gente nueva, y esto es ideal para los tímidos ya que en el comedor uno se integra sin esfuerzo. Para los supertímidos, que desean estar con gente pero no hablarles se les recomienda que se incorporen al equipo de trotadores. Este es un grupo muy silencioso que sale a recorrer el observatorio todas la mañanas.

Pero el orgullo de La Silla son sus equipos de Baby-football. Cada equipo sale a la cancha de concreto con cinco magníficos cracks super profesionales con sus uniformes impecables. Cada equipo tiene sus hinchas por lo que se pone especial énfasis al escoger los nombres que los van a identificar. Es así como tenemos los: "Come Fierro", del Astrotaller; los "Super H.P." de Construcción y Mantención; los "Troncales" de la Bodega y Mantención los OVNIS de Administración, y los "P.P.Q.P" de Electrónica (es mejor dejar este nombre tal cual).

El primer equipo se fundó hace 15 años y desde entonces los partidos de la temporada son el evento recreacional mas importante en La Silla. Desgraciadamente por falta de un gimnasio cerrado y bien iluminado, la temporada es muy corta, ya que sólo se juega despues del trabajo y mientras dure la luz natural.

El Club Deportivo hace las veces de relacionador público y se asegura de que la prensa esté al tanto de los eventos deportivos en La Silla, es así como la televisión ya ha asistido a las finales dos años consecutivos. El Club Deportivo también organiza partidos con otros equipos.

Hace poco nació también el equipo de Volley Ball en un picnic en el Beño. El Beño es el parque nacional particular de La Silla. La razón del picnic, muy lógica por lo demás, fue que se juntaron demasiadas personas de Garching en La Silla, y estó había que celebrarlo de algun modo. Se mandaron invitaciones y se le pidió al personal del Hotel que tuvieran la amabilidad de servir el Buffet frio del Domingo en el Beño. Antes de que llegaran todos los invitados ya se había instalado la red del Volley Ball y en el juego participaron todos los deportistas. Después de comida alguien conecto un toca casette a la batería de un auto y el baile empezó entre las piedras y las lagartijas . . . El comentario general al otro día era que debieran hacerse picnics mas a menudo.

Sin embargo no siempre pueden bajar todos los empleados del Cerro y entonces se invita a los familiares del personal de turno para que pasen las fiestas en La Silla. En esos días, se escuchan muchas voces infantiles en el comedor, lo que es un cambio muy agradable; el consumo de helados se multiplica y la máquina de bebidas funciona sin cesar durante dos días.

Se dice que todos deben estar felices para el Año Nuevo, así es que esa noche la ley seca se pone de lado, y mientras no manejen autos ningunos de los que asisten a la fiesta, la Organización hace la vista gorda y dirige todos los ojos a los telescopios.

Vemos pues que los esfuerzos para mantener una vida social en condiciones tan austeras no son tan en vano. Por lo anterior, se diría que los mas fuertes son capaces de sobrevivir donde sea. Es solamente en esos fines de semana interminables, cuando la moral anda por el suelo, que los mas fuertes empiezan a examinar sus capacidades de aguante y se preguntan: "¿Por que siento hoy ganas de bajar?"

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