No. 54 – December 1988

ESO'S EARLY HISTORY, 1953–1975
I. STRIVING TOWARDS THE CONVENTION

ADRIAAN BLAAUW, Kapteyn Laboratory, Groningen*

L'astronomie est bien l'école de la patience.
From a letter by A. Danjon to J.H. Oort, 21 September 1962.

A Historical Statement

On January 26, 1954 twelve leading astronomers from six European countries issued the historical statement we reproduce here [1]. It carries the signatures of Otto Heckmann and Albrecht Unsöld of the German Federal Republic, Paul Bourgeois from Belgium, André Couder and André Danjon from France, Roderick Redman from Great Britain, Jan Oort, Pieter Oosterhoff and Pieter van Rhijn from the Netherlands, and Bertil Lindblad, Knut Lundmark and Gunnar Malmquist from Sweden.

The statement (drafted by Danjon, Oosterhoff and Redman) expresses the wish that the scientific organizations in the respective home countries recommend to the authorities concerned, the establishment of a joint observatory in South Africa, equipped with a telescope of 3 metres aperture and a Schmidt telescope of 1.2 metres aperture. In the paragraphs preceding this expressed wish, they present the considerations that led them to this statement. Their wish would ultimately lead to the Convention between five of these six countries – Great Britain went its own way – signed on 5 October 1962. By that time almost ten years had passed since the notion of a joint European observatory had been expressed for the first time. Another year and three months would have to elapse until the impatient hands of the astronomers would be free to lay the first solid foundations for the erection of the observatory. The date is January 17, 1964 when, with the completion of a series of parlamentary ratifications, not only the moral, but also the financial commitments of the respective governments had been ensured.

In this series of articles I shall first describe the developments of the first decade, that is the period preceding the signing of the Convention and the Ratifications, and, hopefully, next try to cover some of the later developments until the year 1975 when I passed on the General Directorate of the organization to my successor Lodewijk Woltjer.

The earliest decade was one of ups and downs – many downs! – in a struggle which may seem surprising to the present young generation of astronomers, and can be fully understood only when seen against the background of a damaged Europe, a decade only after devastating World War II. Traditional nationalism and mutual misgiving had to be replaced by joint effort. As my colleague and friend Charles Fehrenbach used to say: "Il faut faire l'Europe." It also was a time at which some of the European countries had to deal with serious internal problems. Governments as well as astronomers had to face this. It is perhaps not surprising, then, that the first instigation towards the joint effort which would become ESO, had to come from one who, although rooted in European ancestry, had been an onlooker on European astronomy for many years from overseas: Walter Baade of the Mount Wilson and Palomar Observatories.

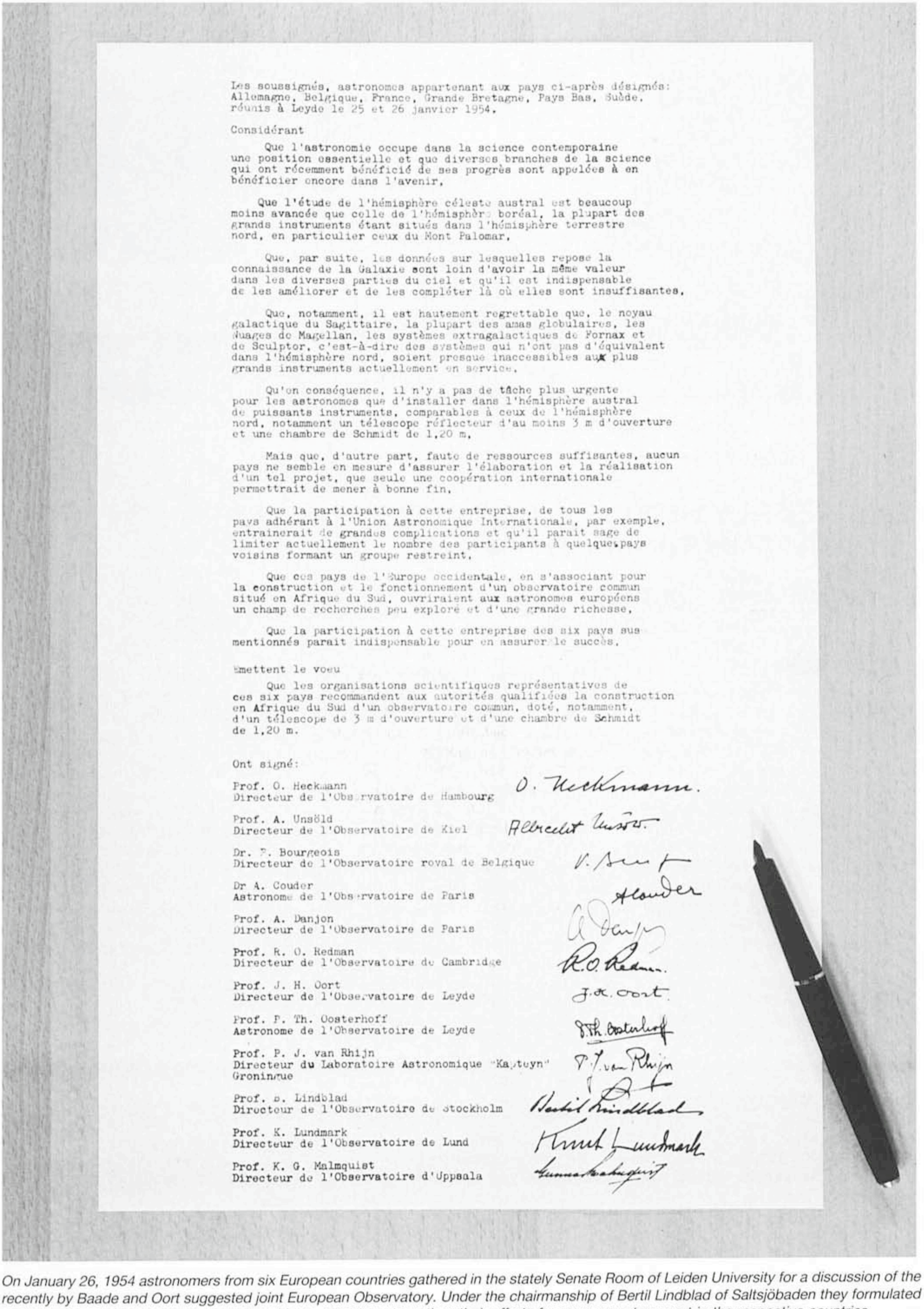
Baade, renowned expert on galactic and extragalactic research, had been invited by Oort to spend two months at Leiden Observatory in the spring of 1953, for lecturing and for collaborating in the preparation of a conference on galactic research to be held near

(Continued on page 3)

* The author was Secretary of the ESO Committee (which preceded the Council) from May 1959 to February 1963, Scientific Director of ESO (part time) during the years 1968 and 1969, and Director General from January 1970 to January 1975. He was a Council member for the Netherlands during the years 1979 through 1982.

TO ALL READERS

Please make sure that the card which accompanies this issue of the *Messenger* is returned, if you want to continue to receive the journal. *The editors*



Les soussignés, astronomes appartenant aux pays ci-après désignés: Allemagne, Belgique, France, Grande Bretagne, Pays Bas, Suède, réunis à Leyde le 25 et 26 janvier 1954.

Considérant

Que l'astronomie occupe dans la science contemporaine une position essentielle et que diverses branches de la science qui ont récemment bénéficié de ses progrès sont appelées à en bénéficier encore dans l'avenir,

Que l'étude de l'hémisphère céleste austral est beaucoup moins avancée que celle de l'hémisphère boréal, la plupart des grands instruments étant situés dans l'hémisphère terrestre nord, en particulier ceux du Mont Palomar,

Que, par suite, les données sur lesquelles repose la connaissance de la Galaxie sont loin d'avoir la même valeur dans les diverses parties du ciel et qu'il est indispensable de les améliorer et de les compléter là où elles sont insuffisantes,

Que, notamment, il est hautement regrettable que, le noyau galactique du Sagittaire, la plupart des amas globulaires, les Nuages de Magellan, les systèmes extragalactiques de Fornax et de Sculptor, c'est-à-dire des systèmes qui n'ont pas d'équivalent dans l'hémisphère nord, soient presque inaccessibles aux plus grands instruments actuellement en service,

Qu'en conséquence, il n'y a pas de tâche plus urgente pour les astronomes que d'installer dans l'hémisphère austral de puissants instruments, comparables à ceux de l'hémisphère nord, notamment un télescope réflecteur d'au moins 3 m d'ouverture et une chambre de Schmidt de 1,20 m,

Mais que, d'autre part, faute de ressources suffisantes, aucun pays ne semble en mesure d'assurer l'élaboration et la réalisation d'un tel projet, que seule une coopération internationale permettrait de mener à bonne fin,

Que la participation à cette entreprise, de tous les pays adhérant à l'Union Astronomique Internationale, par exemple, entrainerait de grandes complications et qu'il parait sage de limiter actuellement le nombre des participants à quelques pays voisins formant un groupe restreint,

Que ces pays de l'Europe occidentale, en s'associant pour la construction et le fonctionnement d'un observatoire commun situé en Afrique du Sud, ouvriraient aux astronomes européens un champ de recherches peu exploré et d'une grande richesse,

Que la participation à cette entreprise des six pays susmentionnés parait indispensable pour en assurer le succès,

Emettent le voeu

Que les organisations scientifiques représentatives de ces six pays recommandent aux autorités qualifiées la construction en Afrique du Sud d'un observatoire commun, doté, notamment, d'un télescope de 3 m d'ouverture et d'une chambre de Schmidt de 1,20 m.

Ont signé:

Prof. O. Heckmann
Directeur de l'Observatoire de Hambourg — O. Heckmann.

Prof. A. Unsöld
Directeur de l'Observatoire de Kiel — Albrecht Unsöld

Dr. P. Bourgeois
Directeur de l'Observatoire royal de Belgique

Dr A. Couder
Astronome de l'Observatoire de Paris — A Couder

Prof. A. Danjon
Directeur de l'Observatoire de Paris

Prof. R. O. Redman
Directeur de l'Observatoire de Cambridge — R.O. Redman

Prof. J. H. Oort
Directeur de l'Observatoire de Leyde — J.H. Oort

Prof. P. Th. Oosterhoff
Astronome de l'Observatoire de Leyde — P.Th. Oosterhoff

Prof. P. J. van Rhijn
Directeur du Laboratoire Astronomique "Kapteyn" Groningue — P.J. van Rhijn

Prof. B. Lindblad
Directeur de l'Observatoire de Stockholm — Bertil Lindblad

Prof. K. Lundmark
Directeur de l'Observatoire de Lund — Knut Lundmark

Prof. K. G. Malmquist
Directeur de l'Observatoire d'Uppsala

On January 26, 1954 astronomers from six European countries gathered in the stately Senate Room of Leiden University for a discussion of the recently by Baade and Oort suggested joint European Observatory. Under the chairmanship of Bertil Lindblad of Saltsjöbaden they formulated and duly signed the statement reproduced here, meant to strengthen their efforts for government support in the respective countries.

Setting Up the ESO Historical Archives

Now that ESO has reached the age and status at which interest in its early beginnings is growing, it is desirable to set up an organized system of documentation that should allow historical studies. For that reason, steps have been taken by the Director General to establish the ESO Historical Archives, henceforth to be abbreviated EHA. These archives are meant to serve two purposes:

– to form a natural framework for the incorporation and classification of documentation that may be relevant to the study of the history of ESO; and

– to provide students of ESO's history with the necessary basic references, accessible at the discretion of the ESO Directorate.

At this moment – fall 1988 – a beginning has been made with the creation of the EHA by means of some quite valuable collections of documentation, pertaining mostly to the earliest decades, that is from the year 1953. They originate from persons who have been intimately involved in the creation of the Organization. The origins and the nature of this documentation can be recognized in the global descriptions in the box ESO Historical Archives accompanying this note.

For the arrangement and numbering I have chosen a system which clearly shows the origin of the documents and which, moreover, has a structure allowing in a natural way the incorporation of additional documents without any manipulating. Eventually, a more sophisticated system may have to be introduced, but for the moment the present, simple one should suffice. The arrangement also allows the description of the documentation in the inventory to be done in as much detail as appears desirable.

This arrangement discriminates first of all between documentation originating from outside ESO, category I, and documents from within ESO, category II. As things stand at the moment, it would seem that category I will be the richer one. Within category I, I have discriminated according to the source of the documents: category I.A. refers to documents originally belonging to J.H. Oort, category I.B. to those originating from the Dutch organization ZWO, category I.C. to documents transferred from my archives at the Kapteyn Laboratory at Groningen to the EHA. Clearly this arrangement invites extensions I.D., I.E., etc. for documents which, hopefully, may be received from other persons or agencies that were involved in the early history of ESO.

Within each of these categories, further subdivision introduces more and more refined classification. The first stages of these are indicated in the accompanying Inventory. Further ones are used in the more extensive descriptions of the EHA now in the making. As an illustration, let me mention the subdivision I.C.2.8. which pertains to the dealings of the Secretary of the ESO Committee (which preceded the ESO Council) with the Marseilles objective-prism radial velocity project as part of the site testing operations, and of which the subdivision I.C.2.8.a. contains the correspondence with Ch. Fehrenbach.

In connection with category II, it should be mentioned that, of course, apart from the contents of this part of the EHA, there are in the ESO Headquarters (and perhaps also in Chile?) many documents of interest for the study of the ESO history which, however, still are part of the body of documentation occasionally used for the regular operation of ESO. Of particular significance appear to be the extensive files kept by the ESO Head of Administration, which contain virtually complete sets of the minutes of the ESO Council and its predecessor, the ESO Committee, minutes of Finance Committee, the series of Council-Meeting Documents, etc. Naturally, access to these documents is also at the discretion of the ESO Directorate. In my articles on the early history of ESO I refer to these documents as FHA (Files Head of Administration).

Finally, mention should be made of the collection of old photographs and slides belonging to the Photographic Department of ESO, which also are of historical interest, but still to be classified.

A. BLAAUW

ESO HISTORICAL ARCHIVES

Inventory per December 1988; Overall Contents

I. Documents received from outside ESO.

I.A. Archives J.H. Oort.

I.A.1. Documents donated by Oort to L. Woltjer, former Director General of ESO.

I.A.2. Documents donated by Oort to A. Blaauw around the year 1976 and transferred by him to ESO Historical Archives.

I.B. Archives J.H. Bannier.

Documents donated in 1987 to H. van der Laan by the Dutch organization ZWO for sponsoring scientific research, pertaining to the directorship of J.H. Bannier of this organization.

I.C. Archives A. Blaauw.

I.C.1 Documents pertaining to the Secretariat of the ESO Committee (which preceded the ESO Council) with the exclusion of those concerning the site-testing expeditions.

I.C.2. Documents pertaining to the Secretariat of the ESO Committee, concerning the site-testing expeditions.

I.C.3. Documents concerning the ESO Working Group for Buildings, 1963–1965.

I.C.4. Other documents before 1968.

I.C.5. Documents pertaining to the ESO Scientific Directorship, 1968–1969.

I.C.6. Documents pertaining to the ESO General Directorship, 1970 through 1974.

II. Documentation originating from inside ESO.

II.A. Documents from the file marked "ESO Allgemein", of the period 1961–1964.

(Continued from page 1)
Groningen from June 22 to 27 [2]. It was during this stay that, between Baade and Oort, the idea arose of a joint effort by some European countries with leadership in astronomy [3].

The suggestion was followed up by Oort immediately. At his invitation a group of astronomers discussed it on June 21, 1953, the day before the Groningen conference [4]. They were Baade, Bourgeois, Danjon, Heckmann, Lindblad, Oort, Oosterhoff and myself. Most of them participated in the Groningen conference [5]. Also present on June 21 was J.H. Bannier, director of the Dutch national science foundation (ZWO) and at that time President of the Council of CERN, the joint European effort in nuclear research. Over the years, the ESO effort would greatly benefit from Bannier's experience. The participants at the meeting represented five "continental" countries. After the meeting Sir Harold Spencer Jones, Astronomer Royal of Great Britain, and Richard Stoy of the Cape Observatory,

Photograph 1: *Walter Baade (left) in characteristic pose, talking to C. Schalén of Sweden.*[1]

both of whom also participated in the Groningen conference, were informed and contributed their views. It appears from the minutes of the June 21 meeting that Baade's ideas deeply influenced the discussions and, in fact, his proposal then made would become the nucleus of the "initial programme" formulated in article II.2 of the 1962 Convention. It is therefore interesting to report in some detail from these minutes.

Baade proposed as principal instruments a 120-inch reflector similar to that of Lick Observatory in combination with a 48-inch Schmidt telescope like the one on Mt Palomar. The fact that for both telescopes existing designs could be used and engineering problems had been solved would speed up the project. The southern hemisphere for the location of these instruments was an obvious choice for several reasons. At that time, several European observatories had their own limited facilities in the southern hemisphere, most of them on the premises of South African observatories, and extensions of these were under consideration. Belgium, the German Federal Republic, Ireland and Sweden participated in Harvard Observatory's Boyden Station at Bloemfontein; Leiden Observatory had its southern station on the premises of the Union Observatory, first at Johannesburg and later at the field station at Hartebeespoortdam; British astronomy had close relations with South Africa through the Radcliffe Observatory at Pretoria and the Cape Observatory near Capetown. Rather than enlarging these facilities, one should pool resources and efforts and strive for equipment comparable in research power to that of the large Californian observatories that had for decades dominated observational astronomy. (All reflectors with aperture of 80 inch or more were located in the northern hemisphere [6].)

Moreover, some of the most interesting objects of research could be reached only from the southern hemisphere: the central parts of the Galaxy and the nearest extragalactic systems. Baade stressed the growing importance of extragalactic work and the fact that only by means of a large telescope Europe might hope to join in it. In addition to the two instruments mentioned, the meeting proposed a meridian circle for the astrometric work that also was much needed in the southern hemisphere. That South Africa was envisaged for the location, was almost self-evident also because it had the best astronomical climate known at that time. The minutes of the meeting contain a provisional cost estimate. Capital investments were estimated at \$ 2.5 million, and annual running costs at \$ 100,000.–. These included salaries for 3 astronomers, 5 technical personnel, 3 night assistants and 3 administrative posts. Participants of the June 21 meeting were invited to discuss these plans with their colleagues at home.

The results of their deliberations were discussed at the meeting of January 1954 mentioned at the beginning of this article [7]. It was chaired by Bertil Lindblad and held in the stately Senate room of Leiden University, where portraits of scientists of Leiden's illustrious past, looking down on the participants, may have inspired their historical statement. The statement reflects the positive response they brought from their colleaques at home. The meeting decided to form an ESO Committee to carry the project further, consisting of Bourgeois (Belgium), Danjon (France), Heckmann (German Federal Republic), Spencer Jones (Great Britain), Oort (Netherlands) and Lindblad (Sweden). The suggestion was made that some intermediate size telescopes should be added to those mentioned earlier. An improved cost estimate was presented: capital investments should be 1.25 million pounds (then corresponding to about \$ 3.5 million), based on preliminary offers from European manufacturers, and an annual budget of 45,000 pounds (corresponding to about \$ 126,000). The project was

Photograph 2: *From left to right: V. Kourganoff (France), J.H. Oort (Netherlands), H. Spencer Jones (Great Britain).*

[1] The photographs accompanying this article were taken by the author during a boat trip on one of the days of the Groningen Conference in June, 1953, immediately after the idea of a joint European Observatory had been discussed for the first time by a group of astronomers at Leiden on June 21. Purpose of the trip were the reclamation operations in the area of the former Zuiderzee, now the domain of large, flourishing farms. All of the participants at the Leiden meeting joined in the boat trip, and the notion of a joint observatory must have been one of the hotter subjects.

envisaged to be realized over the next ten years. The meeting was aware that this financial support might be very hard to obtain from research councils or governments, but the suggestion was made that perhaps this might be facilitated if funds from private foundations or societies could be added. It was also realized that the project would need a convention between learned societies or between governments; the former was preferred (but would later have to be abandoned for the latter).

Next steps were taken at the Committee meeting of November 1954 in Paris, chaired by Oort, the principal subjects being the drafting of the convention and site testing in South Africa [8]. Beginning with this meeting, these two subjects determined the two main lines of the Committee's activity. Later on, a third would be added: the planning of the instrumentation. Of these three lines of activity of the first decade, we shall first follow developments leading to the Convention and Ratification, next describe the site testing expeditions, and subsequently the first planning of the instrumentation.

In these first years the Committee had no permanent President or Secretary. It met in various astronomical centres and usually was chaired by the host, for instance by Heckmann in Bergedorf and by Lindblad in Saltsjöbaden, until at the October 1957 meeting it made Oort its President and Bannier its Secretary and Treasurer. In May 1959 Blaauw succeeded Bannier as Secretary.

Photograph 3: *O. Heckmann (left, German Federal Republic) in discussion with B. J. Bok (United States).*

Towards the Convention

A first proposal for the Convention, between organizations, was drafted for the November 1954 meeting by Bannier and Funke [9]. G. Funke, Director of the Swedish National Research Council, was, like Bannier, a member of the Council of CERN. Amendments were made to this draft, but on the whole the matter of the Convention proceeded slowly during the first years. Little of what happened within the participating countries filters through in the minutes of the Committee meetings, until in 1960 the matter comes into focus again. In its meeting of July of that year, held in Heidelberg, the ESO Committee discussed in detail a new draft; it still was one between organizations, but its author, Bannier, stressed the necessity of a convention between governments [10].

What had caused this change, and at the same time made the matter rather urgent, were the sharply increasing costs of the site testing expeditions in combination with plans for modest observational programmes which, apart from contributing to the site testing, would produce scientific results. They will be discussed in the section on the testing programmes. Over the whole year 1959 and half of 1960 the total budget for the site testing and other expenses had been only $ 32,346.–. For the following one year and a half, however, a total of $ 363,000 had been estimated. Of this, France and Germany were supposed to contribute 1/3 each, and the three smaller continental countries about 1/9 each; the chances of Britain's participation having become quite small already at this stage. Whereas, so far, the financial resources had come from national science research councils or equivalent bodies on a year-to-year basis, these new estimates called for commitments at higher, government level.

The new draft was largely adapted from the Cern Convention. Although ESO is, of course, in essential aspects different from CERN, especially because it has its principal establishment, the observatory, outside Europe, its constitutional set-up, its financial basis and its personnel regulations have become very similar to those of CERN through this early adaptation of the CERN model. At the same time, this similarity has often led governments to appoint on the ESO Council the same delegates as on the CERN Council, resulting in similar policies.

Some features that have marked the drafts from the beginning are worth noting here: Every participating country would be represented on the ESO Council by two delegates, of which at least one should be an astronomer, and each member has equal vote – although in practice, of course, opinions of the largest countries carry strongest weight. Financial contributions are proportional to the national income but only up to a fixed limit, so that excessive domination of one member is avoided. The convention also stated from the beginning that the observatory should be located in the southern hemisphere, no broader geographical choice was ever seriously considered. As to the equipment of the observatory, there is the first set-up with the large optical telescope and the Schmidt telescope referred to before, but this is called the initial programme and the Convention allows in principle extension with any kind of other instrumentation, whatever frequency domain of the electromagnetic spectrum it may cover.

What slowed down the signing of the Convention was not any serious disagreement concerning its contents, although there had been quarreling about details – the fact that CERN successfully operated on a very similar basis was helpful – but rather the fluctuating and sometimes very low expectation with regard to the governments' willingness to embark upon this project in times of sometimes deep financial problems. Naturally, in this respect there was a large difference between CERN and ESO: development of nuclear physics being a must in the post-war era for virtually every nation, in contrast to the apparent lack of usefulness of promotion of the study of the sky. An additional, serious drawback was the gradual withdrawal of Great Britain.

Withdrawal of Great Britain

At the April 1956 meeting of the ESO Committee Great Britain was still represented by R. O. Redman and R. v. d. R. Woolley [11]. The latter succeeded Spencer Jones as Astronomer Royal in 1956. At the April 1957 meeting Redman was present, but after this, several years would elapse before a British astronomer appeared again. British interest

Photograph 4: *From left to right: Mrs Mieke Oort (Netherlands), B. Strömgren (Denmark) and B. Lindblad (Sweden).*

turned towards a Commonwealth Observatory in Australia, in preference to the ESO project. However, the attitude was not univocal. Thus, in a letter of May 13, 1959 Redman informed Oort that there had been *"a rather unexpected swing of opinion among a number of astronomers and physicists in this country – – –"* [12], and in July 1960, Sir William Hodge, Secretary of the Royal Society, wrote to Oort: *"You have no doubt heard that the British National Committee for Astronomy has been giving fresh consideration to the possibility of taking part in an international effort to construct a 120" telescope in the southern hemisphere – – –"* [13].

Later that month, on the 27th, Woolley informed Oort more specifically: *"The British National Committee prefers participation in a Commonwealth telescope to participation in a European telescope, but would favour participation in a European telescope if it is not possible to organise a Commonwealth telescope. – – –"* [14]. Moreover, Woolley stated, they *"– – – would only favour support in any scheme if the result of the participation was an allocation of telescope time, proportional to share taken of the expenses – – – and if the affairs of the Observatory – – – were vested in the hands of a Council, on which voting strength was again proportional to the financial share borne by each nation."* Clearly, on these latter points British views diverged from those among the ESO partners. These points might have become the subject of further negotiations, but that stage was never reached.

In spite of the divergence between British and continental views and intents, British authorities were regularly kept informed on developments regarding ESO. They continued to be invited to the meetings of the ESO Committee. It also happened through other channels, for instance in correspondence between Bannier and the Office of the Minister for Science at Whitehall, notably in an extensive letter by Bannier of February 3, 1961 [15]. At the January and June 1961 meetings of the ESO Committee Great Britain was represented again, by both Woolley and O.J. Eggen, and at the November 1961 meeting by A. Hunter. Meanwhile, another link had been established through which British astronomy was kept informed: the meetings of ESO's Instrumentation Committee were attended by a representative of the Astronomer Royal, first by O.J. Eggen, later by A. Hunter [16]. After 1961 no British representative attended the meetings of the ESO Committee any more.

The Grant of the Ford Foundation

Whereas the withdrawal of Great Britain had seriously weakened the basis for the ESO project, there appeared at least one bright spot above the horizon. As mentioned before, the possibility of financial help from non-government funds was alluded to in an early stage. I remember – but this is not documented – that on the occasion of a visit to the southern Leiden Observatory Station in the 1950's, Oort explored the possibility of financial help from within South Africa, but that it failed because of lack of support from certain astronomical circles in the country. On the other hand, the case of ESO has much benefitted from a grant allocated by the Ford Foundation which has its seat in New York. This foundation was well known for its promotion of international collaboration on a world-wide scale.

After an early approach by Oort had not met positive reaction, a renewed application led to the Foundation's decision in October of the year 1959, to allocate a grant of one million dollars under certain conditions, the most important of which was, that at least four of the five nations still positively involved at that time, Belgium, France, the German Federal Republic, the Netherlands and Sweden, would sign the Convention [17]. This condition was in full harmony with what had become common understanding anyhow – that participation of four countries would be a minimal base for further pursuing the effort. In order to fully appreciate the significance of the Ford Foundation's grant, one should realize that at that time the estimate of the capital investment required for the establishment of the observatory used to be $ 5 million [18]. The grant thus was equivalent to the average of the five countries' shares, and thereby had the character of pushing the project financially over the threshold in the case of stagnation of one of them. The amount also happened to cover approximately the cost of the mirror blank of the large telescope.

There can be little doubt that the grant has been most beneficial for bringing the negotiations between and within the countries mentioned to a successful end. A letter of Oort to Dr. C.W. Borgmann, Director of the Ford Foundation, of April 22, 1960 testifies to this in connection with the Dutch government's decision to participate [19], and so does Heckmann's account on the early ESO history in his introduction to the Annual Report of ESO for the year 1964 [20], as well as in his book *Sterne, Kosmos, Weltmodelle* [21]. The grant was transferred to ESO soon after the ratifications had been completed, on September 21, 1964 [22].

The history of the grant of the Ford Foundation has recently been the subject of an investigation by F.K. Edmondson. A summary, kindly offered by Dr. Edmondson for the *Messenger*, accompanies this article.

Founding Fathers

The archival documents of the last years of the 1950's and the early 1960's reflect the extremely difficult political circumstances under which especially the French adherence had to be gained. This was the more serious because from the outset it had been agreed that the initiative for convening the representatives of the member states for the signing of the Convention – their ambassadors – should be with the French government [23]. Under the still delicate political circumstances of those years this seemed natural from a diplomatic point of view. It is also to be understood in this context, that the basic text of the Convention should be the French one, particularly after the withdrawal of Great Britain [24].

Most of the French governments of those years were short-lived as a consequence of internal political division of the country, and on top of this, the Algerian independence movement made great demands on the successive cabinets from the year 1954 until independence was agreed in March 1962. The other major partner in the ESO effort, the German Federal Republic, went through its "economic miracle" in these years and seldom posed financial problems. Naturally, it was aware that a positive attitude with respect to matters of European integration should help bridge the cleavage caused by the war. In the smaller partner countries, however, post-war rebuilding programmes drew heavily on financial resources and made governments hesitant to commit themselves to a long-term financial obligation in astronomy.

Whereas the project was the subject of frequent consultation between many astronomers mutually and with their governments, there are three persons who, due to their key position, emerged as the principal spokesmen in the international discourse. They were: Jan H. Oort who as initiator and deeply convinced of the necessity of the project constantly strived for its realization; André Danjon of Paris, leading French astronomer and also strong supporter who had the difficult task of attaining his government's approval; and Otto Heckmann, one of the leading German astronomers, Director of the Hamburg Observatory and one of the strongest advocates of the project in his country. He would become ESO's first director. More in the background, but not to be forgotten, were such men as Bertil Lindblad (close to Oort by personal friendship and similarity of research interests), Charles Fehrenbach of Marseilles (close to Danjon), J.H. Bannier and G. Funke, to mention a few. Deeply interested in the developments was also Pol Swings of Liège, but a certain lack of communication between Belgian astronomical centres at that time has hampered Swings full involvement [25]. Without the growing mutual respect and friendship between the people mentioned here, the ESO project might not have surmounted the many obstacles on its way towards realization. The correspondence between these men (telephone and cable messages played only a minor role in these days) sometimes was of a strong personal nature and represents a touching "document humain". Not all letters are type-written, nearly all of Danjon's letters in the ESO Archive are handwritten.

Not all of these Founding Fathers have lived to see the dream realized. Walter Baade died already on 25 June 1960, and Bertil Lindblad on 25 June 1965, a little more than a year after the ratifications had been completed. André Danjon died on 21 April 1967, only shortly after ESO's first constructions on La Silla had begun.

The Ford Foundation and the European Southern Observatory

FRANK K. EDMONDSON, Indiana University, U.S.A.

The Ford Foundation supported projects around the world and expanded its activities to include science and engineering after Henry Heald became President of the Foundation in 1956. Carl Borgmann, President of the University of Vermont, was hired in 1958 to be the Director of the new Programme in Science and Engineering. Four large grants to support major astronomical programmes in the southern hemisphere were made during the period from late 1959 to early 1967. The Ford Foundation was restructured in March 1967 by Heald's successor, McGeorge Bundy, and the Programme in Science and Engineering was discontinued. Borgmann served as Advisor on Science and Technology until he retired in 1970.

Oort and Lindblad met with Heald and Borgmann on October 9, 1958 to discuss possible Ford Foundation support for the European Southern Observatory. Oort had written to the Ford Foundation in August 1956 but then received a negative reply. Little encouragement was given during the 1958 meeting, but a year later the Ford Foundation Board of Trustees approved an appropriation of $ 1.0 million to be granted if three conditions were met. The first condition was that at least four of the five nations (Belgium, France, German Federal Republic, the Netherlands and Sweden) must sign the Convention to create ESO. The other two conditions were administrative. Borgmann wrote to Oort on October 2, 1959 to inform him about this action.

Shepard Stone, the Ford Foundation's Director of International Programmes, went to Paris three weeks after the $ 1.0 million had been appropriated. He discussed the matter with Jean Monnet, the closest advisor to the Finance Minister, Pinay. Stone's personal friend Gaston Berger, who was Director of Higher Education, wrote in October 1959 a memorandum in French for Stone's signature. Monnet personally delivered it to Pinay, who presumably discussed it with De Gaulle. The French government decided to participate, and this was announced on June 28, 1960.

The $ 1.0 million grant was paid in full on September 16, 1964. This grant was later used to buy the quartz blank for the 3.6-metre telescope.

The great importance of the $ 1.0 million appropriation by the Ford Foundation cannot be overestimated. The Ford Foundation's promise of a $ 1.0 million grant was the "catalytic agent", a term used in the Ford Foundation staff's recommendation, that persuaded the French government to join in creating ESO. Without it, ESO might never have been more than the dream of Baade and Oort.

The three other grants were: Yale-Columbia astrograph in Argentina, $ 750,000 in 1960; CSIRO for Australian Radioheliograph, $ 550,000 in 1962, and $ 80,000 in 1966; AURA for half the cost of the Cerro Tololo 4-metre telescope, $ 5,000,000 in 1967.

I wish to thank the Ford Foundation for giving me access to the archives for the four grants in Astronomy, and Eldon Jones and Ann Newhall for their assistance in using these archives.

The Final Struggles

By the middle of 1957, the chances for approval of the project by the French government were very low. Summarizing a discussion with Heckmann on August 26 of that year, Danjon wrote that he feared opposition to the project by the Ministry of Finance [26]; it even seemed impossible to obtain funds for the site tests of the years 1957 and 1958. Danjon nevertheless thought that the project should be pursued, with France possibly joining at a later stage. Under these circumstances, serious consideration was given to a German financial guarantee to save the project and yet retain broad international character [27]. The suggestion received support from the German astronomical community [28] and the meeting of the ESO Committee of October 1957 accordingly drafted alternative budgets for the cases with and without France [29]. The guarantee was not really effectuated, and the situation remained gloomy.

When the ESO Committee met in October/November 1958 in Uccle, there was no French representation; Danjon and Fehrenbach requested to be excused because their country seemed to be unable to help support the site testing [30]. The other countries decided to go on, but the situation underlined once more the urgency of arriving at the binding international contract between parties. It would take another year for chances to become better.

In a letter to Oort of 6 November 1959, Danjon could write: *"Enfin, le* *mouvement est déclenché. – – –"*, after having received an invitation for a discussion between high officials of the Ministries of Sciences and Finances [31]. This move had very likely been prompted by the Ford Foundation grant of preceding October. In letters of 10 and 12 December, Danjon sounded quite optimistic about both the fundamental decision for participation and the financial prospects: *"J'ai en effet indiqué au gouvernement que, compte tenu de la Subvention Ford, la dépense des 5 pays de l'Europe Occidentale serait de 4 millions $, à répartir sur 8 ans, et que, tant que d'autres pays n'auraient pas décidé de participer à la réalisation du projet, la France devrait en couvrir 1/3. – – – J'attends avec impatience le retour du gouvernement, qui est à Dakar. J'espère que la décision officielle de la participation sera prise et que les invitations seront lancées. – – –"* [32].

On January 12, 1960, Danjon wrote to Oort that the Prime Minister had issued letters to the Ministries of Finances and Foreign Affairs, and the ESO project was to be submitted to the coming Cabinet Council [33]. And *"La démission du Ministre de l'Education Nationale nous aura fait perdre 1 mois entier, mais maintenant, les choses en sont au point où seule, une crise du gouvernement pourrait les compromettre. – – –"*. On February 1, Oort, not yet having heard from France, enquired discretely whether the Dutch Ministry of Foreign Affairs might now expect soon to be approached [34], and he may have drawn hope from Danjon's message that Dr. Sheppard Stone, Director of International Affairs of the Ford Foundation, one of these days would take up the matter of ESO with the new French Minister of Education [35]. But then, when by the end of the month Oort has not yet heard the good news, the correspondence between the two friends takes a dramatic turn. On March 1, Oort writes to Danjon [36]:

"Mon cher ami,

Je viens de passer une demie nuit sans sommeil avec mes soucis concernant l'ESO. La responsabilité pour ce projet pèse un peu lourd. – – – Pourquoi est-ce qu'on nous fait tant attendre? Votre ministre ayant pris la décision de principe, pourquoi ne peut-on pas prendre aussi la décision ferme de participer, de sorte que nous puissions commencer? – – – Vous comprendrez sans doute que je m'inquiète et que je commence à perdre le courage. – – – Je regrette, mon cher ami, que je dois ainsi vous faire part de mes soucis. – – –"

In reply, Danjon immediately writes, on March 3, 1960 an unusually long letter which seems so well to describe the situation that I like to quote it in full [37]:

"Mon cher ami,

Croyez bien que je partage votre inquiétude et que je ressens vivement la responsabilité de la France dans les ajournements successifs du projet. J'ai été tenté plus d'une fois de vous écrire que je renonçais à m'en occuper, mais je suis persuadé que votre tâche ne serait pas facilitée par le retrait de la France, lequel en entraînerait d'autres. Quant à faire des démarches, il m'est impossible de m'y consacrer plus que je ne le fais. Au mois de décembre, j'ai vu une dizaine de fois une personne du Cabinet du Ministre, qui avait tout préparé pour que l'affaire soit soumise au Conseil des Ministres. Mais M. Boulloche, le Ministre de l'E.N. [Education Nationale] a donné sa démission vers Noël, pour des raisons de politique intérieure. D'autres motifs ont déterminé le départ du Ministre des Finances et retardé la désignation du nouveau ministre de l'Education. Alas est survenue la révolution d'Alger dont vous n'avez peut-être pas évalué les répercussions sur la vie publique en France. Le nouveau ministre, M. Joxe, que je connais bien, n'a pas pris ses fonctions immédiatement, car il était engagé dans de difficiles négociations avec les républiques noires d'Afrique. Il n'y a guère plus de 3 semaines qu'il a constitué son cabinet. Or il a à résoudre les problèmes insolubles qui ont causé la démission de son prédécesseur! Cependant, au cours de l'intérim, j'ai pu obtenir que le Premier Ministre écrive aux Affaires Etrangères et aux Finances. J'ai vu le Ministre vendredi 26 février. Dès le 8 février, j'avais fait rechercher le dossier de l'ESO, et M. Berger en avait entretenu le Ministre. Je suis retourné au Ministère les 29 février et 2 mars, pour prendre contact avec un membre du cabinet qui venait de recevoir le dossier. Il fallait l'informer de l'affaire, toute nouvelle pour lui. Ce matin, j'ai eu une autre conversation avec M. Piganiol. A tous, j'ai affirmé la nécessité pour la France de prendre une décision.

Croyez-vous que j'aurais pu faire davantage? Toute personne approchant du gouvernement se rend bien compte qu'il est obsédé par l'Afrique du Nord et non par l'Afrique du Sud. Soyez assuré, mon cher ami, de ma constante et fidèle amitié, A. Danjon"

From letters of Fehrenbach and Danjon in the months following, it appears that, while a decision in principle by the French authorities had been taken, executive action was further delayed by the instabilities within the government. Towards the middle of the year 1960 Danjon wrote to Oort: *"– – – La lourde machine administrative – – – dépend de 4 ministères dont 3 ont changé depuis le début de l'année! J'ai l'impression d'être condamné à rouler le rocher de Sisyphe pour l'éternité! Mais j'ai tout de même très bon espoir."* [38].

About that time, in correspondence between Oort and Heckmann preparing for the Committee meeting of July 15, 16, 1960, the possibility of German advance financing was taken up again, combined with a Dutch initiative for convening the five governments [39], but this did not appear to open promising perspectives. However, towards the end of the year 1960 French authorities occupied themselves with the formulation of the text of the Convention, and of the Financial Protocol that belongs to it, so that these texts could be discussed at the meetings of the ESO Committee and presented to the Foreign Ministries of the partner countries [40].

Further delay was then caused by difficulties in arriving at an acceptable text of the German version of the Convention. Towards the end of 1961 it was the general impression that universal agreement had been reached, but then unexpectedly a new dispute arose between German and French officials on the interpretation of the Convention text concerning the distribution of the contributions of the member states. By the end of March 1962 Heckmann had also removed this obstacle [41]. At the June 1962 meeting of the ESO Committee in Bruges, Belgium, it could be announced that the date for the signing was approaching. And on September 21, 1962 Danjon wrote to Oort [42]:

"Mon cher ami,

Les Affaires Etrangères ont fixé au 5 octobre la signature de la Convention. Enfin! – – – Je ne saurais vous dire combien je suis heureux de voir enfin prendre corps votre grand projet. Mais il aura fallu plus de dix ans! L'astronomie est bien l'école de la patience. – – –"

The Convention was indeed signed on that date, at the Ministry of Foreign Affairs in Paris, for the foreign countries by their ambassadors and for France by the Secretary-General of the Ministry of Foreign Affairs. That same date, Danjon wrote to Heckmann [43]:

"Mon cher Collègue,

Un mot seulement, pour vous confirmer que les représentants des 5 pays ont signé la Convention aujourd'hui à Midi! Alleluia!!

Bien cordialement votre A. Danjon"

After this memorable event, it would still take more than one year before the Convention would be ratified and thus governments could assume financial commitments. As it is stated in the Convention, this situation would be reached when at least four of the governments had ratified and, moreover, these four would represent at least 70 % of the total of the contributions. This implied

LIST OF MEETINGS OF THE ESO COMMITTEE (PRECEDING THE ESO COUNCIL)

No.	Date	Place	Chairman	Minutes made by:	Reference in ESO Hist. Archives
1	1953 June 21	Leiden	J.H. Oort	P.Th. Oosterhoff	I.A.1.1.
2	1954 January 25–27	Leiden	B. Lindblad	P.Th. Oosterhoff	I.A.1.1.
3	1954 November 8–9	Paris	J.H. Oort	P.Th. Oosterhoff	See FHA*
4	1956 April 20–21	Bergedorf	O. Heckmann	W. Fricke + O. Heckmann	I.A.1.3.
5	1956 October 15–16	Saltsjöbaden	B. Lindblad	P.Th. Oosterhoff	I.A.1.4.
6	1957 April 1–2	Uccle	P. Bourgeois	B.G. Hooghoudt	See FHA*
7	1957 October 28–29	Leiden	J.H. Oort	J.H. Bannier	I.A.1.6.
8	1958 July 23–24	Paris	J.H. Oort	J.H. Bannier	I.A.1.7.
9	1958 Oct. 31 – Nov. 1	Uccle	J.H. Oort	J.H. Bannier	I.A.1.8.
10	1959 May 29–30	Noordwijk a/Zee (Neth.)	J.H. Oort	A. Blaauw	I.A.1.9.
11	1959 July 4	Paris	J.H. Oort	A. Blaauw	I.A.1.10.
12	1960 July 15–16	Heidelberg	J.H. Oort	A. Blaauw	I.A.1.11.
13	1961 January 3–4	Paris	J.H. Oort	A. Blaauw	I.A.1.12., 13.
14	1961 June 12–13	Tübingen	J.H. Oort	A. Blaauw	I.A.1.14.
15	1961 November 6–7	Paris	J.H. Oort	A. Blaauw	I.A.1.15.
16	1962 March 5–6	Paris	J.H. Oort	A. Blaauw	I.A.1.16.
17	1962 June 18–19	Bruges	J.H. Oort	A. Blaauw	I.A.1.17.
18	1962 October 19–20	Stockholm	J.H. Oort	A. Blaauw	I.A.1.18.
19	1963 February 5–7	CERN, Geneva	J.H. Oort	O. Heckmann	I.A.1.19.
20	1963 July 23–24	Amsterdam	J.H. Oort	O. Heckmann	I.A.1.20.
21	1963 November 15	Bonn	J.H. Oort	J. Ramberg	I.A.1.21.

* FHA = Files Head of Administration of ESO.

that in any case France and the Federal Republic of Germany should be included. It was accomplished when France ratified on 17 January 1964 [44]: the Netherlands had ratified on 21 March 1963 [45], Sweden on 4 November 1963 [46], and the German Federal Republic on 10 November 1963 [47].

So, then, from early 1964 on, ESO was on solid grounds and could begin realizing its long-term building project. It would within a few years do so on an even broader base, after Belgium had ratified on 2 October 1967 [48] and a sixth member, Denmark, had even done so a little earlier, on 23 August 1967 [49]. But before we enter this new phase, we hope to describe, in the following article, what meanwhile had been accomplished in the search for the site of the Observatory and in the preparations for its instrumentation.

References and Notes

Abbreviations used:

EHA = ESO Historical Archives. The numbers following EHA identify the (folder containing the) archival document according to the Inventory explained in the separate box accompanying this article.

ECM = ESO Committee Meeting. The meetings of this Committee, which preceded the ESO Council, are listed in a separate box accompanying this article.

Heckmann Sterne = O. Heckmann, *Sterne, Kosmos, Weltmodelle,* Verlag Piper & Co, München, Zürich, 1976.

FHA = Files belonging to the Office of the Head of Administration of ESO.

[1] For the text with authentic signatures, see EHA-I.A.1.1.

[2] See EHA-I.B.1. for correspondence between Oort and the Dutch funding organization ZWO in preparation of Baade's stay.

[3] I well remember Jan Oort one day entering my office – opposite to his at Leiden Observatory – to share with me his excitement about the idea!

[4] The Memorandum on this meeting, later called ECM No. 1, is in the FHA; a copy of it in EHA-I.A.1.1.

[5] For a report on the Conference see IAU Symp. No. 1, 1955, ed. A. Blaauw.

[6] For the distribution of observatories in geographic latitude in 1954, see R. Coutrez and L. Bossy in *Ann. de l'Obs. R. de Belgique,* 3^{e}Ser., Tome VI, 1954, quoted in J.H. Oort, *ICSU Review,* Vol. 3, No. 1, 1961.

[7] ECM No. 2, Minutes ("Memorandum") in EHA-I.A.1.1.

[8] Memorandum on this meeting (ECM No. 3) is in the FHA; a copy of it in EHA-I.A.1.2.

[9] A copy of this draft Convention is in EHA-I.A.1.2. It is marked "1st draft of Bannier and Funke" (in Dutch) in Oort's handwriting.

[10] A copy of this draft is in EHA-I.A.1.11., with accompanying letter from Bannier to Blaauw.

[11] Minutes in EHA-I.A.1.3. [12] EHA-I.C.1.1.g. [13] See ref. 12. [14] See ref. 12. [15] See ref. 12.

[16] According to a letter of Blaauw to Hunter, EHA-I.C.1.1.g.

[17] See letter of C.W. Borgmann, Director Ford Foundation, to J.H. Oort of October 2, 1959 in EHA-I.C.1.3.

[18] See, for instance, Minutes of ECM No. 6, in FHA; a copy of it is in EHA-I.A.1.5.

[19] In EHA-I.C.1.1.c.

[20] page 6 of English version.

[21] Heckmann Sterne, p. 265, 266.

[22] *ESO Annual Report* 1964, p. 6.

[23] Minutes ECM No. 12, p. 3 in EHA-I.A.1.11. [24] See ref. 23.

[25] See, for instance, correspondence between Swings and Blaauw in March–April, 1961, 1961 in EHA-I.C.1.1.a.

[26] EHA-I.C.1.1.c.

[27] See Oort's report in a discussion by the Netherlands Astron. Council on 24 Sept. 1957, in EHA-I.C.1.1.c.

[28] See ref. 27.

[29] Minutes ECM No. 7, p. 8 in EHA-I.A.1.6.

[30] Minutes ECM No. 9, p. 1 in EHA-I.A.1.8.

[31] See EHA-I.C.1.1.c. [32] See ref. 31. [33] See ref. 31. [34] See ref. 31.

[35] See letter by Oort to Heckmann of 13 February 1960 in EHA-I.C.1.1.d.

[36] See EHA-I.C.1.1.c. [37] See ref. 36.

[38] Undated copy in EHA-I.C.1.1.c.

[39] See correspondence between Oort and Heckmann in May, June 1960, in EHA-I.C.1.1.d.

[40] Undated letter of Oort to ESO Comm; January 1961? In EHA-I.C.1.1.c.

[41] See correspondence between Oort and Heckmann in January–March, 1962, in EHA-I.C.1.1.d.

[42] In EHA-I.A.2.5.

[43] Heckmann Sterne, p. 267.

[44] Circular letter by Fehrenbach of 23 January 1964 in EHA-I.C.1.1.f.

[45] Circular letter by Bannier of March 27, 1963 in EHA-I.C.1.1.f.

[46] Communication by the Dutch Ministry of Foreign Affairs of January 6, 1964 in EHA-I.A.2.5.

[47] See ref. 46.

[48] Communication Dutch Ministry of Foreign Affairs of May 9, 1968 in EHA-I.A.2.5.

[49] See ref. 48.

Paul Ledoux (1914–1988)

Paul Ledoux passed away on October 6, aged 74. President of ESO's Observing Programmes Committee from 1972 till 1975, he had with his fellow members the difficult task of selecting among observation proposals. He was also member of the ESO Council for which he served as President from 1981 till 1985.

His wisdom as well as a deep kindness, essential qualities for such an important leadership, helped him to gain respect and friendship among his colleagues in the ESO Council. Paul Ledoux, a student of P. Swings, graduated in Physics in 1937 at the Liège University. He soon went to Oslo to work with A.S. Rosseland where he became interested in the structure and stability of stars. This led him in 1941 to establish the existence of a maximum mass value for stable main sequence stars in a famous *Astrophysical Journal* paper entitled "On the Vibrational Stability of Gaseous Stars".

The Second World War had already started and Paul Ledoux actively participated in the defense of the allied countries, serving as a member of the meteorological service of the Royal Air Force. Just after the war, he returned to stability problems, studying the effect of a variation of the adiabatic exponent on the onset of a dynamical instability. Dealing with white dwarfs, he also showed that no hydrogen can be present in the central layers of a white dwarf while only a very limited amount can be acceptable in the external layers.

In 1947, Paul Ledoux published an analysis of the effect of a discontinuity in mean molecular weight on stellar structure. He showed that this situation leads to a partial mixing called semi-convection. Convection itself was one of his favourite subjects but he also devoted himself to the problem of the helium content in the Galaxy, proposing a source of helium enrichment through homogeneous evolution of massive stars, as a result of rotation.

Non radial oscillations did receive a great deal of his attention. He associated the presence of unstable g modes to the existence of a superadiabatic gradient and presented those results in his "thèse d'agrégation" in 1949.

Among the most famous papers published in the past decades on Stellar Stability, everyone will remember two 1958 reviews contained in the *Handbuch der Physik*, signed by Paul Ledoux, the first one in cooperation with Th. Walraven.

Celebrated in Belgium as well as in foreign countries, he was honoured by the "Prix Francqui" in 1964, the "Prix décennal des Mathématiques appliquées" in 1968, the "Eddington Medal" of the Royal Astronomical Society in 1972 and the "Médaille J. Jansen" of the Academy of Sciences of Paris in 1976, to cite but these few.

He became Professor at the University of Liège in 1959 and since then, performed enormous teaching charges covering Astronomy, Astrophysics, Analytical Mechanics, Celestial Mechanics, Meteorology and Hydrodynamics. He was very devoted to his students and all of them discovered in him not only a talented scientist but also a warm although deeply earnest man. His death will be felt as a great loss by all his colleagues, collaborators and friends in the whole astronomical community.

A. NOELS

List of ESO Preprints

September–November 1988

608. J. Surdej, P. Magain, J.P. Swings, M. Remy, U. Borgeest, R. Kayser, S. Refsdal, H. Kühr: Preliminary Results from a Search for Gravitational Lensing within a Sample of Highly Luminous Quasars. Communication given at the first DAEC Workshop in Paris.
609. F. Murtagh: Hierarchical Trees in N-Body Simulations: Relations with Cluster Analysis Methods. Computer Physics Communications.
610. H.E. Schwarz, S. van Amerongen, M.H.M. Heemskerk, J. van paradijs: Outbursts in TV Columbae: Walraven Photometry and CCD Spectroscopy. *AA Letters.*
611. A. Terzan, Ch. Ounnas: A Photometric Study of the Bright Cloud B in Sagittarius. VI. 1592 New Variable Stars and 30 Diffuse Objects. *AA Suppl.*
612. R. Arsenault: The Preponderance of Bar and Ring Features in Star-Burst Galaxies. *AA.*
613. E. Oliva, A.F.M. Moorwood, I.J. Danziger: Infrared Spectroscopy of Supernova Remnants. *AA.*
614. Z.I. Tsvetanov, I.M. Yancoulova: Reddening in the Narrow-Line Region of Active Galactic Nuclei. *M.N.R.A.S.*
615. A.F.M. Moorwood, E. Oliva: Infrared [FeII] and H_2 Line Emission in Active Galactic Nuclei. To appear in Proceedings of IAU Symposium 134, *Active Galactic Nuclei* (eds. D.E. Osterbrock and J.S. Miller, Kluwer Academic Publishers).
616. E. Brocato, R. Buonanno, V. Castellani, A.R. Walker: CCD Photometry of the LMC Cluster NGC 1866: Observational Results. *Astrophysical Journal.*
617. G.A. Tammann: The Distance of the Virgo Cluster – a Review.
618. J. Andersen, J.V. Clausen, P. Magain: Absolute Dimension of Eclipsing Binaries. XIV: UX Mensae. *AA.*
619. R. Gathier, S.R. Pottasch: Properties of Planetary Nebulae. II. Central Star Evolution. *AA.*
620. G. Srinivasan: Millisecond Pulsars: a New Population of Gamma Ray Sources? Invited talk presented at the Symposium on Advances and Perspectives in X-ray and Gamma-ray Astronomy held in Espoo, Finland, 18–21 July 1988, as part of the COSPAR General Assembly.
621. A. Cavaliere, E. Giallongo, F. Vagnetti: Uncertainties and Apparent Trends in the Evolution of Quasars. *The Astronomical Journal.*
622. S. D'Odorico, S. di Serego Alighieri, M. Pettini, P. Magain, P.E. Nissen, N. Panagia: A Study of the Interstellar Medium in Line to NGC 5128 from High Resolution Observations of the Supernova 1986G. *AA.*
623. G. Meylan: Studies of Dynamical Properties of Globular Clusters. V. Implications of the Observed Flat MS Mass Function in 47 Tucanae. *AA.*
624. R.M. West: Halley's Comet (Part I): Ground-Based Observations. V.I. Moroz: Halley's Comet (Part II): Space Studies. Invited Discourses at the XXth IAU General Assembly. To be published in IAU Highlights, Vol. 8 (1989).

ERRATUM

In the article "Active Optics: The NTT and the Future" (*The Messenger* No. 53, September 1988, p. 1), there was an error in the text of Fig. 7 (p. 6). The text given for Fig. 7 *(ii)* should refer to Fig. 7 *(iii)*; conversely, the text given for Fig. 7 *(iii)* should refer to Fig. 7 *(ii)*.

NTT Picture Gallery

Figure 1.

Figure 3.

Figure 2.

Figure 4.

The arrival of the NTT mirrors and mirror cell on La Silla on 22 September coincided with the first and only day of snow on La Silla this year (Fig. 1). The mirror was installed near the aluminization chamber in the 3.6-m telescope building, where aluminization of the NTT mirrors will take place in the coming weeks (Fig. 2). In October the telescope mechanics and electronic hardware as well as the building were completed (Figs. 3 and 4). Software integration then started with the first pointing and tracking tests on the sky using the finder telescope attached to the tube structure. Integration of the mirror and optical alignment are expected to take place in January 1989 when the telescope will have its "first light". *M. TARENGHI*

ESO Workshop

An ESO Workshop on the subject of "Extranuclear Activity in Galaxies" will be held at ESO, Garching bei Muenchen (F.R.G.) during the second half of May 1988 (provisional dates 16–18 May).

The preliminary programme includes the following topics:

– Observations of warm gas (optical emission lines) and cool gas (Radio lines and optical/UV absorption lines) – Cooling processes, ionization mechanisms and chemical composition of the gas.

– Radio rotation measure and depolarization measurements – the nature and location of the magnetoionic medium.

– Relationship between the warm gas and radio structures – jet/gas interactions, radiation field anisotropies and beaming.

– Kinematics of the extended gas – galaxy mass distributions.

– Relationships with the hot (X-ray) haloes – the fate of the cooling gas.

– Implication for the appearance of galaxies at high redshift.

Keynote speakers include F. Bertola (Padua), L. Browne (Jodrell Bank), R. Fosbury (ST-ECF), L. Hansen (Copenhagen), R. Laing (RGO), G. Miley (Leiden), P. Quinn (STScI/MSSSO) and A. Robinson (Cambridge).

The initial registration deadline is 31st January 1989. It is the intention to house the workshop within the ESO building and so the total number of participants will be limited to 80.

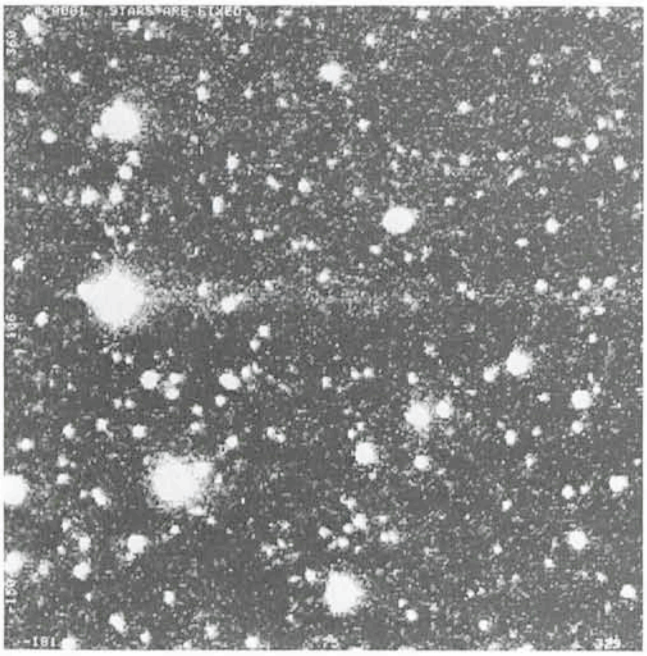
Contact address:

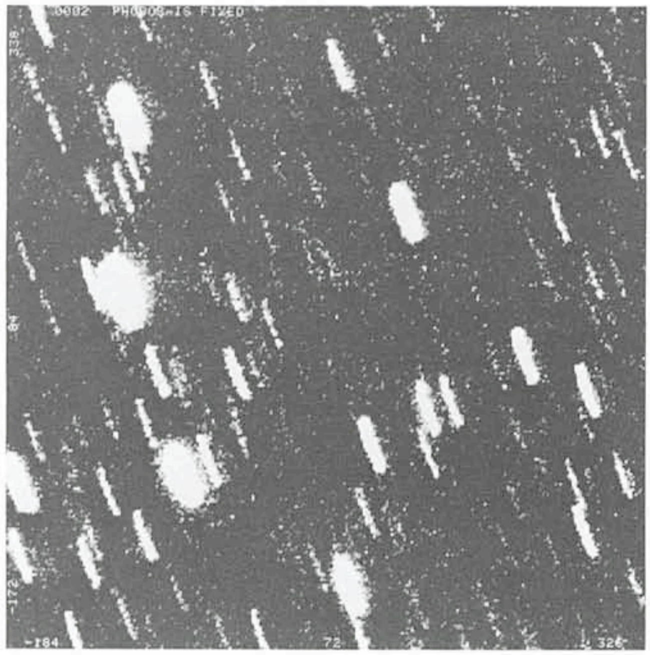
Bob Fosbury (ST-ECF) and Evert Meurs (ESO)
European Southern Observatory
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München, Federal Republic of Germany
Telephone: +49-89-32006-0, Telex: 52828222 eo d

TO ALL READERS

Please make sure that the card which accompanies this issue of the *Messenger* is returned, if you want to continue to receive the journal. *The editors*

Where is Phobos 1?





The Soviet spacecraft Phobos 1, launched in July this year and now en route to Mars and its major moon, was lost due to an incorrect ground control command. Many attempts were made to reestablish radio-contact, but unfortunately in vain.

On September 21, ESO received a request for observation of Phobos 1 from the Space Research Centre in Moscow. If it were possible to obtain a sequence of images of the spacecraft – of course only as a faint point of light – then its accurate position and perhaps even its rotational status could be determined. This would help the efforts to reacquire contact.

At La Silla, the first possible night, September 22, was lost due to snow (see the "NTT Picture Gallery" in this issue) and no observations of such a faint object could be made during the ensuing full moon period. However, observations were carried out with the Danish 1.5-m telescope on October 1/2, 2/3, and 3/4, resulting in at total of fifteen 10-minute exposures with the CCD camera. Moreover, nine 3-minute exposures were made with the EFOSC instrument at the 3.6-m telescope during the night October 3/4. The observers were visiting astronomers D. Hatzidimitriou and C.A. Collins (Edingburgh); the image processing was made at La Silla by H.-U. Nørgaard-Nielsen (Copenhagen) and H. Pedersen (ESO), who was also responsible for the coordination.

We show here the central areas of two images from EFOSC. The one to the left is a direct exposure of the Phobos 1 field; the right one is a combined frame in which the 3.6-m telescope was set to follow the motion of the spacecraft; the stars are therefore seen as trails. The limiting magnitude in both cases is magnitude 25 or fainter. Since Phobos 1 is not seen, it must either have been outside the field (did a rocket fire after the contact was lost?) or it was positioned so unluckily in space that the sunlight reflected from its surface in our direction was too faint to be detected, even with the present, extremely sensitive equipment.

A final attempt was made with EFOSC on October 9/10, by visiting astronomers G. Suchail and Y. Mellier (Toulouse). Four frames, totalling 36 minutes were obtained, but again there was no sign of Phobos 1.

It is a pity that this last-ditch effort was unsuccessful and that it was not possible to help our space colleagues this time. But it is a good example of the collaborative spirit that reigns in our field of science, and which transgresses all borders. *The editor*

Open-House at ESO

On October 22, 1988, the science institutes in Garching again jointly organized an open-house day. With the help of many of the staff members, a well-defined path was established through the ESO Headquarters with demonstrations and exhibitions along the route.

This year, around 1,800 persons visited ESO. They were received at the entrance by the most "photogenic" staff members and guided towards the auditorium, where a new ESO slide show was running at 20-minute intervals.

Next, the NTT and VLT projects were explained in the Council room; this included a full-scale model of an 8.2-metre VLT mirror! (See the picture; this room was the only one at the Headquarters which was big enough.) In the terminal room, the advanced image processing systems caught the eyes of computer-minded persons of all ages and also the interesting demonstration by the ST/ECF of artificial intelligence. An overview of the Hubble Space Telescope was followed by a visit to the "Remote Control Room", from where two telescopes at La Silla are used for observations.

As usual, the names and orbits of minor planets attracted much interest and an impressive demonstration of a CCD camera ("seeing" in a completely dark room) convinced quite a few visitors about the witchcraft of modern astronomical technology.

Finally, there was a possibility to participate in the "ESO Astroquiz". Well over 1,200 response sheets were counted in the box at the end of the day and when the prize-winners were drawn, the first three were found to come from places as far apart as München, Wolfratshausen and Regensburg. Each of them received a copy of the ESO Book "Entdeckungen am Südhimmel".

For them and many others, ESO was "worth the journey".

R.M. WEST

NOTE

ESO/NOAO Workshops

In the *Messenger* No. 52 and in the Proceedings of the NOAO/ESO Conference on "High Resolution Imaging" it was announced that the next ESO/NOAO Workshop on experimental astrophysics with the title "Infrared Array Detectors" would be held in Tucson, Arizona, in the autumn of 1989.

We regret to inform you that this Workshop has been cancelled. Information on the next joint Workshop will be given in due time.

F. MERKLE, J. BECKERS

Upcoming ESO Exhibitions

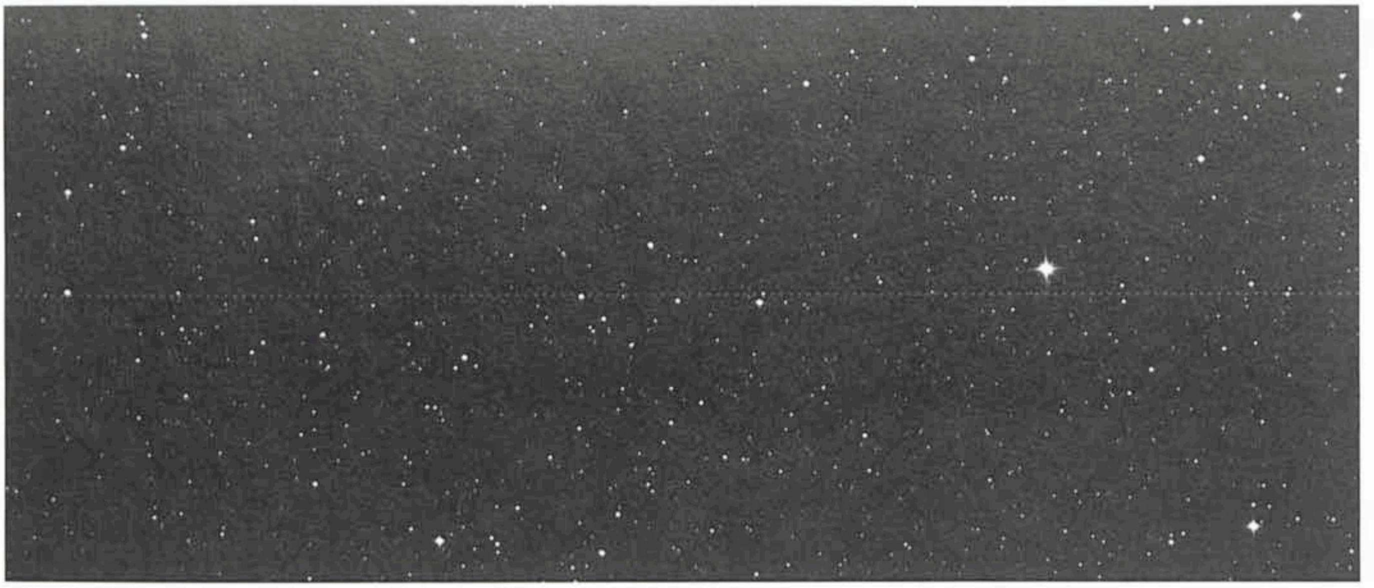
As reported in the last issue of the *Messenger,* ESO organized a special exhibition booth at the XXth IAU General Assembly in Baltimore (see photo). After the exhibitions in Malmö (Sweden) which is still running and another in Innsbruck (Austria) during November–December, the following are planned for next year:

The Hague, Netherlands, Museon, opening on January 27;
Münster, F.R. Germany, Museum für Naturkunde, opening on April 20;
Klagenfurt, Austria, Planetarium, opening end of June;
Copenhagen, Denmark, Tycho Brahe Planetarium, opening in October;
Stuttgart, F.R. Germany, Planetarium, opening before Christmas.

We hope that our local readers will take the opportunity to visit these events.

Potentially interested organizers of future exhibitions are kindly requested to contact the ESO Information Service (address on last page), since the planning for 1990 is about to start.

The exhibition has now been enlarged to include more information about the newest scientific and technological developments. Of particular interest is the full-scale model of a VLT mirror (53 m^2) and the fischertechnik VLT model of a unit telescope, described elsewhere in this *Messenger* issue.



A "Blinking" Satellite

This unusual satellite trail was recorded on an ESO Schmidt plate for the extension of the Quick Blue Survey towards the equator. It was obtained on August 31, 1988 and covers field 815 of the ESO/SERC grid (R.A. = 21^h20^m; Decl. = $-5°$). Whereas the brightness of most other photographically recorded satellite trails is rather uniform or slowly varying, the rapidly changing light along this trail indicates a very fast rotation. Also, the "blinks" are different, and do not repeat in a uniform sequence, showing that the rotation axis changes.

Indeed, if the satellite is at an altitude that corresponds to one revolution around the Earth each 100 minutes, then it rotates about 9 times per second (but it may of course be in a higher, slower orbit). What kind of instruments are on-board? Or is it just another piece of tumbling space junk?

Report on IAU Colloquium 112[1], on Light Pollution, Radio Interference and Space Debris

(Washington, 13 to 16 August 1988)

Light Pollution

Astronomers are the only minority concerned by this problem and thus have to lead the fight without expecting any help, apart from the lighting industry which recently discovered that computer aided design could help improving the efficiency of lighting equipments!

Kitt Peak observatory reported encouraging news from the results of light pollution control in Tucson. Mount Palomar Observatory, where the sky is 0.75 magnitude brighter than it would be without light pollution, is now trying to follow the same path. Apart from getting a legislative support, it is advised to acquire comprehension, understanding and help from the population. This is possible through a long term policy aiming at raising interest about the science made in astronomical observatories, for instance by means of guided tours, with a better long term efficiency when school children are concerned.

The main cures for light pollution are the generalized use of low pressure sodium lamps because their radiation is easier to filter out, and a better shielding of street lighting (60 % of the total pollution). Outdoor sport facilities remain a problem but most are fortunately not lighted during the whole night. Time control of residential area lighting can help darkkening part of the nighttime.

An argument to convince city mayours to take actions is that the young urban generation is raised without having the possibility to enjoy the vision of the night sky (of course, in that case, as for amateur astronomers, the low pressure sodium does not help much). Planetariums are also considered as a way to sensitize the population and should include some striking examples in their shows (polluted versus non-polluted sky).

As shown on Figure 1, La Silla lies in a particularly favourable area now, and so did Mount Palomar observatory when the site was chosen . . .

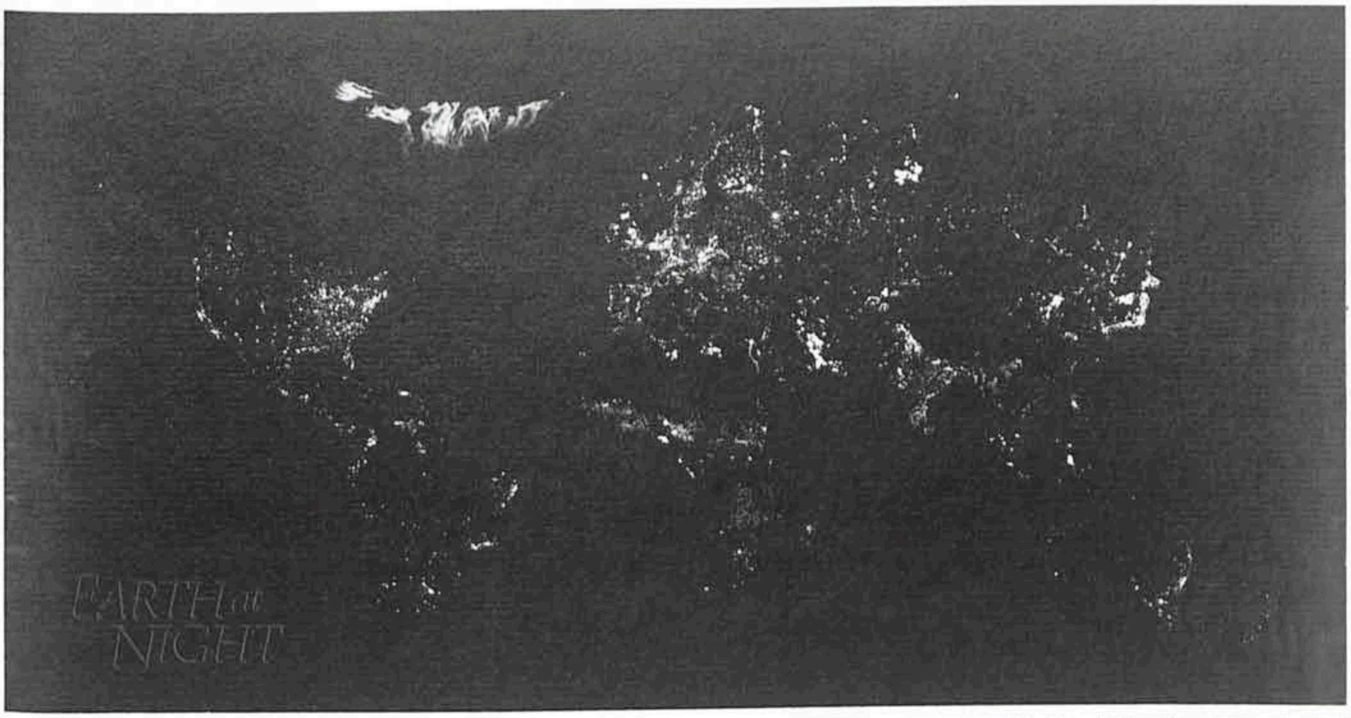
Radio Interference

Radio astronomers represent a small percentage of radio wave users, all of them being concerned with maintaining some good order in the radio community. With the expansion of satellite radio communications, there is a growing need for frequencies. The distribution of the radio spectrum is made on a worldwide basis during a so-called "World Administrative Radio Conference" (WARC).

The U. S. radio astronomers have several channels in their administration to get a voice at WARCs, the situation is somewhat more difficult in Europe where each country has its own regulations. The newly created European "Committee on Radio Astronomical Frequencies" (CRAF) tries to be present during negotiations. Radio astronomers are advised that it will be practically impossible to get new frequencies in the future and that they have to keep on justifying the usefulness of the already attributed ones.

Among the most affected users by

[1] This colloquium was organized by D.L. Crawford (Kitt Peak National Observatory) and T. Gergely (National Science Foundation, Div. Ast. Sci.)



The Earth at night: this photo-composition of many satellite pictures illustrates the different sources of light pollution. In addition to light emission from urban areas, note the agricultural savannah fires in central Africa, natural gas flares from oil fields (Persian Gulf, North Sea . . .) and also the Aurora Borealis in the north. Credits: United States Air Force / DMSP Archives, National Snow and Ice Data Center, NOAA, University of Colorado / W. T. Sullivan, II, University of Washington, Seattle / Kerry Meyer.

radio frequency interference, one could mention the SETI programme, dedicated to the Search for Extraterrestrial Intelligence in the 1–10 GHz band.

The main pollution is created by radars but in urban areas, there are various other less known sources such as defective home appliances or high success gadgets like garage door remote openers. U.S. regulations allow observatories to proceed to inquiries in case of nuisance from such local sources of radio pollution.

A satellite dedicated to the detection of radio frequency interference from space will be operational in 1992 in frequency bands near 300 MHz.

Space Debris

This is an issue which goes far beyond the astronomical community. Any new spacecraft design has to include an anticollision shield. Damages due to collision with objects other than meteoroids may be severe and the pressure for reducing the threat will be stronger and stronger. ESA created in 1986 a working group on space debris and a report will soon be available.

It is estimated that 70% of debris come from military explosions which have now been banned. More than 7,000 objects larger than 10 cm are tracked by the North American Aerospace Defense Command (NORAD). A catalogue is available to civilians and astronomers from the Naval Space surveillance Center (Dr. S.H. Knowles, Dahlgren, VA, U.S.A).

The number of debris increases constantly because of mutual collision and the critical density could be reached in 50 years if nothing is done. Cleaning the small debris by retrieval is considered as unrealistic nowadays because of the cost. Short term solutions such as propulsion of obsolete satellites to a "disposal" orbit could create a belt of debris around the earth. A third solution is the re-entry through the earth atmosphere for disposal.

As for consequences on astronomy, each photographic plate of the new Palomar sky survey includes an average of five tracks from satellites or debris. The space telescope will see 4 debris of 10^{th} magnitude per hour per degree of field of view and 1,000 debris of 20^{th} magnitude per hour per degree of field of view. A geostationary satellite is seen from ground with mag 14. The space shuttle is mag −3. Solar panels send bright flashes to ground and may interfere with gamma ray burst observations. According to the relative position of the Sun, one square inch of solar cell can be visible with the naked eye. At least one optimistic information to conclude: those problems usually occur only until two hours after sunset and start two hours before sunrise. *M. SARAZIN*

50 Years of RGU Photometry

A. SPAENHAUER, C. F. TREFZGER, L. LABHARDT, S. GABI,
Astronomisches Institut, Universität Basel, Switzerland

1. Introduction

Fifty years have elapsed since W. Becker (1938) proposed to use three-colour photometry for the study of stars which are too faint for spectral classification. He stressed that the choice of the passbands had to be guided by the properties of stellar radiation rather than by the properties of existing instruments. The three passbands were chosen such as to reflect the two basic characteristics of the visible spectral energy distribution of a star: a long-wave colour index (G-R) as a measure of temperature and a short wave colour index (U-G) defined by two well separated passbands measuring the UV-depression caused by line blocking and the Balmer depression.

Since then a multitude of different photometric systems have been established, each serving a different purpose. The UBV system (Johnson and Morgan 1953) as the most similar one to the RGU system has become the most widely known and used because it could be established both photographically and photoelectrically. Although a systematic comparison of the RGU and UBV system has not been undertaken, we refer to Fenkart and Esin-Yilmaz (1985) and the third section for some aspects of this comparison. Due to the lack of red sensitive photocathodes, the RGU system was originally defined as a photographic system (see Table 1, Becker 1946, Becker 1965, Buser 1978). In the past 10 years the photoelectric RGU system has been established (Trefzger et al. 1983) and we want to present here some new results based on photoelectric measurements along with a brief historical outline of the photographic RGU programme.

TABLE 1: *Characteristics of the photographic RGU system.*

	Emulsion	Filter	λ_o	$\Delta\lambda$ (FWHM)
U	Kodak 103aO	UG2 (2 mm)	3593 Å	530 Å
G	Kodak 103aO	GG5 (2 mm)	4658 Å	495 Å
R	Kodak 103aE	RG1 (2 mm)	6407 Å	430 Å

2. The Photographic RGU System

From ~1940 through ~1960, the first photographic RGU measurements were carried out with the Hamburg, Ann Arbor, Asiago and Cleveland Schmidt telescopes. The interpretation of the data confirmed that progress in the following fields could be expected (Becker and Steinlin 1956):

1. Identification of faint main sequence stars as well as statistical absolute magnitude determinations (photometric parallaxes).
2. Determination of interstellar reddening along the line of sight.
3. Distance determination of galactic clusters.
4. Distinction between late-type main sequence and giant stars.

Among the first objects studied with the RGU system during that period were the open clusters (Becker and Stock 1958) using the still widely applied technique of main sequence fitting (both with a long *and* short wave colour-magnitude diagram) in order to determine distance as well as interstellar reddening. This technique led to an internally consistent distance scale with random errors less than ~15% together with crude relative ages (main sequence turnoff). The distribution of the very young open clusters (Becker 1963) clearly revealed part of a spiral arm pattern in the solar neighbourhood consistent with other optical spiral tracers (e.g. H II regions) and thus proved the power of the method. The basic data of the Basel cluster work is contained in two cluster catalogues (Becker and Fenkart 1971, Fenkart and Binggeli 1979).

In the next phase the more ambitious goal of exploring the distribution of the field stars of our Galaxy was envisaged. In the late 1950's, but especially after 1961, when the first RGU plates with the Palomar Schmidt telescope were taken by U.W. Steinlin, the foundations were laid to the Basel Galactic Structure programme. At that time (and probably still nowadays) most of the information about the structure of the galactic halo (today often called spheroidal component SC) came from the study of globular clusters and RR-Lyrae stars, whose masses may constitute as little as 1% of the total SC. Therefore the investigation of the field SC was a challenging task and led to a *halo survey* consisting of systematic, three-colour photometric investigations of starfields down to limiting magnitudes of 18 m to 19 m. These fields were chosen more or less in the meridional plane passing through the Sun and the galactic centre and, if possible, overlapping with Selected Areas.

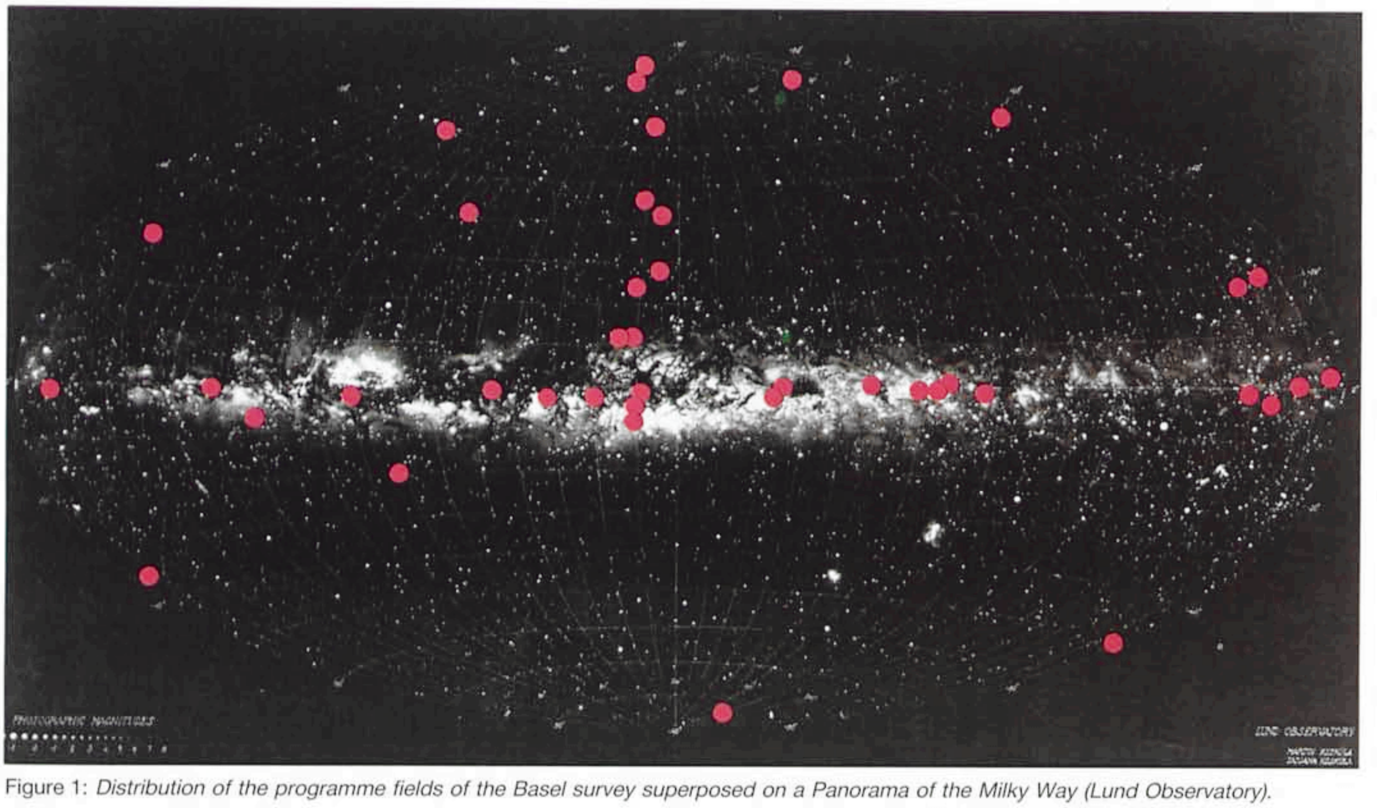


Figure 1: *Distribution of the programme fields of the Basel survey superposed on a Panorama of the Milky Way (Lund Observatory).*

The so far published 10 photometric catalogues (can be distributed on request) contain the RGU data of 16 starfields of the *halo survey* (~30,000 stars) as well as of 33 starfields of the *disk survey* ($|b| < 10°$, ~55,000 stars). The distribution of these fields projected on the sky is shown in Figure 1. The field sizes were chosen in order to give a statistically significant number of stars between 1,500 and 2,000. The typical halo field sizes are between 1 and 3 square degrees whereas the typical disk field sizes are between 0.1 and 0.3 square degrees. For every field the stellar space densities along the line of sight have been determined for those stars which can be photometrically classified using the stellar statistical tools as described by Becker (1965). Furthermore, these data can serve as a powerful preselective tool for sampling specific stellar populations in order to study them spectroscopically or with intermediate-band photometry as will be exemplified next.

When comparing the morphology of the two-colour diagrams in different regions of the Galaxy, several important features can be noted, which reflect the sampling of photometrically distinct populations. As an example, Figure 2 shows the two-colour diagrams of SA 57 (pointing to the galactic northpole) and of a field in the galactic anticentre. Four groups of stars, which are marked with different symbols and which are described in the caption, can statistically be identified by the photometry. So far, the RGU data have been used to select complete samples of F and G type dwarfs and subdwarfs at the galactic north and southpole regions for more detailed studies with intermediate band photometry (Pel et al. 1988, Spaenhauer and del Rio 1989). Special interest deserves the fact that the mean loci of the late-type giant stars show a large variation (Fig. 2b). This led to the distinction between "left" and "right side" giants (relative to the main sequence) and was qualitatively interpreted as a metallicity effect (Becker 1979, see also the next section). Up to now only a small part of the RGU data contained in the catalogues has been exploited in the context of "Galaxy modelling" (Buser and Kaeser 1985, Bahcall et al. 1985, Fenkart 1989). The main reason preventing to extract the full information, especially the one contained in the U magnitudes because of their metallicity dependence, was the lack of a sound physical calibration of the RGU colours in terms of T_{eff}, log g and [Fe/H]. Two basic approaches exist to achieve this goal, both of which have been undertaken during the past 10 years at Basel observatory. On the one hand, one has to define the photoelectric RGU system with a set of standard stars as well as a grid of programme stars with known physical parameters. On the other hand, one can use synthetic photometry in conjunction with spectral scans or theoretical model atmospheres provided the system is well defined. Both approaches should ideally go together controlling each other and giving additional information. For instance, because model atmospheres can be constructed as a function of continuously varying physical parameters, synthetic photometry will fill the gaps in the dis-

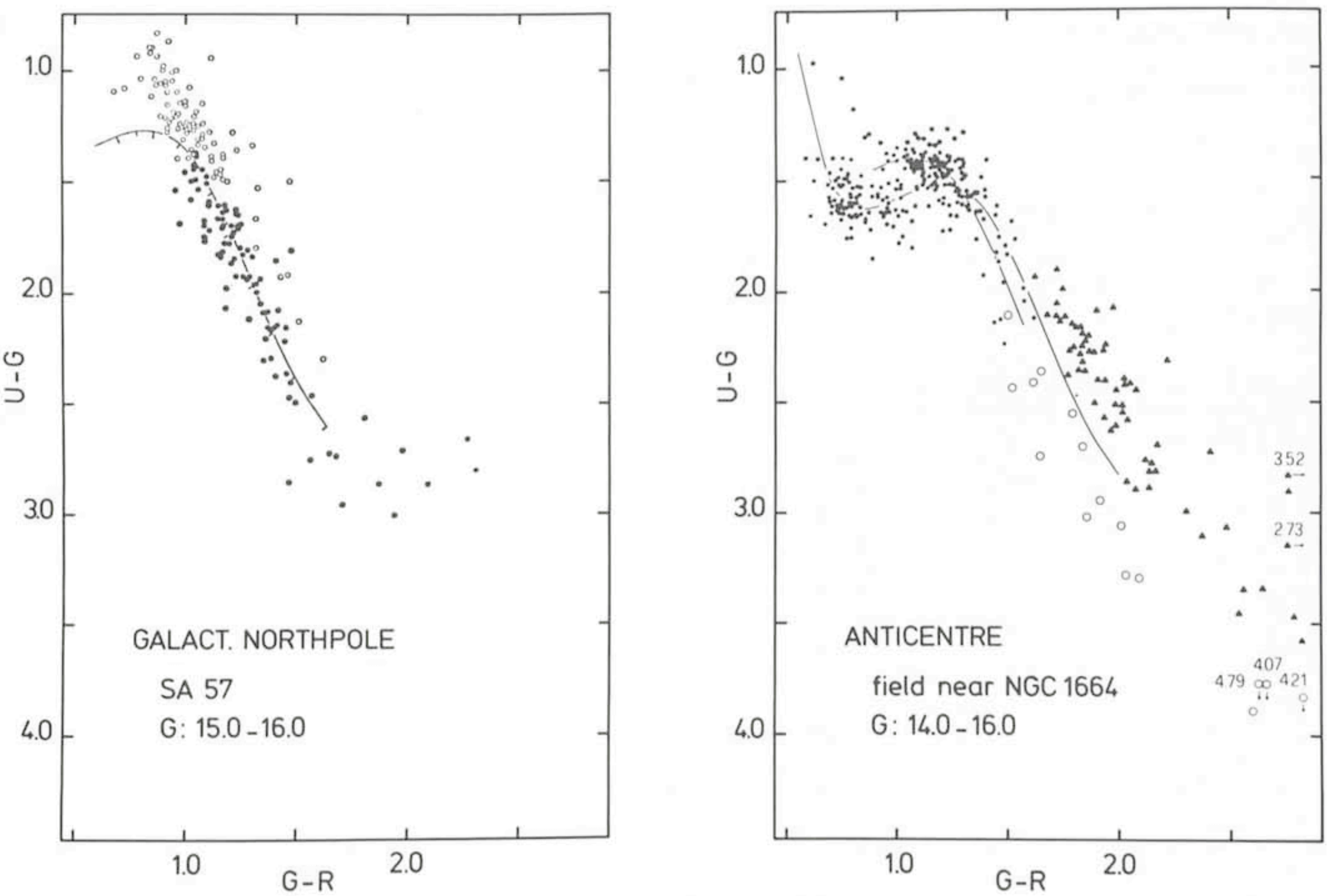


Figure 2a: *RGU two-colour diagram of stars in the galactic northpole region SA 57 (Fenkart 1967). Only stars in the apparent magnitude range 15 m < G < 16 m are shown. Two groups of stars can be statistically identified: main sequence stars of population I (●) and main sequence stars of population II with large UV excesses (o).*
2b: *RGU two-colour diagram of stars in the galactic anticentre region (Becker and Fang 1973). Only stars in the apparent magnitude range $14^m < G < 16^m$ are shown. Three groups of stars can be statistically identified: main sequence stars of population I (●) which are split into two groups because of a steplike increase of interstellar reddening caused by a nearby cloud; giant stars of population I (o, "left-side" giants) and giant stars of population II (▲, "right-side" giants).*

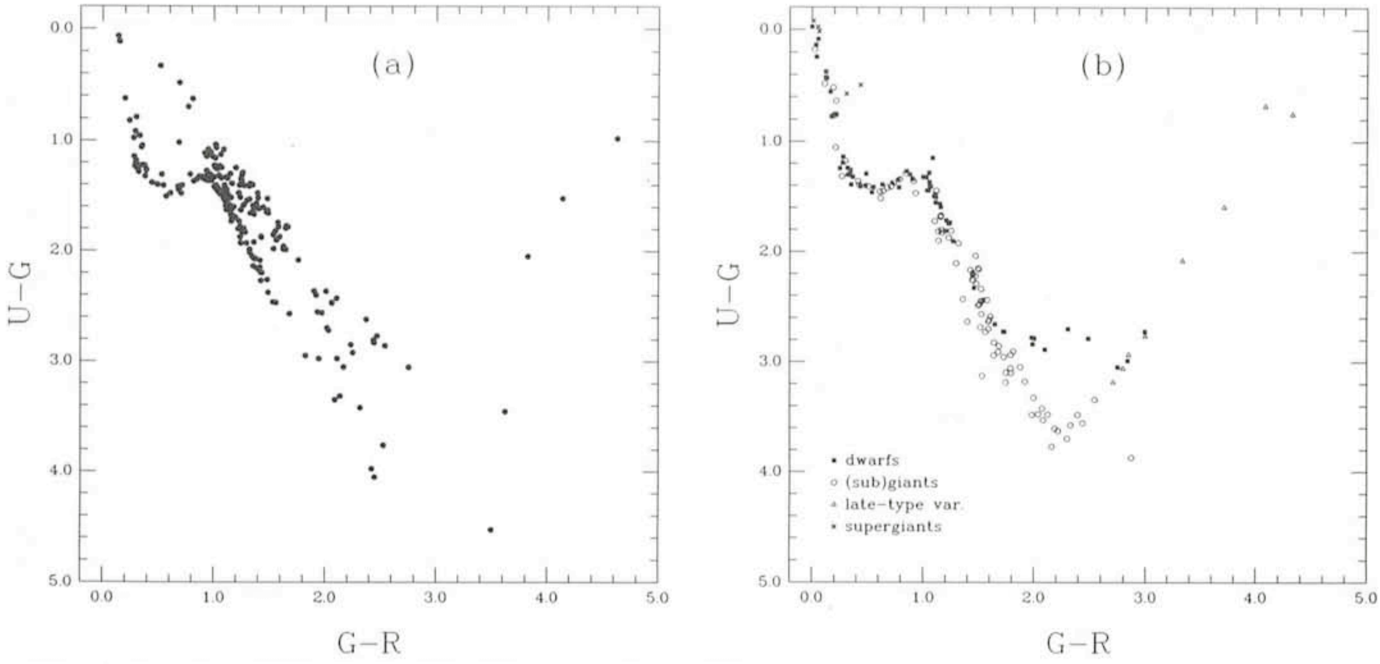


Figure 3: *The two-colour diagram for the photoelectric RGU system: a) compilation of 275 well-observed stars covering a broad range in both colours. The sample comprises stars covering a large metallicity range and they are not corrected for reddening; b) measurements resulting from synthetic-filter photometry of the spectrophotometric data by Gunn and Stryker (1983). Due to the chemical homogeneity of the sample, the dereddened stars show very little scatter for a given luminosity class. Different luminosity classes are marked by different symbols.*

crete grid of photoelectrically observed stars. Furthermore, the internal consistency of a photometric system or catalogue essentially depends on the proper transformations between the standard system and the instrumental systems, a problem that can be tackled by synthetic photometry. For a discussion of the use of synthetic photometry concerning the photographic RGU system, we refer to Buser (1979) and the references therein.

3. The Photoelectric RGU System: Steps Towards the Physical Calibration

The photoelectric RGU system is defined by a combination of a photomultiplier with an S-20 cathode and three broad-band interference filters for the pass-bands R, G and U (Trefzger et al. 1983) matching closely the photographic system. Observations of northern standard stars were carried out using the 1-m telescope at the Gornergrat Observatory in Southern Valais, Switzerland, during several observing runs between 1980 and 1983. The observations on La Silla were carried out using the 1-m telescope and the ESO 50-cm telescope during 5 observing runs between 1984 and 1987.

The goal of these observations is the study of the photometric properties of stellar samples with well-known physical parameters, e.g. effective temperature, gravity, absolute magnitude, metallicity and reddening. The following samples were chosen for this purpose:

- Main sequence stars of different effective temperatures, both field stars and members of open clusters, in order to determine the position of the main sequence in the two-colour diagram and to establish a calibration in terms of absolute magnitude.
- Stars of different luminosities, especially cool stars, for luminosity calibration of field stars.
- Dwarfs and giants in a large metallicity range with the aim of calibrating their UV excesses as a function of metal abundance, thus providing the empirical basis for a statistical study of the chemical structure of the galactic halo (Trefzger 1981).

Figure 3a shows the two-colour diagram of a compilation of our stellar samples. The S-shaped lower envelope in the left part of the diagram indicates the main sequence for unreddened stars. Those stars lying above the main sequence are either affected by interstellar extinction and/or metal deficiency (see below). In order to determine the shape of the two-colour diagram for normal (solar abundance) stars, we derived colours from observed stellar energy distributions by digitally simulating the photoelectric RGU system. The library of stellar spectrophotometric data published by Gunn and Stryker (1983, hereafter GS) provides a large sample of various normal stellar types and represents a valuable tool for the calibration of photometric systems (cf. Labhardt and Buser 1985, Labhardt 1988). The GS fluxes were dereddened employing the interstellar reddening law as given by Seaton (1979) and Howarth (1983). Furthermore, the corrective function recently published by Rufener and Nicolet (1988) was adopted. Synthetic colour indices were obtained by numerically multiplying the relative response functions of the photoelectric RGU system with the intrinsic energy distributions of the stars in the GS library. The resulting two-colour diagram is shown in Figure 3b for different luminosity classes. It will be used as a guide for the proper interpretation of an observed two-colour diagram like the one shown in Figure 3a. The detailed comparison of the observed and calculated two-colour diagrams is subject to further investigation and will be published elsewhere.

In the following we want to discuss some results obtained from photoelectric observations of dwarf and giant stars belonging to different stellar populations of our Galaxy. Figure 4 shows the two-colour diagrams of Hyades dwarf stars with spectral types between A1 and K2 for the UBV and RGU systems. Also indicated are measurements of 46 mostly metal-poor dwarf stars, selected from the comprehensive catalogue of Cayrel et al. (1985) of stars with known parameters T_{eff}, log g and [Fe/H]. Their metallicities vary in the range $-3.5 < [Fe/H] < +0.6$; their temperatures are between 6260 K and 4800 K and their gravities are around log g = 4.3. We used the UBV colours published in the catalogue mentioned above to compare

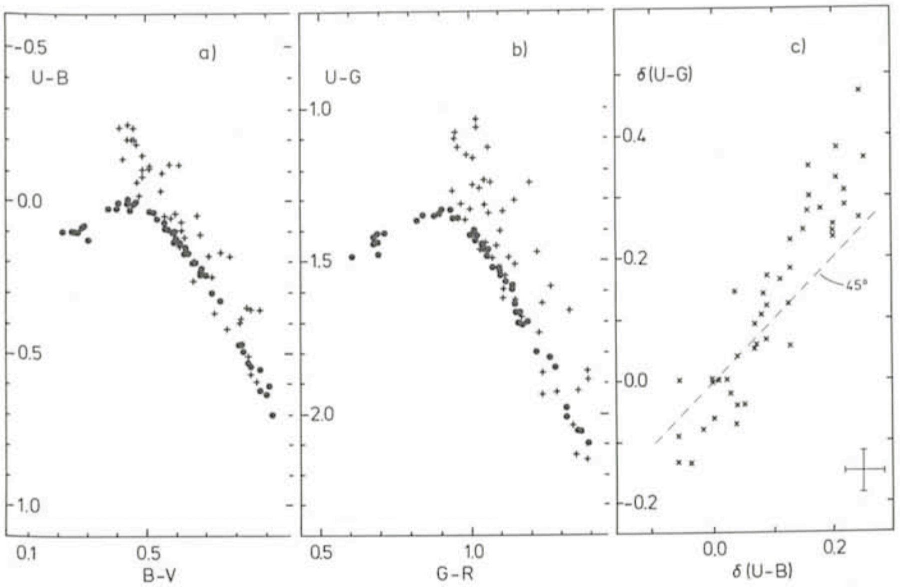


Figure 4: *The two-colour diagrams of the Hyades main sequence (●) and metal-poor dwarfs (+) are shown for the UBV system (Fig. 4a) and for the RGU system (Fig. 4b). Figure 4c compares the UV excesses as measured in the two photometric systems (UV excess = vertical distance of a particular star above the Hyades main sequence).*

the UBV system with the results obtained in the RGU system. In both photometric systems these stars show substantial UV excesses relative to the (somewhat metal-rich) Hyades. This is in qualitative agreement with the properties of halo stars as observed in the photographic survey.

However, the UV excesses δ (U-G) measured in the RGU system are considerably larger than the δ (U-B) values of the UBV system. Figure 4c displays a star-by-star comparison of the corresponding UV excesses as measured in the two photometric systems relative to the Hyades main sequence. The slope of the linear relationship is 1.52 showing clearly the higher sensitivity of the RGU system to separate metal-poor stars from metal-rich ones. The stars with the highest UV excesses are expected to be those with the lowest metallicities, because weakening the lines predominantly enhances the stellar flux in the U band. This is confirmed by the spectroscopically determined [Fe/H] values. It is interesting to note that those stars in our sample that are still more metal-rich than the Hyades are located below the Hyades main sequence, showing negative UV excesses. Again, this effect is more pronounced in the RGU system than in the UBV system.

The variation of δ (U-G) as a function of [Fe/H] depends on stellar temperature and therefore on (G-R); the lines of different metallicities and temperatures in Figure 4b can be drawn on the basis of our empirical data in combination with theoretical colours calculated from model atmospheres (Buser 1979). This work is still in progress. It will eventually provide a statistical method to estimate metallicities of large samples of halo stars based entirely on three-colour photometry thus allowing a physical interpretation of the large data base of the Basel halo and disk survey.

As mentioned already in the preceding section, giant stars sampled from fields in different parts of the galactic disk and bulge show systematic displacements in the two-colour diagram. It was suspected some time ago (Becker 1979, Spaenhauer and Thévenin 1985) that this could be related to variations of the mean metallicity within the galactic disk and inner halo. In order to study the properties of metal-poor giants in the RGU system, we observed a sample of stars from the list of extremely metal-poor giants published by Bond (1980). Their metallicities were determined from Strömgren photometry and are in the range between $-2.7 < [Fe/H] < -1.5$. In Figure 5 we compare the positions of these metal-deficient giants with the location of the giants of the old disk cluster M 67 (Tammann 1963). The large displacement of the metal-poor giants towards the upper right is obvious and is related to the same kind of UV excess in these weak-line stars as is observed in halo dwarfs as well. This strongly supports the conjecture that metallicity differences between giants in different parts of the Galaxy show up in the two-colour diagram; after proper calibration this gives us the possibility to map the metallicity gradient within the galactic disk, see e.g. Neese and Yoss (1988), as well as within the inner halo.

Measuring very cool stars is a quite difficult task because the U-band signal always remains low due to the small amount of stellar flux in the blue part of the spectrum. However, there is a strong interest in learning more about the RGU colours of the reddest stars: a good fraction of the photographically recorded field stars are red and in order to understand their contribution to the local galactic structure we would like to distinguish between late-type dwarf and giant stars. By observing a representative sample of both M-type dwarfs and giants, all of which are MK standard stars, we are in the process of tackling these problems. The reduction of the relevant measurements necessitates a safe extrapolation of our transformation equations, as the colour range of our standard stars does not yet include very red stars. For this purpose, the GS library was used to establish the relations between the photoelectric RGU colours and MK spectral classification. For a large part of the diagram given in Figure 6 the relations are monotonically increasing and are almost identical for dwarf and giant stars. It is interesting to note the large range covered in (U-G) by the stars of the MK spectral classes K and M, and the ambiguity of the relation in the right-most part of Figure 6a. Nevertheless, these relations turn out to be defined well enough in order to calibrate the intrinsic colours of late-type stars.

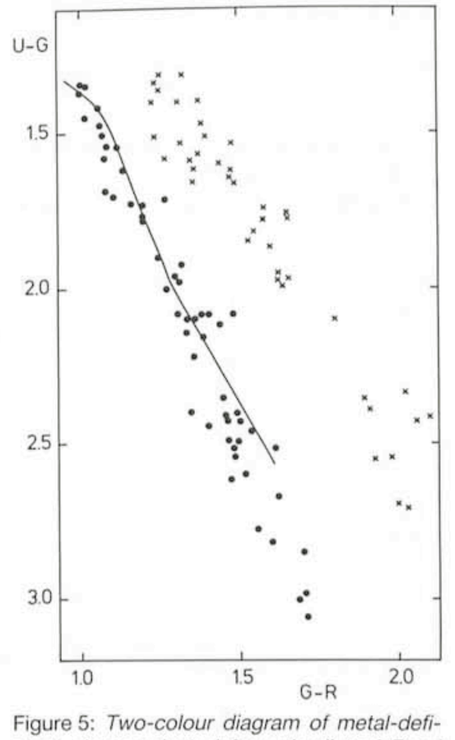
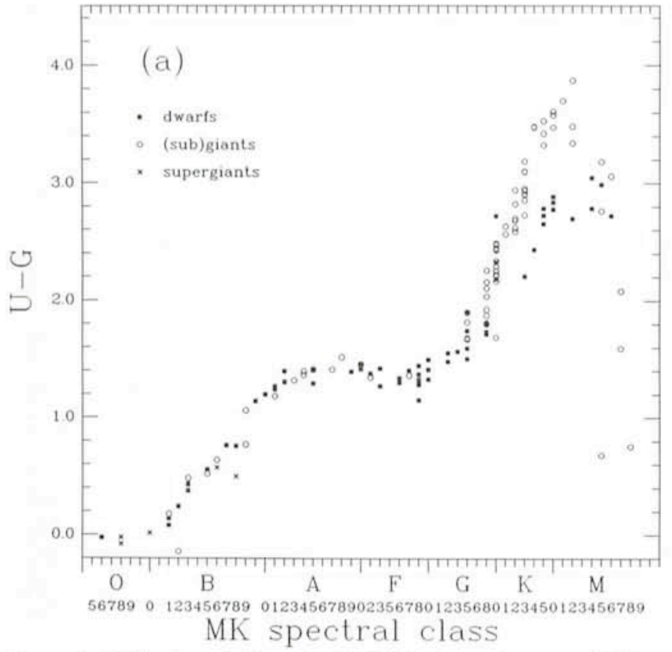


Figure 5: *Two-colour diagram of metal-deficient giants selected from the list of Bond (1980) marked by crosses. The dots indicate the location of giants of M 67 in the photographic RGU system. The line shows the position of the main sequence K stars.*



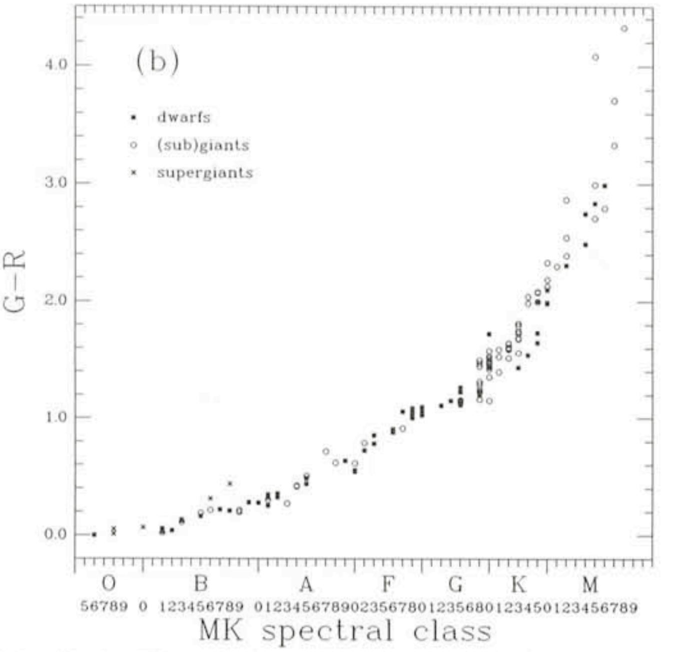


Figure 6: *Calibration of photoelectric RGU colours in terms of MK spectral classification. These relations are based on synthetic photometry of the GS library and MK spectral classes obtained from the Centre de Données Stellaires (Strasbourg).*

4. Conclusions

The photographic RGU system was proposed 50 years ago by W. Becker as a tool for the study of galactic structure and has been the foundation of the Basel RGU survey. The establishment of the photoelectric RGU system was naturally required in order to extract the full information contained in the photographic RGU database. The photoelectric measurements described in the preceding section along with the use of synthetic photometry will provide the essential physical calibration needed for Galaxy modelling as well as for the purpose of preselecting specific stellar samples. With respect to Galaxy modelling we expect that the inclusion of ultraviolet data will put essential constraints on the chemical structure of the principal galactic components (halo, bulge, thick disk and disk). The majority of the stars appearing in the photographic survey belong to the colour domain covered by the photoelectric observations: dwarf and giant stars ranging from spectral type O through K and covering the metallicity range from extreme population II to extreme population I. The extension of the photoelectric system to the very cool (M-type) stars is under way. Furthermore, CCD RGU observations have been carried out on La Silla in order to make faint objects accessible for RGU study.

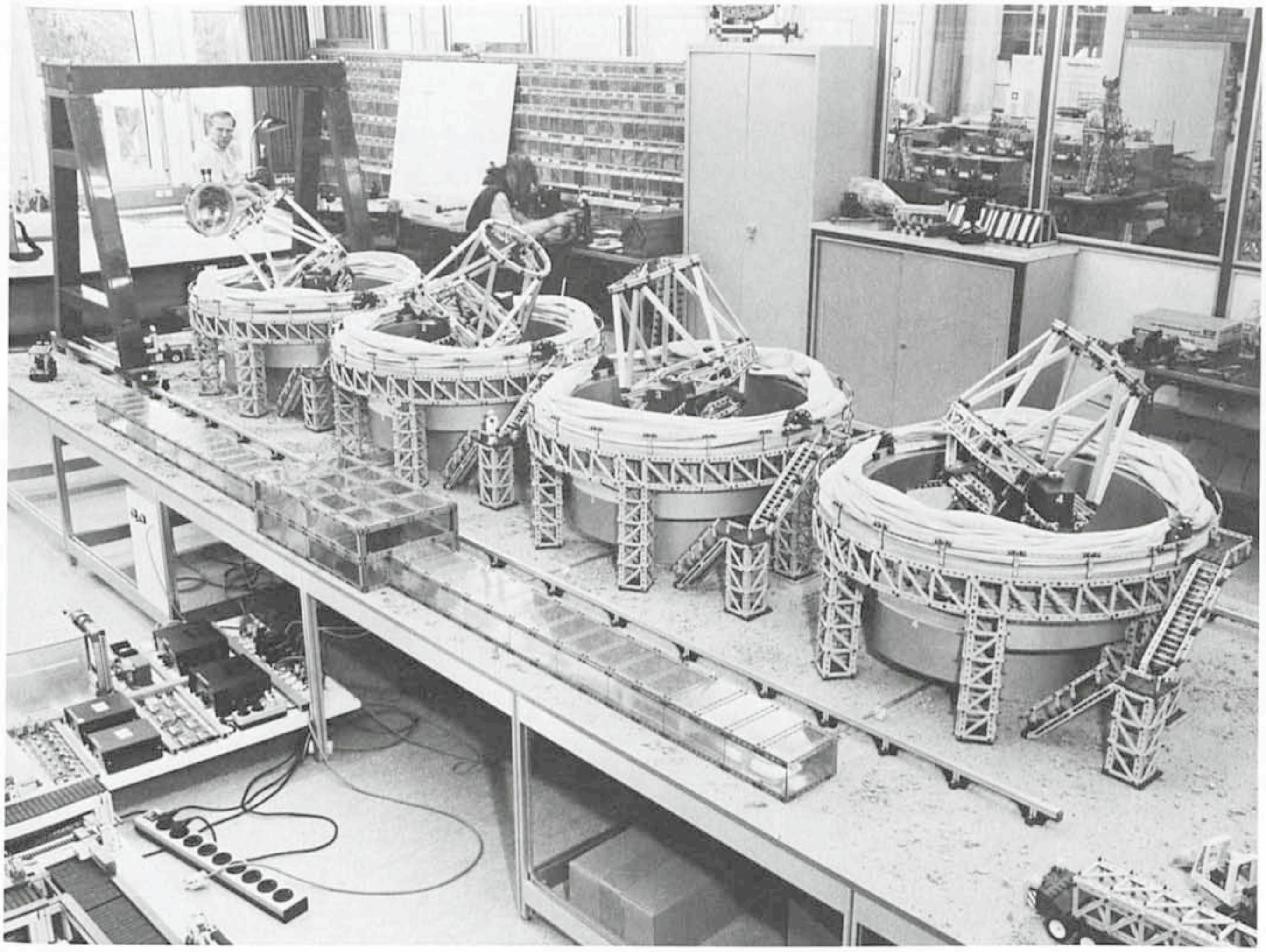
Acknowledgements

We gratefully acknowledge the ESO telescope time that has been allocated to this project, and we would like to thank the ESO staff on La Silla for valuable help as well as the Swiss National Science Foundation for financial support of this project.

References

Bahcall, J.N., Ratnatunga, K.U., Buser, R., Fenkart, R.P., Spaenhauer, A., 1985: *Astrophys. J.* **299,** 616.
Becker, W., 1938: *Z. f. Astrophys.* **15,** 225.
Becker, W., 1946: *Veröff. Univ. Sternwarte Göttingen,* No. **79.**
Becker, W., Stock, J., 1958: *Z. f. Astrophys.* **45,** 269.
Becker, W., Steinlin, U.W., 1956: *Z. f. Astrophys.* **39,** 188.
Becker, W., 1963: *Z. f. Astrophys.* **57,** 117.
Becker, W., 1965: *Z. f. Astrophys.* **62,** 54.
Becker, W., Fenkart, R.P., 1971: *Astron. Astrophys. Suppl.* **4,** 241.
Becker, W., Fang, Ch., 1973: *Astron. Astrophys.* **22,** 187.
Becker, W., 1979: *Astron. Astrophys. Suppl.* **38,** 341.
Bond, H.E., 1980: *Astrophys. J. Suppl.* **44,** 517.
Buser, R., 1978: *Astron. Astrophys.* **62,** 411.
Buser, R., 1979: in *Dudley Observatory Reports* No. **14:** "Problems of Calibration of Multicolor Photometric Systems", A.G.D. Philip, ed., p. 1.
Buser, R., Kaeser, R., 1985: *Astron. Astrophys.* **145,** 1.
Cayrel de Strobel, G., Bentolila, C., Hauck, B., Duquennoy, A., 1985: *Astron. Astrophys. Suppl.* **59,** 145.
Fenkart, R.P., 1967: *Z. f. Astrophys.* **66,** 390.
Fenkart, R.P., Binggeli, B., 1979: *Astron. Astrophys. Suppl.* **35,** 271.
Fenkart, R.P., Esin-Yilmaz, F., 1985: *Astron. Astrophys. Suppl.* **62,** 39.
Fenkart, R.P., 1989: in preparation.
Gunn, J.E., Stryker, L.L., 1983: *Astrophys. J. Suppl.* **52,** 121.
Howarth, I.D., 1983: *Monthly Notices Roy. Astron. Soc.* **203,** 301.
Johnson, H.L., Morgan, W.W., 1953: *Astrophys. J.* **117,** 313.
Labhardt, L., Buser, R., 1985: in IAU Symposium No. **111,** "Calibration of Fundamental Stellar Quantities", D.S. Hayes, L.E. Pasinetti and A.G.D. Philip eds. (Reidel Dordrecht), p. 519.
Labhardt, L., 1988: *New Directions in Spectrophotometry,* A.G.D. Philip, D.S. Hayes, S.J. Adelman, eds., L. Davis Press, Schenectady (in press).
Neese, C., Yoss, K., 1988: *Astron. J.* **95,** 463.
Pel, J.W., Trefzger, Ch.F., Blaauw, A., 1988: *Astron. Astrophys. Suppl.* **75,** 29.
Rufener, F., Nicolet, B., 1988: *Publ. Obs. de Genève Série C,* Fasc. **26.**
Seaton, M.J., 1979: *Monthly Notices Roy. Astron. Soc.* **187,** 73.
Spaenhauer, A., Thévenin, F., 1985: *Astron. Astrophys.* **144,** 327.
Spaenhauer, A., del Rio, G., 1989: in preparation.
Tammann, G.A., 1963: *Z. f. Astrophys.* **58,** 100.
Trefzger, C.F., 1981: *Astron. Astrophys.* **95,** 184.
Trefzger, C.F., Cameron, L.M., Spaenhauer, A., Steinlin, U.W., 1983: *Astron. Astrophys.* **117,** 347.

NOTE: Photographer Gudrun Ewaldt also participated in the making of the centrefold image of the ESO Headquarters in *Messenger* No. 53 (September 1988).



The ESO VLT as fischertechnik-Model

The first fully steerable VLT *has already been built!*

Early in 1988, the well-known German firm "fischerwerke" approached ESO with an interesting suggestion. Having read in the local press about the decision to build the VLT, one of their engineers thought that a model of the VLT, built with the "fischertechnik" building blocks, might become an eye-catching centre on the next toy-fairs in Germany.

The ESO people involved in the VLT project felt the same way and after some consultations, fischerwerke built a 6-metre long model, here seen during the final checkout in their workshop. It is controlled by a small computer (PC) and the telescopes move individually and in unison during a demonstration sequence. Light guides illustrate the light-paths through the system, all the way down to the combined coudé focus in the auxiliary building. A giant crane lifts one of the enormous mirrors and moves along its rails.

The model went on display at the autumn toy fair in Cologne and will later be shown in Frankfurt. It attracted at lot of attention and made good publicity for fischerwerke, ESO and European technology. It is too big and complicated to travel with ESO's own exhibitions, but ESO will receive a similar model of a single telescope to be shown for the first time at the Council meeting in December. It will thereafter be included in the ESO exhibition.

It would be interesting if a smaller VLT model could also be made, similar to those of airplanes, cars and rockets, which are available as build-it-yourself kits. However, this has not yet been decided.

The Astronomy and Astrophysics Review

This new review journal will be started in 1989 to publish critical reviews of the worldwide astronomical literature that are reasonably complete and balanced. It will encompass all subjects in astronomy and astrophysics and boundary areas with other fields. Developments in atomic, molecular, or particle physics directly relevant to astronomy may be included as well as cosmic-ray physics, solar-system studies, and relevant computational procedures. All important fields will be reviewed periodically with the frequency a function of the level of activity. Within about six years, the collected volumes should present a view of the important developments in all of astronomy. The relatively rapid publication schedule aims at four issues per year.

All reviews will be commissioned by the Editor, who will be assisted by the Associate Editors M.C.E. Huber (ESTEC), P. Léna (Meudon), P.G. Mezger (Bonn), F. Pacini (Florence) and S.R. Pottasch (Groningen). While the new journal will be an independent publication, a loose cooperation has been established with *Astronomy and Astrophysics*. Subscription information (including a special rate for individuals) and sample copies may be obtained from Springer-Verlag, attention: Ludwig Kuhn, P.O. Box 105280, D-6900 Heidelberg 1, Federal Republic of Germany, except for the U.S. (Springer-Verlag, attention: Margo Martin, 175 Fifth Ave., New York, N.Y. 10010).

L. WOLTJER, Editor

Infrared Emission from the Sub-Arcsecond Vicinity of SN 1987 A

A. A. CHALABAEV, CNRS, Observatoire de Haute-Provence, St-Michel-l'Observatoire, France
C. PERRIER and J.-M. MARIOTTI, Observatoire de Lyon, St-Genis-Laval, France

Introduction

The fireball in the LMC called SN 1987 A offered an exceptional opportunity to study spatial structure of a supernova phenomenon. Obviously, special high angular resolution techniques at large telescopes had to be employed. The results of speckle interferometry in the visible spectral range, carried out at CTIO and AAT were reviewed by Meikle (1988). Here, we would like to present the results of speckle interferometry in the near infrared ($\lambda\lambda$ 2–5 μm), carried out at the ESO 3.6-m telescope during May–August 1987. In contrast with the work in the visible range, mainly concerned with the ejecta ($\approx$ 10 marcsec), the near IR speckle interferometry deals with the structure of the close environment of the supernova ($\approx$ 100 marcsec). In particular, it addresses the interesting question whether this environment contained dust and thus provides a useful test of current models of the progenitor evolution. Indeed, some models suggest that the exploded blue supergiant (BSg) Sk-69°202 has once been a red supergiant (RSg). Part of the dust, condensed around the progenitor during its RSg phase, could survive destruction by the fast and hot wind of the BSg (Chevalier, 1987; Renzini, 1987). The burst of supernova radiation at shock breakout with $L_b \sim 10^{43}-10^{44}$ erg $\cdot$ s^{-1} should heat this dust up to 1,000–2,000°K. The corresponding thermal emission should then appear as an infrared echo (Bode and Evans, 1979). The size of the dusty region was expected to be of the order of $10^{17}-10^{18}$ cm. At Earth, the corresponding angular size of 0.1–1.0 arcsec is well within the possibilities of speckle equipment. Shortly after the announcement of the supernova, we began to study the feasibility of observations. Computer modelling showed that the IR echo, if it existed, could be resolved already during the first months following the arrival of the explosion light. Independently, Prof. L. Woltjer, ESO Director General at that time, reserved 5 nights in May 1987 at the ESO 3.6-m telescope for IR speckle observations. After an exchange of telexes, we were in a plane to Santiago.

We used the ESO general user's IR specklegraph designed for the 1–5 μm spectral range. It provides a one-dimensional spatial spectrum of an image up to the maximum frequency of 3 to 6 arcsec^{-1}, depending on the spectral band and seeing (for more details, see Perrier, 1986). The observing procedure consists in scanning a stellar image at the telescope focal plane across a narrow slit. The width of the slit is chosen according to the spectral band and/or the seeing conditions: for example, for the L'band in good seeing conditions we use a 0.2 arcsec wide slit. The scanning must be fast enough to "freeze" the

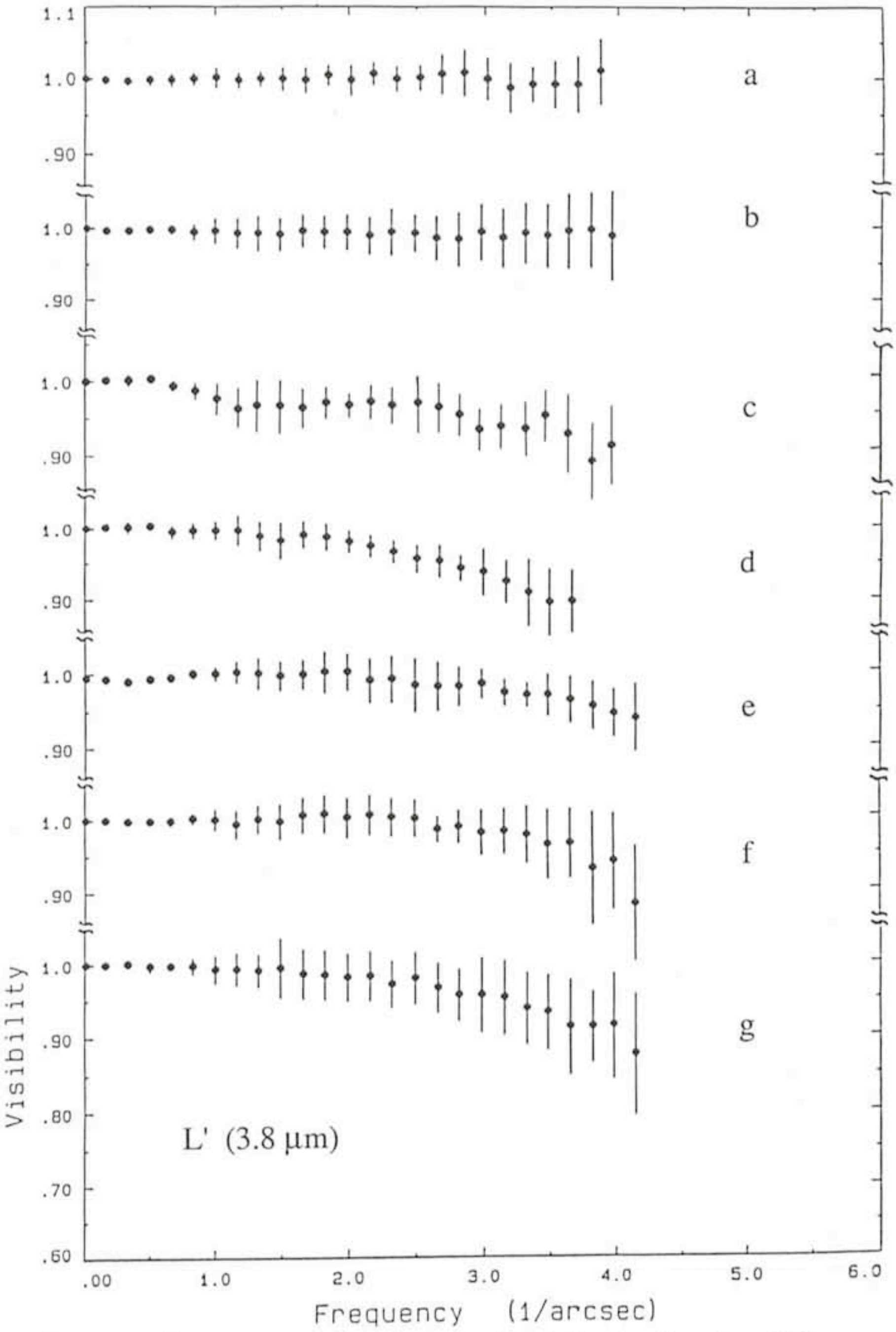


Figure 1: *Evolution of visibility curves of SN 1987 A in the L' band in May–June 1987: a: May 9, NS direction; b: June 8, EW direction; c: June 16, NS direction; d: June 17, NS direction; e: June 18, EW direction; f: June 22, EW direction; g: June 22, NS direction.*

speckles; typically, the image is crossed in 50 ms time. Each scan is Fourier transformed; the average power spectrum of the object is divided by that of a reference star thus giving the visibility curve. More details on the observing procedure, data and their discussion can be found in accounts given by Perrier et al. (1987) and Chalabaev et al. (1988a, b). Note, however, that, as a rule, the presentation of speckle results makes extensive use of technical terms. Let us recall that, as it is always the case of interferometric methods, we deal with measurements of Fourier transform of light pattern. Often, a speckle observer has no possibility to "come back" into the image space, i.e. to present a nice, easily understandable reconstructed image. Then, he is bound to "live" in Fourier space which is not an every-day experience of everybody. The necessity to use terms like Fried parameter, MTF of speckles, phase of Fourier transform and so on, makes articles on speckle interferometry difficult to digest. We would like to take advantage of writing for the *Messenger* to try a more friendly way of reporting on speckle data. Let us use where it might help terms of fishing, at least in parentheses. This may be especially important for our June observations.

TABLE 1. *Journal of observations.*

Date 1987	Day[1]	Band	Direction	Quality[2]	$\Delta\varphi$ marcsec[3]
May 9	75	L'	NS	3	non resolved
May 9	75	M	NS	1	non resolved
June 7	104	L'	EW	2	non resolved
June 8	105	K	EW	3	non resolved
June 8	105	L'	EW	4	non resolved
June 8	105	M	EW	1	non resolved
June 16	113	K	NS	2	non resolved
June 16	113	L'	NS	2	marginally resolved
June 17	114	L'	NS	4	144 ± 44
June 18	115	L'	EW	4	92 ± 18
June 22	119	L'	EW	4	126 ± 19
June 22	119	L'	NS	4	73 ± 49
August 5	163	K	EW	4	330 ± 80
August 6	164	K	NS	4	330 ± 80
August 6	164	L'	NS	4	350 ± 50
August 6	164	M	NS	2	390 ± 100

Notes:
[1] Day is counted from the arrival of the neutrino pulse, 1987 Feb 23.4
[2] "Eye-estimated" quality of a visibility ranging from 1 (acceptable) to 5 (excellent)
[3] For days 114–119, $\Delta\varphi$ is the FWHM of a Gaussian disk contributing 15% to the total flux; for days 163–164, $\Delta\varphi$ is the separation of a secondary spot from the supernova.

Bendings of the Rod

The Journal of observations is given in Table 1. The evolution of visibility curves in the L'band is illustrated in Figure 1. [In terms of fishing, we were observing the L-rod . . .]. Visibility curves, measured on May 8–9 and on June 8, could be described merely as a horizontal line, corresponding to the unresolved supernova. [The rod was straight, no fish . . .). On June 16, the visibility curve showed a first, though marginally perceptible, sign of emerging spatially distinct structure: namely, the high frequency part of the visibility curve began clearly to deviate from a straight line. [The rod got bent: a fish began to bite . . .]. This was confirmed by further observations on June 17, 18 and 22. [See Fig. 1; it bit even stronger . . .]. No significant difference was found between the visibility curves measured in the North-South and East-West directions of scans. The curves in the K and M bands remained those of the unresolved supernova (see Fig. 2 and 3).

The type of visibility curves like those observed in the L'band from June 16 to 22 is usually referred to as "partially resolved": that is only a fraction of the spatial spectrum of a resolved object could be measured. One can also say that the size of the object was less than the Rayleigh resolution. Attempting to restore the image is subject to extrapolation of the recorded tendency beyond the maximum frequency of the equipment. Due to extrapolation, the image reconstruction is not unique. Theoretical visibility curves produced by the most plausible images are given in Figure 5 together with typical observed visibilities. [There was a fish in mid-June. It was not possible to get it out of the water. But we kept record of the rod reaction. Now we go to a fish shop, take different fishes and see the reaction of the rod. It turns out that only fishes of a certain kind and of a certain size can reproduce the observed reactions . . .] They come in two kinds: a "point-like" spot(s) and a disk halo emission. Three images can equally account for the visibility curves in L', measured on June 17–22, namely: (1) two "point-like" spots, one in the NS direction (180° ambiguity) and another one in the EW direction; (2) one "point-like" spot, resulting from the combination of two spots, and laying in one of the intermediate directions: NE, NW, SW or SE; and (3) an axially symmetric disk halo around the supernova. To estimate the angular scale, we need to know the relative contribution, ε, of the source(s) to the total flux from SN (cf. Perrier et al., 1987). [Stronger the fish, smaller its size . . .]. The lowest value of ε which is

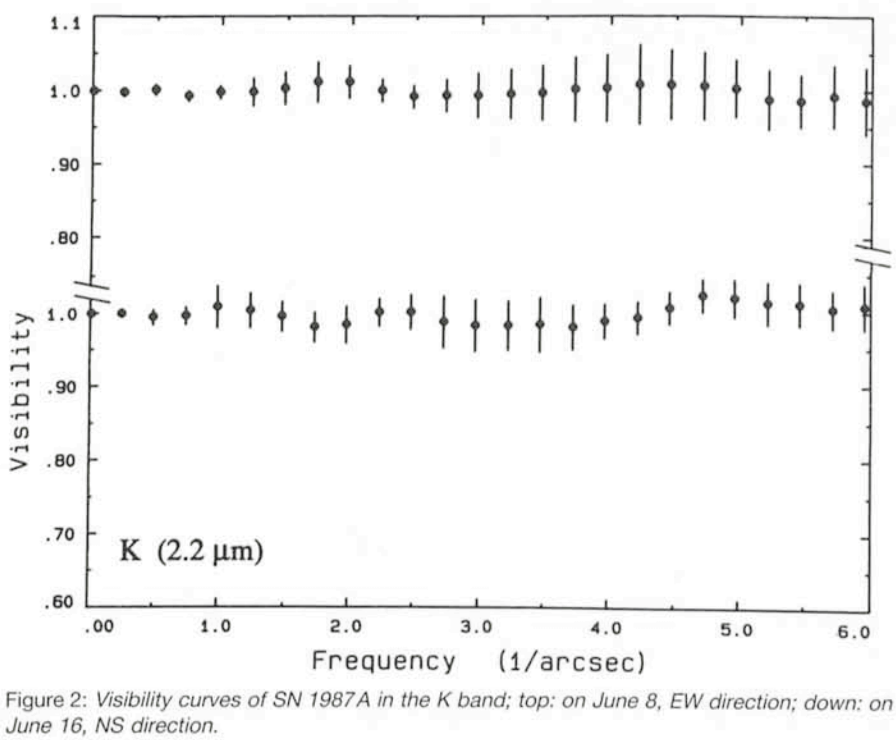


Figure 2: *Visibility curves of SN 1987A in the K band; top: on June 8, EW direction; down: on June 16, NS direction.*

still compatible with the observed shape of the visibility curves is about 10% or 17 Jy. On the other hand, the relative smoothness of the light curve in L' between June 8 and 18 seems to discard any "flare", exceeding 20% of the total flux. We adopt $\varepsilon \approx 15\%$. Then, in the case of two spots, their angular separation from the supernova is $\Phi \approx 55$ marcsec and the projected distance $p \approx 17$ light-days (l.d.). If the spots are combined in one, then $\Phi \approx 78$ marcsec and $p \approx 24$ l.d. Finally, if the real image was an axially symmetric disk halo, which we favour as the most simple case, its weighted average FWHM was about 109 ± 24 marcsec (Gaussian distribution of brightness was assumed). The corresponding projected distance from the supernova to the edge of the halo at half maximum was $p \approx 17$ l.d.

On August 5 and 6, the visibility curves (Fig. 4) displayed a different pattern: an oscillation with the amplitude of about 4% and the first minimum at about 1.25 arcsec^{-1}, superimposed on the visibility of the unresolved supernova. [It bit once again, but that was a different fish . . .]. This is a very faint signal, comparable to the level of systematic errors. However, none of the numerous test observations of unresolved stars showed this pattern, and we must conclude that the oscillation was related to the supernova. It appeared in all three bands: K, L' and M, scanned in North-South. One visibility curve, in the K band, was measured in EW; it showed a similar oscillation. Since the August visibility curves display secondary maxima and minima, there is no necessity in extrapolation, and interpretation is less ambiguous than for the mid-June data. A disk halo is easily ruled out. We have suggested a ring of light of 420 marcsec diameter (Chalabaev et al., 1988a). However, it produces too strong a damping of secondary oscillations (cf. Fig. 5) and is also ruled out. Only secondary "point-like" spots match the observed oscillations. Yet, as far as the phase of the Fourier transform is not restored (although we hope to resolve this problem), there is an ambiguity concerning the number of spots (one or two) and their positional angle. [We got some fish parts out of the water. However, the puzzle is not assembled . . .]. One needs a secondary spot, contributing $2.6 \pm 1.0\%$ (3.0 ± 1.2 Jy) in K, $2.7 \pm 1.0\%$ (2.5 ± 0.9 Jy) in L' and $1.8 \pm 1.0\%$ (2.8 ± 1.6 Jy) in M, situated in the North-South direction (180° ambiguity) and separated from the supernova by 350 ± 40 marcsec. This corresponds to the projected distance $p = 106$ l.d. A similar secondary spot in the East-West direction explains the visibility curve measured in the K band. As in the previous case, the spots can be combined in one, lying at 495 ± 60 marcsec ($p = 150$ l.d.) in one of the intermediate directions.

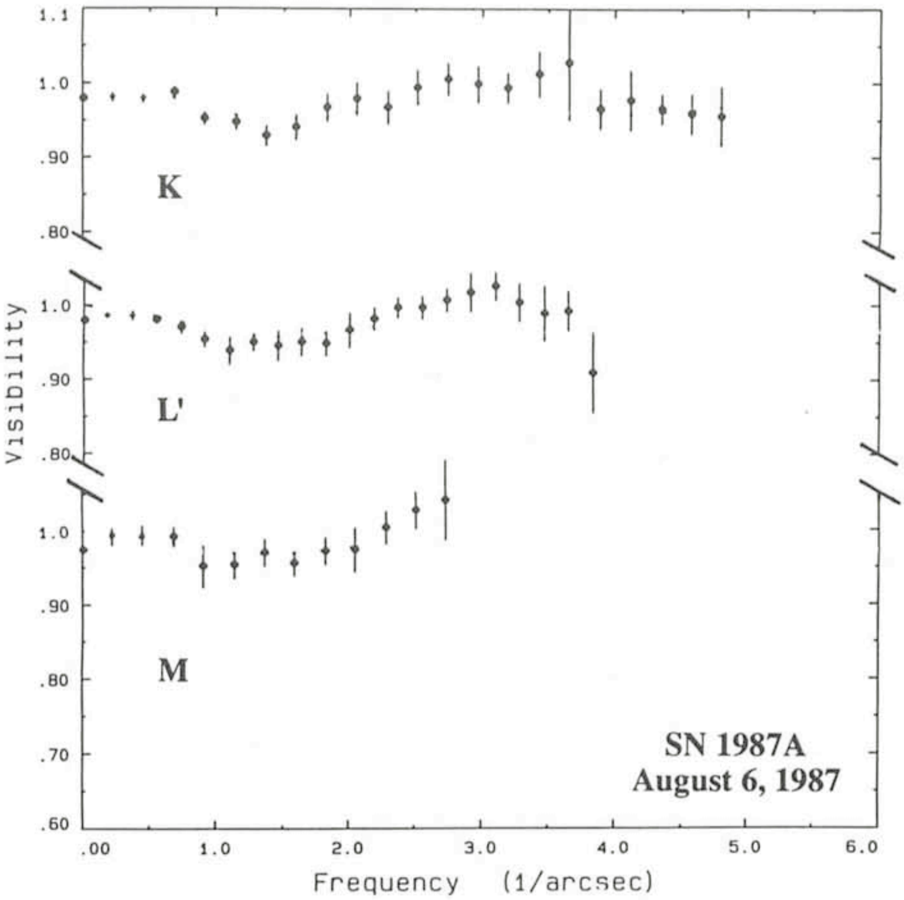


Figure 4: *Visibility curves of SN 1987A on August 5–6, NS direction.*

What Was It?

The first fact we wish to point out is the projected distance from speckle source(s) to the SN: in June 17–22 it was about 20 l.d. which implies the apparent velocity of the source(s) to have been 18% of the speed of light c. In August, the distance was at least 106 l.d., and the velocity was at least 0.65 c. Clearly, the speckle sources must be located outside the ejecta. We see two possibilities to explain the observed velocities. Following Rees (1987), one can consider a relativistic jet. However, the apparent June-August acceleration makes this explanation unlikely. Instead, we suggest a light echo to be the origin of the speckle sources. In this case, the apparent velocities close to the speed of light find a natural explanation. The second fact we wish to

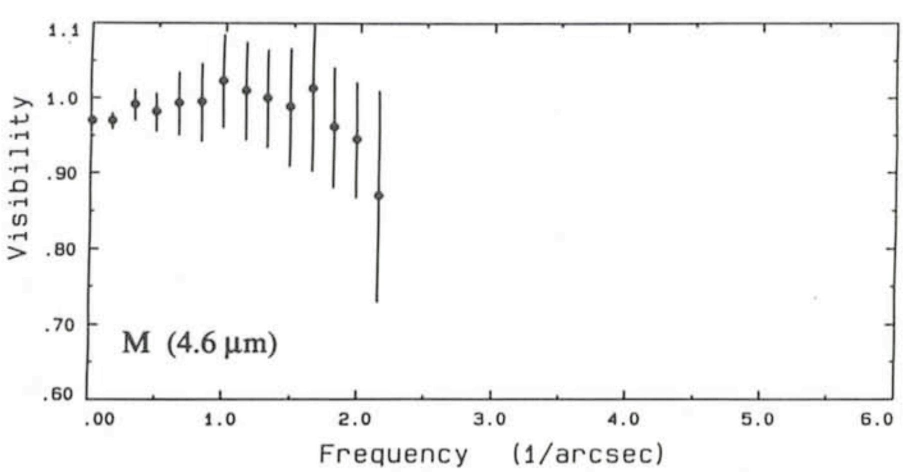


Figure 3: *The visibility curve of SN 1987A in the M band on June 8, 1987, EW direction.*

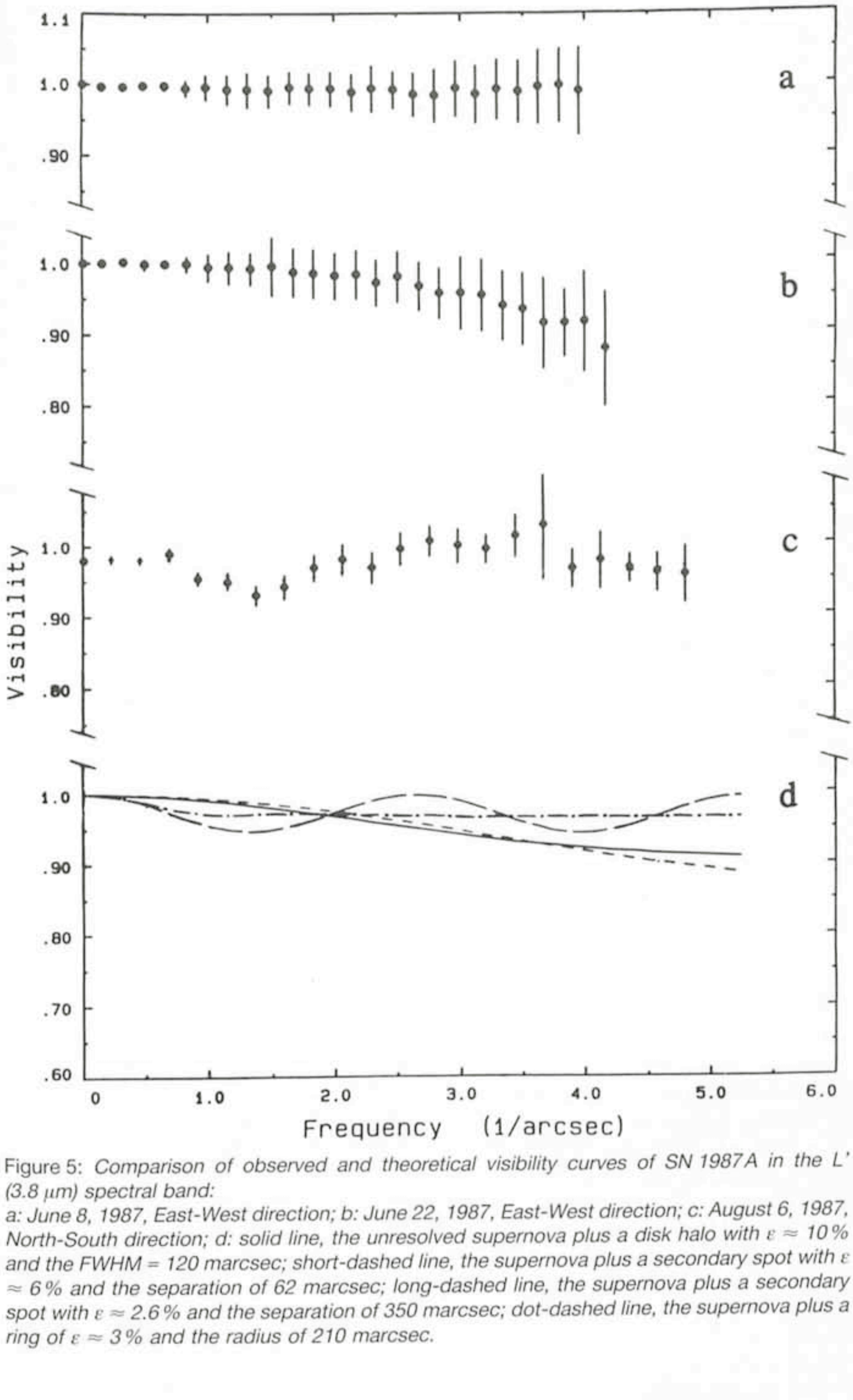


Figure 5: *Comparison of observed and theoretical visibility curves of SN 1987A in the L' (3.8 μm) spectral band:*
a: June 8, 1987, East-West direction; b: June 22, 1987, East-West direction; c: August 6, 1987, North-South direction; d: solid line, the unresolved supernova plus a disk halo with $\varepsilon \approx 10\%$ and the FWHM = 120 marcsec; short-dashed line, the supernova plus a secondary spot with $\varepsilon \approx 6\%$ and the separation of 62 marcsec; long-dashed line, the supernova plus a secondary spot with $\varepsilon \approx 2.6\%$ and the separation of 350 marcsec; dot-dashed line, the supernova plus a ring of $\varepsilon \approx 3\%$ and the radius of 210 marcsec.

point out is the rather low colour temperature of the speckle emission. On June 16, when we have measured both K and L' visibilities, $T_{col} \leq 2200$ °K. In August, $T_{col} = 2000 \pm 900$ °K. This is close to what one would expect for a hot dust emission. Thus, as we have suggested (Perrier et al., 1987), an IR light echo from dust, heated by the light burst at shock breakout, appears as the most plausible explanation.

Applying the theory of light echoes (Couderc, 1939), we can deduce the location of the IR speckle sources. As seen by a distant observer, the echoing dust grains lie on a paraboloid of revolution with the vertex point at the distance $c\tau/2$ from the supernova, where τ is the time interval counted from the arrival of the explosion light to the Earth. The distance from the supernova to the sources is: $R = (p^2/c\tau + c\tau)/2$, where p is the projected distance. Therefore, the distance to the edge of the disk halo or to the spots, detected in mid-June, is $R \simeq 1.5 \cdot 10^{17}$ cm; for the August spots, $R \simeq 3 \cdot 10^{17}$ cm. Chevalier and Fransson (1987) and Chevalier (1987) also considered the possibility of the IR echo from SN 1987A. According to their work, the shock wave of the BSg wind expansion should sweep the relict RSg dust into a shell. They expected only a weak IR echo, appearing as a ring of light, coming from the inner edge of the shell at $R \approx 10^{18}$ cm or 400 l.d. At this distance, the temperature of dust, heated by the light burst with the luminosity $L_b \approx 10^{43}$ $erg \cdot s^{-1}$, should be about 500–600 °K. The detection of speckle emission at $T_{col} \sim 2000$ °K in the form of spots or halo, and not of a ring, and at a distance to the supernova closer than expected then looks surprising. However, even at this distance, dust could partially survive the destruction by the BSg wind if it is concentrated in clumps, formed when the RSg wind material fragmented due to the Rayleigh-Taylor instability (Renzini, 1987). The observed IR speckle sources can well be the emission from the clumps of the relict dust. Thus, the following three spherical regions can be distinguished in the environment of SN 1987A:

(1) the inner cavity, free of any dust because the dust supply by the RSg wind had been turned off; its radius $R_1 = t_1 v_d$, where t_1 is the time elapsed since the RSg wind ceased to blow, and v_d is the velocity at which dust flowed away from the star; (2) an intermediate region where the fast BSg wind is passing through the RSg wind material; it is delimited by a shell of swept RSg wind material at $R_2 = t_2 v_{sh}$, where t_2 is the time elapsed since the BSg wind began to blow and V_{sh} is the velocity of expansion of the BSg wind into RSg wind material (Chevalier, 1987) and, possibly, (3) the region of the unperturbed RSg wind at $R > R_2$. This is illustrated in Figure 6.

Time Scale of the Progenitor Evolution

In the favoured case of the Gaussian halo for the mid-June L' visibilities, the heated dust closest to the supernova grains are at the vertex point of the paraboloid, at $c\tau/2$. Then, the first detection of the dust echo on day 113 suggests an upper limit on the radius of the dust free cavity, $R_1 < 56.5$ l.d. or $1.46 \cdot 10^{17}$ cm. The corresponding limit on the time interval, elapsed since the wind of the RSg ceased to blow, is $t_1 < 4600 \cdot (10\ km\ s^{-1}/v_d)$ yr. The typical RSg wind velocity about $10\ km \cdot s^{-1}$ is used as a first guess for v_d, but the actual value of v_d might be greater if dust is accelerated by the fast BSg wind. For the halo, R_1 cannot exceed the distance to its edge which is at the distance of about $1.5 \cdot 10^{17}$ cm from the supernova. Consequently, a stronger upper limit on t_1 is $5000 \cdot (10\ km\ s^{-1}/v_d)$ yr. Finally, allowing for the uncertainty of image reconstruction, we must consider the most distant unique "point-like" spot case. Then $p \approx 24$ l.d. and $R \approx 1.6 \cdot 10^{17}$ cm. The corresponding con-

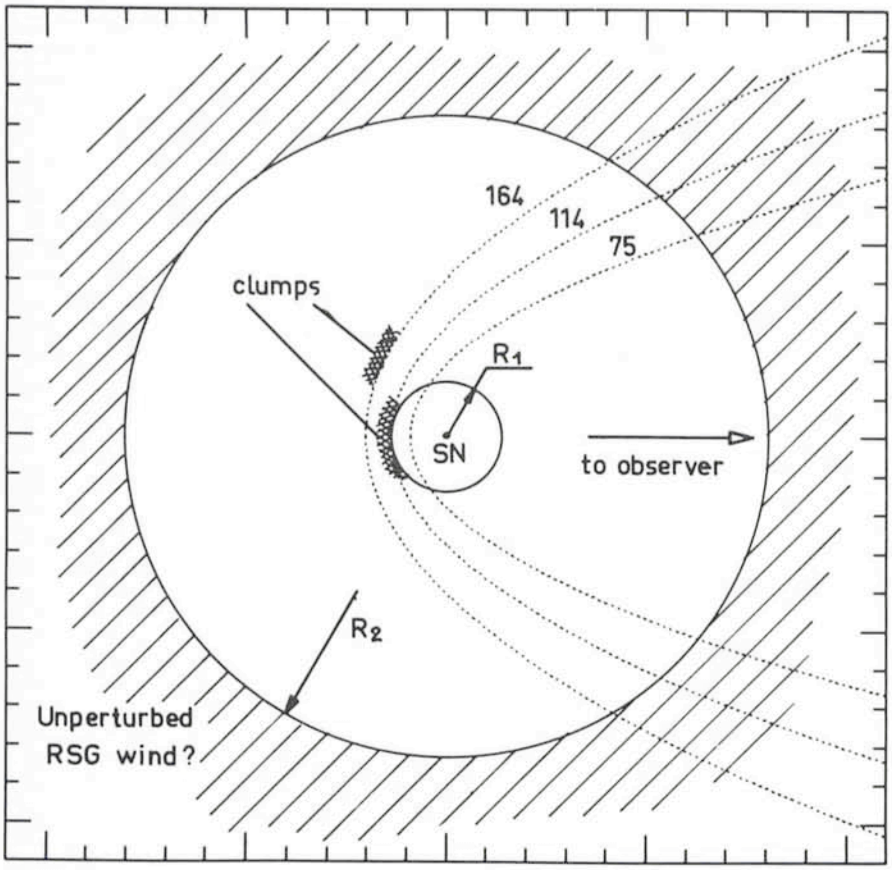


Figure 6: *The close environment of SN 1987A as suggested by IR speckle interferometry. Parabolae of light echo are labeled by number of days after the arrival of the explosion light. Double hatched areas show the location of dusty clumps heated by the light burst. For further explanations, see the text.*

servative upper limit on time scale is: $t_1 < 5100 \cdot (10\ \mathrm{km\ s^{-1}}/v_d)$ yr. The upper limits on t_1 are rather small. They imply that the evolution from red to blue was unexpectedly short, just of the order of the thermal timescale of the hydrogen envelope about 10^3 yr. Another hint on the time scale of the RSg –> BSg evolution can be obtained from the absence of the ring-induced pattern on August 5–6 visibilities. A ring emission would be the signature of the shell sweeped by the BSg wind. From the August visibilities, the lower limit on the diameter of such a ring is 0.5 arcsec. Then the shell should be at $R_2 > 2.6 \cdot 10^{17}$ cm, and the BSg wind should have begun to blow at least $1{,}600 \cdot (50\ \mathrm{km \cdot s^{-1}}/v_{sh})$ yr ago. However, the upper limit on the flux from the ring in the L' band is rather high, 14 Jy. This limit is not that significant: a faint ring would escape detection. A stronger constraint on the ring emission will be hopefully set by later IR speckle observations.

The UV Burst

The colour temperature of the IR speckle emission allows to constrain the magnitude of the very first point of the supernova light curve, i.e. the luminosity of the burst of radiation at shock break-out, L_b. The upper limit $T_{col} \leq 2200$ °K on June 16 implies the dust temperature $T_d \leq 1500$ °K (we assume that the dust absorption depends on wavelength as λ^{-1}). Solving the equation of the radiative balance for dust grains, we obtain $L_b < 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$. With similar assumptions, we obtain for the August 5–6 spots $T_d = 1{,}350 \pm 500$ °K and $7 \cdot 10^{42}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 5 \cdot 10^{44}\ \mathrm{erg \cdot s^{-1}}$ (the case of two spots at $R = 3.2 \cdot 10^{17}$ cm) and $1 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 8 \cdot 10^{44}\ \mathrm{erg \cdot s^{-1}}$ (the case of a unique spot at $R = 3.9 \cdot 10^{17}$ cm). Finally, combining the June and August estimates, we obtain $7 \cdot 10^{42}\ \mathrm{erg \cdot s^{-1}} \leq L_b \leq 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$. The IR speckle emission comes from a mixture of dust grains at different temperatures. However, theoretical models give an extremely short burst with the e-folding time not exceeding a few minutes (e.g. Woosley, 1988). Therefore, the echo emission is strongly dominated by the hottest grains and our estimate of L_b should be close to the value at maximum within a few percent. It compares well with the calculations of Woosley who gives $L_b = 3 \cdot 10^{43}\ \mathrm{erg \cdot s^{-1}}$ for the model 10 H (which is also his best model to account for the whole body of observations of SN 1987A).

Relation to Other Data

Given that the IR speckle data gathered at ESO are unique, we can verify them only indirectly. The first set of data which provides comparison are observations of the fluorescence echo in UV lines of HeII, OIII, CIII, NIII, NIV and NV, detected by the IUE satellite (Fransson et al., 1988) and in the visible lines of OIII and H, detected at ESO (Wampler and Richichi, 1988). They gave strong evidence in favour of reality of the RSg phase in the past evolution of the progenitor. This is in agreement with the interpretation of the IR speckle emission as due to dust grains, formed in the "antique" RSg wind. Furthermore, Wampler and Richichi (who coined the term "antique" wind) succeeded in measuring the spatial extent of the line emitting region and thus obtained an estimate of the time interval elapsed since the BSg wind began to blow, $t_2 \approx 7{,}000 \cdot (50\ \mathrm{km\ s^{-1}}/v_{sh})$ yr. Taking into account uncertainties in measurements and in scaling factors, we consider the agreement with our estimate of the end of the RSg wind epoch, $t_1 \leq 4{,}600–5{,}100$ yr at $v_d = 10\ \mathrm{km\ s^{-1}}$, as encouraging. Another point of comparison may be provided by observations of the far UV scattered echo (the external "invisible" part of the famous rings at 30 and 50 arcsec). As proposed by Chevalier and Emmering (1988), such observations could yield an independent estimate of L_b. The third kind of observations to keep eye on are the X-ray data and IR photometry. Indeed, Itoh et al. (1987) and Itoh (1988) predicted intense X-ray and IR emission at the time when the supernova ejecta will collide with the dense RSg wind material. Assuming the velocity of the blast shock wave from the supernova to be $2 \cdot 10^4\ \mathrm{km\ s^{-1}}$, it should reach the mid-June IR speckle source(s) at $R = 1.5 \cdot 10^{17}$ cm in the middle of 1989, giving rise to a flare of X-ray and IR radiation.

The Companion Object

A speckle companion (alias the "Mystery Spot") was announced to have been detected in the vicinity of SN 1987A from the speckle observations in the visible range in March-April 1987 (Nisenson et al., 1987; Meikle et al., 1987). It was situated approximately South of the supernova. Measured values of the angular separation vary from 52 to 74 marcsec. Our closest-in-time observations, carried out on May 9, i.e. 24 days after the last detection in the visible, did not reveal the companion, yielding an upper limit of 21 Jy on its flux in the L' band. Further, as the reader recalls, the partially resolved L' visibilities in mid-June can be fitted by "point-like" sources, situated about 50 marcsec from the supernova. However, ascribing the NS source to the Companion would lead to a quite inconsistent picture. One needs a second companion to explain the EW source. Also, one would have to explain why none of the companions were seen during the June 7–13 observing period. Therefore, we conclude that the mid-June L' visibilities, although they show a resolved structure, are not related to the companion. Further, speckle observations in the visible, carried out between May 30 and June 2, did not detect the companion (Karovska et al., 1987).

A number of mechanisms (synchrotron radiation, bremsstrahlung, line emission from ionized gas) have been proposed to explain the companion. However, according to a summary by Phinney (1988), the only model without severe difficulties with observations was a thermal emission at T = 3,000 K from a compact object. The corresponding black-body curve together with the visible and IR data is plotted in Figure 7. Our upper limit in L' lies below by a factor of 2.8 and provides a useful constraint. It implies that the temperature of the compact object should have remained constant at 3,000 °K from March 25 to April 14 (dates of observations in the visible) and then dropped down to below 1,800 °K by May 8, 1988. Phinney also mentioned the possibility of an echo from melting dust. Given the projected distance of about 17 l.d. on April 14, the corresponding distance from the dust to the supernova was about 28 l.d. From the equation of thermal equilibrium, we estimate the luminosity of radiation, necessary to heat this dust up to 3,000 °K, as $L_b = 2 \cdot 10^{44}$ erg $\cdot$ s^{-1}. This appears to be in conflict with the non-resolved K visibility on June 16.

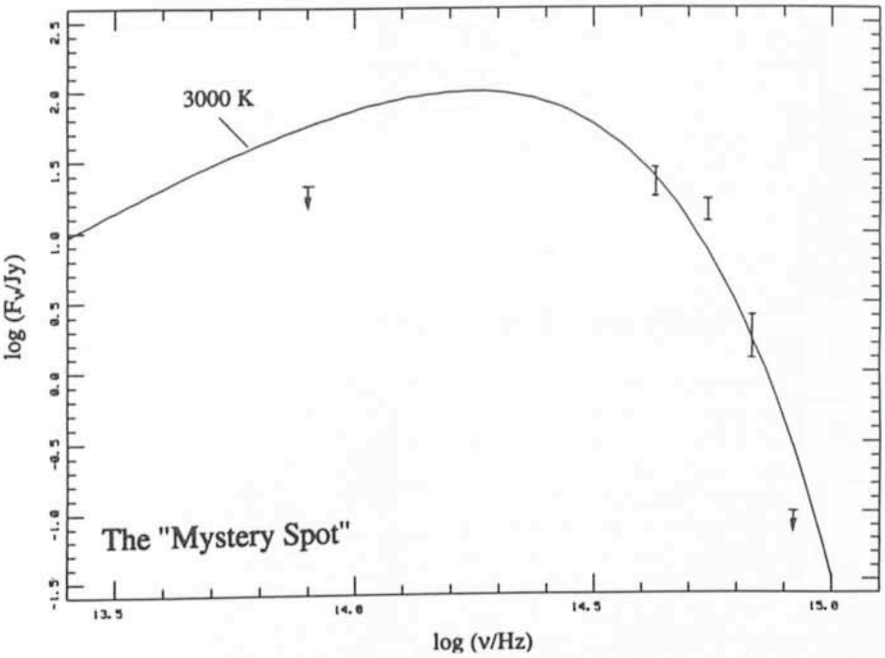


Figure 7: *The spectral distribution of energy for the companion object, implied by the visible and infrared data. The solid line corresponds to a black body of 3,000 K.*

Some Conclusions and Future Horizons

The reported work is the first study of a supernova at high spatial resolution in the infrared. Discussion of data from this sort of measurements provides valuable information on the past progenitor evolution as well as on the important parameter L_b, the luminosity of light burst at shock breakout, which is difficult to measure. More IR speckle data on SN 1987A were obtained in December 1987 and June 1988 and await their analysis. Further development of this new field can be easily foreseen. We think first of all about galactic supernovae and bright novae. A higher signal-to-noise ratio than what we had on SN 1987A would allow much more refined studies. Also, spatially resolved observations of an echo at a high signal-to-noise ratio may give the distance to the exploded object (Chalabaev, 1987). Overwhelming possibilities are promised by the coming new generation of telescopes of 8–10 m diameter. Estimates show that with such a telescope one could undertake similar studies of supernovae up to the distance of the M31 galaxy. Furthermore, the ESO VLT project includes the IR interferometry option and will certainly play a highly privileged role.

Acknowledgements

Behind the visibilities of SN 1987A presented here there is an effort of a number of persons at La Silla. Jacques Roucher spent long sleepless hours in improving the electric set-ups of the specklegraph. The electronics were refined by Michel Maugis and the control software by Flavio Gutierrez. The first 4 nights out of 5, allocated in May, were lost due to a snowfall. Due to the courtesy of Paul Le Saux, we could get the May 9 visibilities. The detection of the L' source(s) in June became possible due to the kindness of scheduled observers, A. Chelli, I. Cruz-Gonzalez, B. Reipurth and H. Zinnecker, who shared the telescope with us. The August oscillations could be detected thanks to difficult technical interventions at the telescope of Daniel Hofstadt, Loïc Baudet and Jacques Roucher. Patrice Bouchet took part in the May observations and supplied IR photometry data all along our observing runs. A trip of A.C. to Chile was financed by INSU-CNRS (France). The analysis of data greatly benefitted from discussions with W.S.P. Meikle, R. Chevalier and E.J. Wampler. Last but not least, Prof. L. Woltjer, the former Director General of ESO, allocated telescope time for this off-schedule programme and constantly encouraged our work. We are indebted to all these persons.

References

Bode, M.F., and Evans, A., 1979: *Astron. Astrophys.*, **73,** 113.

Chalabaev, A.A., 1987: in *ESO Workshop on SN 1987A*, ed. I.J. Danziger, Garching, p. 643.

Chalabaev, A.A., Perrier, C., and Mariotti, J.-M.: 1988a, in *George Mason University Workshop on SN 1987A*, ed. M. Kafatos, Fairfax, p. 236.

Chalabaev, A.A., Perrier, C., and Mariotti, J.-M.: 1988b, *Astron. Astrophys.*, in press.

Chevalier, R.A., 1987: in *ESO Workshop on SN 1987A*, ed. I.J. Danziger, Garching, p. 481.

Chevalier, R.A., and Emmering, R.T., 1988: *Ap. J.*, **331,** L 105.

Chevalier, R.A., and Fransson, C., 1987: *Nature*, **328,** 44.

Couderc, P., 1939: *Ann. d'Astrophys.*, **2,** 271.

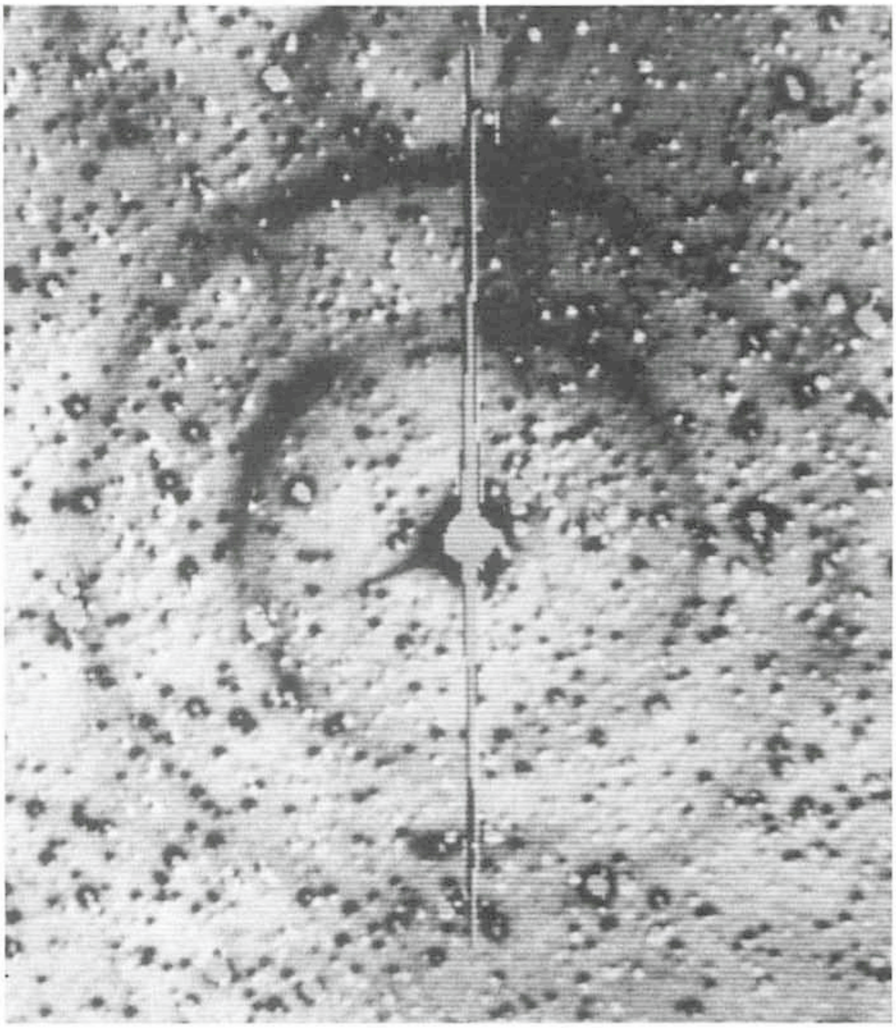
Fransson, C., Cassatella, A., Gilmozzi, R., Panagia, N., Wamsteker, W., Kirshner, R.P., and Sonneborn, G., 1988: *Ap. J.*, in press.

Itoh, H., Hayakawa, S., Masai, K., and Nomoto, K., 1987: *Publ. Astron. Soc. Japan*, **39,** 529.

Itoh, H., 1988: *Publ. Astron. Soc. Japan*, **40,** 263.

Karovska, M., Nisenson, P., Papaliolios, C., and Standley, C., 1987: *IAU Circ.*, No. 4440.
Meikle, W.S.P., 1988: *Proc. of Astron. Soc. of Australia*, in press.
Meikle, W.S.P., Matcher, S.J., and Morgan, B.L., 1987: *Nature,* **329,** 608.
Nisenson, P., Papaliolios, C., Karovska, M., and Noyes, R., 1987: *Astrophys. J.,* **320,** L15.
Perrier, C., 1986: *The Messenger,* No. 45, p. 29.
Perrier, C., Chalabaev, A.A., Mariotti, J.-M., and Bouchet, P., 1987: in *ESO Workshop on SN 1987A*, ed. I.J. Danziger, Garching, p. 187.
Phinney, E.S., 1988: *Nature,* **331,** 566.
Rees, M., 1987: *Nature,* **328,** 207.
Renzini, A., 1987: in *ESO Workshop on SN 1987A,* ed. I.J. Danziger, Garching, p. 295.
Wampler, E.J., and Richichi, A., 1988: *The Messenger,* No. 52, p. 14.
Woosley, S.E., 1988: *Ap. J.,* **330,** 218.

An Update on the Light Echoes of SN 1987A



The ring shaped light echoes found earlier this year around the supernova SN 1987A in the LMC (*The Messenger* **52,** 13) have been under close monitoring ever since. The picture shows an artificially enhanced image of the rings as observed by H. Pedersen and J. Melnick on the nights 29th through 31st of October 1988, using a CCD camera in the Gascoigne adapter at the prime focus of the 3.6-m telescope. The resolution is 0.58 arcsec per pixel and the seeing was about 1.2 arcsec. In order to enhance the contrast, the photo shows the ratio of averages of five 3-minute exposures in B and V each.

The outer ring has reached a radial distance of about 77 arcsec and the inner ring of about 45 arcsec, very close to the predictions for plane parallel sheets of reflecting material perpendicular to the line of sight. In February the radii measured 52 and 32 arcsec respectively. The most interesting aspect is that the echoes retain their near circular shape. This implies that, at least over the area swept by the echoes since February, the interstellar dust must be highly concentrated into two thin layers located roughly 120 und 320 pc in front of the supernova. The very small deviation from circularity of the rings imposes tight constraints on any inclination and curvature of these sheets of matter, which are likely to belong to the halo of the LMC. *M. ROSA*

The ESO Schmidt Telescope

The ESO(R) half of the joint ESO/SERC Survey of the Southern Sky will soon be finished. For more than 90 % of the 606 fields, Atlas-quality plates have now been obtained. Reasonably good, but not quite optimal plates are available of another 5 % of the fields and only for ~20 fields (3 %) has no acceptable plate yet been obtained. The Atlas production in Garching in also nearing the end; 22 shipments out of a total of 24 have been sent to about 200 customers. It is hoped that the last two shipments will become available in the course of 1989.

Most of the missing Atlas plates are in the right ascension interval between 20 hours and 4 hours and high priority will be given to the atlas work during the corresponding season (August to December). For the rest of the year, virtually all time is now available for other purposes.

One of the current programmes is the extension of the Quick Blue Survey from declination -20° to the equator. This involves taking about 300 Atlas-quality IIa-O + GG 385 plates, each with 60-minute exposure time. This project procedes rapidly and more than one quarter of the fields have been covered with excellent plates.

Other Projects now under consideration include retaking the entire QBS, about 15 years after the first survey of this type. This would provide a very good basis for determination of proper motions in the southern sky, even of rather faint stars. The supernova search programme in brighter galaxies might also be re-activated. Other possibilities include deep infrared plates along the galactic plane or very long exposures (up to 5 hours) of selected objects through the available Hα and S II interference filters which have a useful field of about 2°.

The approximate limiting magnitudes for direct plates are quoted in the table. They depend on the seeing; the numbers given are for medium seeing and deeper plates are obtained under excellent conditions. These values may possibly be further improved after the installation of the new Grid Processing machine in November 1988. At the same time, tests are being made of the new Kodak T-max emulsion, although the sensitization appears to be more difficult than first expected. We shall report in one of the next *Messenger* issues about the initial results.

The ESO Schmidt telescope is equipped with one of the world's largest objective prisms, giving a dispersion of about 450 Å/mm at Hγ. Under good seeing conditions, it is possible to obtain widened spectra which allow MK classification, down to magnitude 14.5–15.0. Unwidened spectra give limiting magnitudes, approximately 2–3 magnitudes fainter. The performance is critically dependent on the seeing, as is the case for all objective prism work. The UBK 7 glass is ultraviolet transparent.

Performance of the ESO 1-m Schmidt Telescope

Emulsion	Sensit.	Filter	Bandpass	Exposure	Lim. mag
IIa-O	no	UG 1	UV	60 min	~19
				120 min	~20
	no	GG 385	B	60 min	~21
IIIa-J	yes	UG 1	UV	60 min	~20
				120 min	~21
	yes	GG 385	B	120 min	~22.5
103a-D	no	GG 495	V	45 min	~19
IIIa-F	yes	RG 630	R	120 min	~21.5
IV-N	yes	RG 715	I	90 min	~19

In the future, the 30 × 30 cm plates will be scanned on the refurbished two-coordinate measuring machine at the ESO Headquarters (formerly the S-3000 machine). With a new CCD head and much improved software and large computer storage space, it will become possible to perform "blinking" of large areas. This will greatly speed up the extraction of data from the photographic plates and may give a new impetus to the use of the ESO Schmidt as a powerful survey instrument.

H.-E. SCHUSTER and R.M. WEST

Monitoring SN 1987A

Since the explosion in late February 1987, more than 130 ESO Schmidt plates have now been obtained of the LMC area in which SN 1987A is seen. They document its slow decrease in brightness as well as the now famous double light echo. It is particularly well visible on red and infrared plates. The supernova magnitude was about 10.5 by mid-November 1988.

Learning About Young Globular Clusters

R. CAYREL, I. TARRAB, Observatoire de Paris, France, and
T. RICHTLER, Sternwarte der Universität, Bonn, F. R. Germany

1. Introduction

Even after many decades of intensive investigation globular clusters still fascinate astronomers. Galactic globular clusters are "fossils" of the epoch of galaxy formation and samples of a very early, but still reachable stellar generation. The situation is different in the Magellanic Clouds where globular-cluster-like objects with a wide variety of ages can be found. We see globular clusters which, judged by their stellar content, cannot be much older than 10^7 yr. Their integrated light is dominated by a slightly evolved upper main sequence. Therefore, they have often been referred to as "blue globular clusters". the question why such clusters are found in the Magellanic Clouds (and perhaps in some other galaxies like M33 and NGC 2403) and not in the Milky Way is certainly of significance for the general understanding of galaxy evolution (see IAU Symp. 126 for more information).

Young globular clusters are ideal laboratories for determining Initial Mass Functions (IMF's), which describe the number of stars found per mass interval in a star forming region. The IMF is of fundamental importance for the evolution of a galaxy, since it controls the energetic feed-back by massive stars to the interstellar medium and largely determines its chemical evolution. However, the determination of the IMF in stellar systems in the Milky Way faces several difficulties. For instance, stars in the solar neighbourhood do not form a coeval sample; open clusters show poor statistics; in galactic globular clusters, only the small mass interval 0.4–0.8 solar masses is observable and they are so old that the observed mass function may be modified by secular dynamical effects. It is evident from these considerations that young globular clusters provide a unique opportunity to study stellar mass functions with good statistics over a large range of masses. Additionally, there is also hope of uncovering a possible dependence of the IMF on metallicity. A spectroscopic high-resolution study by some of us (Spite et al. 1986) confirmed earlier suggestions that NGC 330, the brightest of the young globular clusters in the SMC, has an abnormally low metallicity of −1.3 dex (Fig. 1). In contrast to this, the overall metallicity of the young SMC population is believed to be around −0.7 dex.

Another cluster for which a high-resolution spectrum hints of a lower metal abundance than is found in the field population, is NGC 1818 in the LMC (Richtler et al. 1988, Fig. 2).

It is of great interest to look into the mass function of these objects to find possible differences to a "normal" IMF.

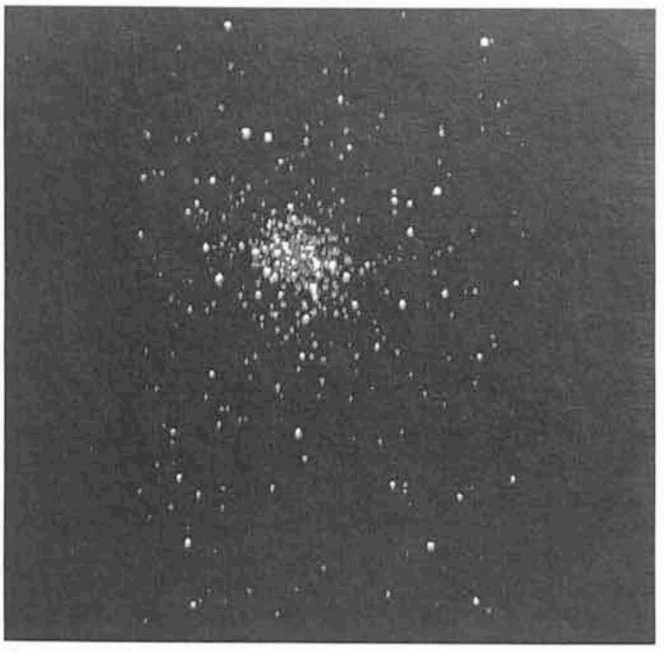


Figure 1: *A 10-sec V exposure of the young SMC globular cluster NGC 330, taken at the 1.54-m Danish telescope. The brightest stars are already saturated.*

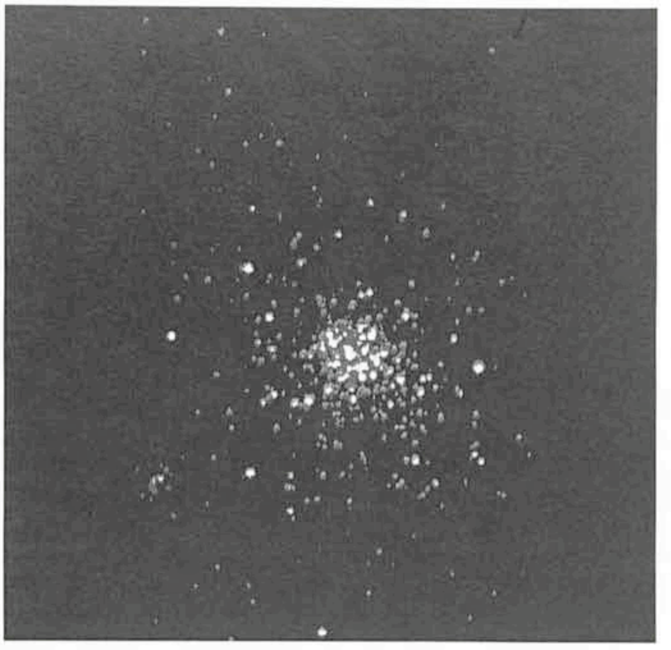


Figure 2: *A 10-sec V exposure of the young LMC globular cluster NGC 1818, taken at the 1.54-m Danish telescope.*

Theoretical considerations indeed point to differences. The concept of opacity-limited fragmentation leads to the prediction that the IMF for massive, zero-metal stars is steeper (Yoshii and Saio, 1986) than a Salpeter mass-function, which characterizes the IMF in the solar neighbourhood.

These ideas are to some degree supported by observational work: strong variations of the IMF in time and space are known to exist in open clusters (Tarrab, 1982). The mass function of galactic globular clusters has been recently investigated (McClure et al. 1986), and a significant dependence on metallicity was found, in the sense that a low metallicity seems to occur with a larger slope. On the other hand, indirect evidence was presented by Melnick (1987) that the IMF of massive stars exciting H II regions is metallicity dependent, but this time in the opposite way. These results are not necessarily in contradiction because the authors address quite different parts of the IMF (15 to 40 $M_\odot$ for Melnick, 0.2–0.8 $M_\odot$ for McClure et al.). To confuse this issue further, Eggen (1987) finds a luminosity function of the field metal-poor population in our Galaxy nearly identical to that of the solar neighbourhood.

During the course of the present work, two papers appeared, dealing with luminosity functions (LF) of young Magellanic Cloud clusters. Elson, Fall and Freeman (1988) investigated the LF's of their objects by visual star counts, while Mateo (1988) employed CCD-techniques to determine LF's of Magellanic Cloud clusters of a large range in age.

These investigations do not arrive at a common conclusion. Mateo finds that the LF's of the clusters he investigated are (within the given uncertainty) similar to each other and also cannot be distinguished from a Salpeter function. Elson et al. find their LF's flatter than a Salpeter function and also differences from cluster to cluster. In a nutshell, this is what we know (or not know) and probably most astronomers agree that further investigations are of importance.

2. Observations

Our data come from two different telescopes. In November 1987, we observed with the 2.2-m telescope in re-

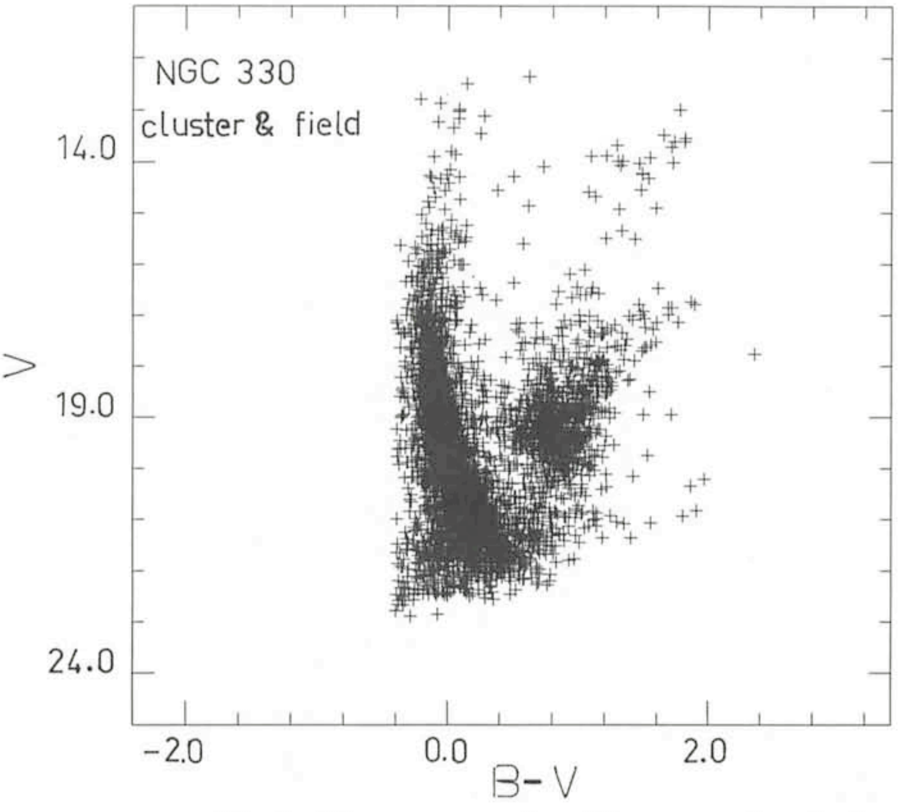


Figure 3: *This is a colour-magnitude diagram of all stars measured in the field of NGC 330. Note that most of the faintest stars are probably field stars, since the deep 2.2-m frames have been taken with the cluster near one edge.*

mote control to take deep B and V frames in the fields of NGC 330 and NGC 1818. The CCD camera No. 5 was attached to the Cassegrain focus. Pixel size was 30 μm leading to a scale of 0.″36 pixel. The exposure times were as long as 40 minutes in B and 30 minutes in V. The 1.54-m Danish telescope had been employed a few nights earlier to take frames of shorter exposure time. Here the CCD-camera operated in binned mode (30 × 30 μm^2) with a scale of 0.″47/pix. Exposure times ranged from 10 s to 1200 s. In both cases, the seeing was of medium quality of about 1.″6, so optimistic astronomers can say that in spite of binning the stellar images were well sampled.

After basic processing (flat-fielding, etc.) the photometric information has been extracted with the DAOPHOT package (Stetson, 1988).

The transformation of instrumental to standard magnitudes was performed via photoelectric standard stars in the field of NGC 330 measured by Alcaíno and Alvarado (1988). For the photometry of NGC 1818 we used the same colour terms, but with the zero-points from the photometry of Robertson (1974). These last data have to be considered as preliminary until an accurate calibration becomes possible.

3. Colour Magnitude Diagrams

Figure 3 shows the CMD of all stars measured in the field of NGC 330. A large fraction of these stars are probably field stars since the deepest frames have been taken with the cluster located at the edge of the frame in order to minimize saturation effects. Very conspicuous is the bulk of stars belonging to an older population. The comparison of Figure 4a and 4b demonstrates the dominance of the field population. Figure 4a plots stars closer than 50″ to the cluster (1.54-m data). Figure 4b shows all stars more distant from the cluster centre than 100″. NGC 330 is embedded in a field population which has a component almost as young as the cluster itself.

A very remarkable feature in the cluster CMD is the gap visible between 13.2 and 14.4 mag. The stars above the gap are with high probability cluster members, since such stars are completely missing in the field diagram. Carney et al. (1985) already noted this gap and presumed that these stars were He-burning supergiants, i.e. stars which are at the blue end of their supergiant evolutionary loop (e.g. Maeder and Meynet, 1988). The number statistics of such stars may be of great importance for testing stellar evolution theories since the respective lifetimes of blue and red He-burning supergiants are sensitive to properties of evolutionary models as effects of overshooting and/or metallicity. Presently, a comparison with theory seems impossible since a suitable grid of massive, metal-poor stellar models is still lacking. Furthermore, these models should be given in observable parameters, i.e. colour-magnitude diagrams. We recall that the slope δ BC/δ (B-V) is larger than 10 for supergiants bluer than B-V = 0 (the same is true for supergiants redder than B-V = 1.6), so transforming observed colours and magnitudes into the M_{BOL} – T_{eff} plane enlarges error bars more than 10 times.

One of the most obvious difficulties connected with observations of Magellanic Clouds clusters is the severe crowding. The density of the field population near NGC 330 is 350 stars/square arcmin down to 23 mag and 100 stars down to 20 mag. Even in a good seeing with a FWHM of 1″, the stellar profile extends from the photometrist point of view to a diameter of at least 4″, which means that the sky is 1.2 times overcrowded with stars as faint as 22.5 mag.

The cluster itself exhibits a further tremendous enhancement in star density over this background field. If we assume the cluster radius to be 50″, we expect 760 background stars down to 22.5 mag within this area. In Figure 4b, 270 stars are fainter than 17 m and 140 of them are statistically field stars. When going to fainter magnitudes, this fraction favours even more the field contribution: of all stars fainter than 18 mag, 60 % are field stars. The reason for this is the growing incompleteness of the photometry in the cluster region.

With NGC 1818, the situation looks much better. Figure 5a shows all stars within 50″ of the cluster and Figure 5b is the field population outside 100″. As a young cluster, NGC 1818 is projected on a field population of intermediate age, which with 35 stars/square arcmin

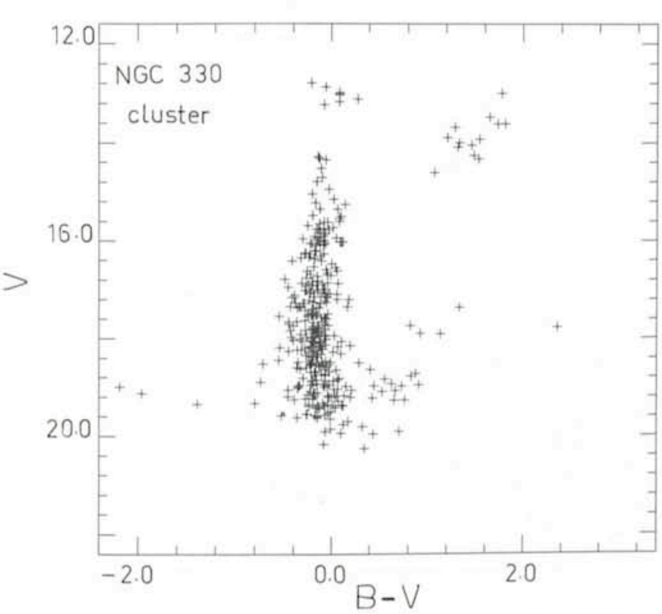


Figure 4a: *This is a colour-magnitude-diagram for all stars within a distance of 50″ from the centre of NGC 330. Note the disappearance of the conspicuous bulk of red stars at V = 19 mag. in Figure 4b. It is also striking that the group of blue supergiants above the gap in the "blue sequence" are only visible for the cluster, thus arguing strongly that these stars are cluster members.*

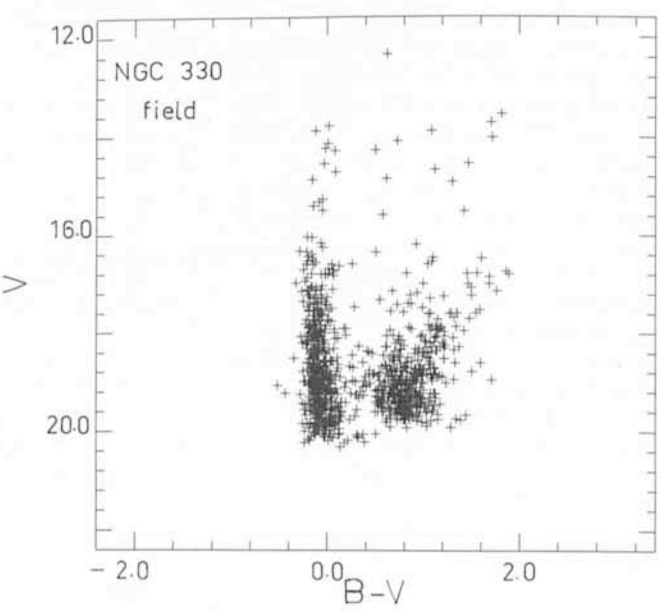


Figure 4b: *In this colour-magnitude-diagram all stars more than 100″ from NGC 330 are plotted. The youngest stars in the field population have ages larger than those in the cluster.*

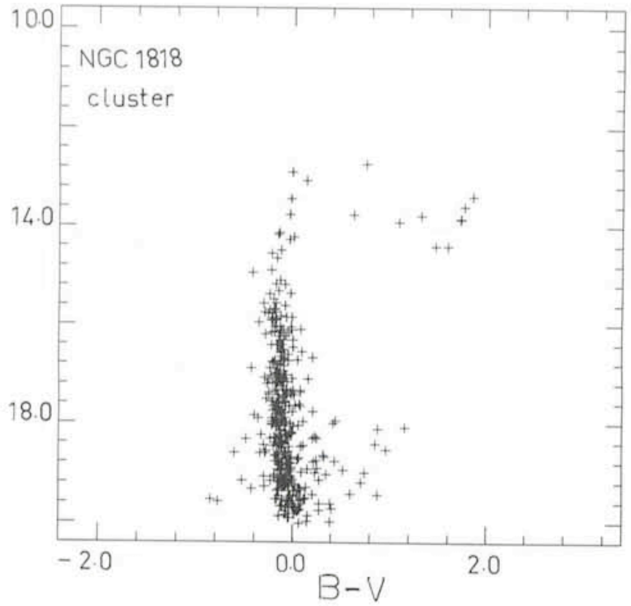


Figure 5a: *A colour-magnitude diagram for stars nearer than 50″ to the centre of NGC 1818. Comparison with Figure 5b reveals that the field population is much less dominant than in the case of NGC 330.*

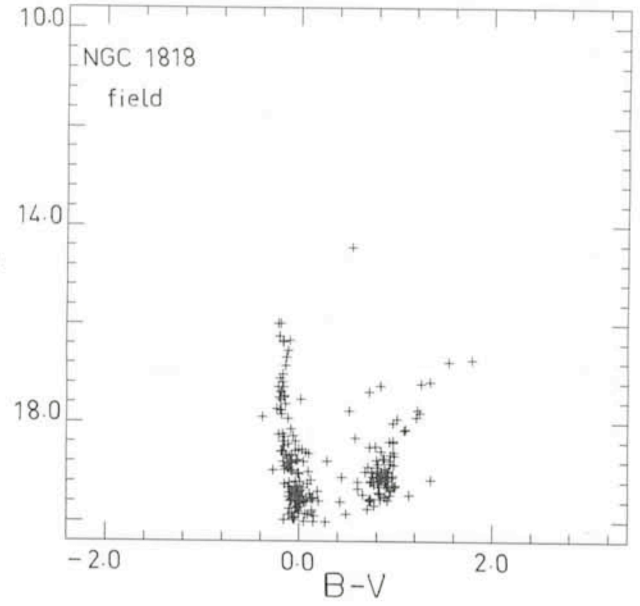


Figure 5b: *A colour-magnitude diagram for stars farther than 100″ from the centre of NGC 1818.*

down to 20 mag is also 3 times less dense than in the case of NGC 330.

4. Derivation of LF's

Once the photometry of the stars is established, it should in principle be easy to derive a luminosity function by simply selecting the main sequence stars and counting the stars in defined magnitude bins. However, during the reduction procedure, we became aware that counting stars can be a very difficult task.

The photometry performed with DAOPHOT is a complex interaction between the routines and the charge distribution on the chip, which especially for the long-exposure frames exhibits a complicated structure due to charge overflow of the bright stars. The star finding routines do not find all stars, in particular not the fainter ones. DAOPHOT offers a comfortable possibility to determine quantitatively "incompleteness factors". One can create randomly artificial stars (the point spread function, PSF, is known) in a selected magnitude range. Then these stars can be searched for by the normal DAOPHOT procedure. A comparison of the original artificial star list with the list of all stars found by DAOPHOT gives directly the required incompleteness factors (see Mateo 1988 for a deeper discussion). Since the data sample is built up from frame pairs (B, V) of different exposure levels, we had to calculate incompleteness factors separately for each frame pair. To achieve statistical reliability we added a large number of artificial stars, about 1,000 stars for each frame. Reducing them means a huge amount of computing time which actually is the limiting factor. It turned out that in the cluster field the completeness quickly becomes uncomfortably low at fainter magnitudes. To be on a safe side, one has to consider, at least in a first stage, counts only down to magnitude 18.0 or 18.5 to avoid completeness factors too different from 1.0.

Having made counts both in the cluster area and outside, each with their own completeness corrections, we subtracted the field counts from the (cluster + field) counts. As we have a colour-luminosity diagram, the counts have been restricted to the main sequence, the evolved phases (blue and red supergiants) being taken out.

The derived luminosity function is shown in Figure 6. The number of stars roughly doubles per magnitude interval.

5. Initial Mass Function

In case of a zero-age main sequence, it would be relatively easy to convert our luminosity function into an IMF. We would have first to convert our $\delta\ M_V$ bins into $\delta\ M_{BOL}$ bins, and then use the zero-age mass luminosity relationship ($L \sim m^{\alpha}$ with $\alpha \simeq 3.0$ to 3.5) to transform it in stars per δ logm bins. Actually we observe an evolved main sequence, so evolution renders the mass-luminosity relation unusable and the number of stars initially in a logm bin ends up in an evolved M'_{BOL}, M''_{BOL} interval, different from the one on the ZAMS. It is then necessary to use evolutionary tracks in order to obtain the relevant (M'_{BOL}, M''_{BOL}) bin corresponding to the initial logm bin. For that procedure the age of the cluster must be known. We can use the luminosity of red supergiants to estimate the age of the cluster. Using evolutionary tracks of the appropriate metallicity kindly provided before publication by Castellani and Chieffi, we have found that the gap between magnitude 14.4 and 13.2 is well explained if the magnitude 14.4 represents the end of the main sequence at an age of 12 Myr, whereas the stars at mag 13.0 are blue supergiants in their He-burning phase with masses near 18 $M_{\odot}$). Assuming that age, we find that $\delta\ M_V$ bins transform into fairly unequal δ logm bins at V = 15 and V = 18. Our computations lead to an IMF index x near 1.2 (we remind

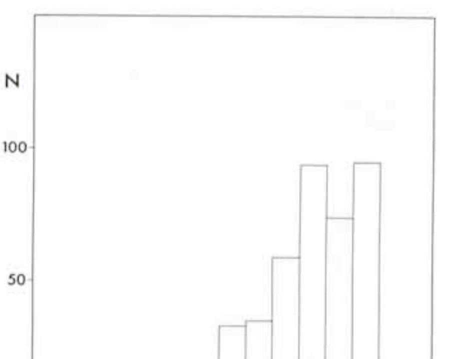


Figure 6: *Luminosity function of NGC 330. The contribution of the field has been estimated and subtracted. Fluctuations on the bright side are due to Poisson statistics. Crowding is the factor limiting the accuracy on the faint side.*

that x = 1.35 for Salpeter law). Although this value is in good agreement with the result of Mateo, we feel that more elaborate work, particularly under outstanding seeing conditions, has to be carried out before we can state that the mass function slope of a metal-poor population is different or not from the value found for normal metallicity Pop I objects currently ≃2.0 (e.g. Tarrab, 1982, Lequeux 1979) for the *upper* main sequence.

A large potential lies in the many still unstudied young Magellanic Cloud clusters in understanding the morphology of the IMF and the evolution of massive metal poor stars. However, very careful observations, reductions and the availability of evolutionary tracks for a wide range of parameters are necessary to use it. If these conditions are fulfilled, then ground-based observations of the upper mass function will not be superseded by the HST whose resolving power is definitely necessary for fainter magnitudes.

Also other clusters should be studied, because NGC 330 is not one of the easiest objects to work with, although being often presented as the prototype of young blue populous globular clusters in the SMC.

6. Conclusions

The study of the young globular clusters in the Magellanic Clouds is rich in hopes, because it is the most direct check available for the theory of stellar evolution of massive stars with non standard metallicities. In particular, it gives some evidence on what could have been the early evolution of galactic globular clusters. However, the distance of over 60 kpc of these clusters make quantitative work difficult, in particular because of the confusion of stellar images at this distance. In the future, other corrections are to be applied to the photometry than a simple "completeness" factor. Stars which are "lost" are probably affecting the luminosity of other stars of the field, and most visual binaries, when observed in the solar neighbourhood, are seen as single stars in the SMC or LMC. The Hubble Space Telescope will drastically change the prospects in a few years, but this is not an excuse for doing nothing in the meantime.

References

Alcaíno, G., Alvarado, F.: 1988, *Astron. J.* **95,** 1724.
Carney, B.W., Janes, K.A., and Flower, P.J.: 1985, *Astron. J.* **90,** 1196.
Eggen, O.E.: 1987, *Astron. J.* **92,** 393.
Elson, R.A.W., Fall, S.M. and Freeman, K.C.: 1988, STScI preprint No. 292.
Lequeux, J., Peimbert, M., Rayo, J.F., Serrano, A., Torres-Peimbert, S.: 1979, *Astron. Astrophys.* **80,** 155.
Maeder, A. and Meynet, G.: 1988, *Astron. Astrophys.*, submitted.
Mateo, M.: 1988, *Astrophys. J.* **331,** 261.
McClure, R.D., VandenBerg, D.A., Smith, G.H., Fahlmann, G.G., Richer, H.B., Hesser, J.E., Harris, W.E., Stetson, P.B., Bell, R.A.: 1986, *Astrophys. J.* **307,** L49.
Melnick, J.: 1987, *Astron. Astrophys. Suppl.* **71,** 297.
Richtler, T., Spite, M., Spite, F.: 1988, submitted to *Astron. Astrophys.*
Robertson, J.W.: 1974, *Astron. Astrophys. Suppl. Ser.* **15,** 261.
Spite, M., Cayrel, R., Francois, P., Richtler, T., and Spite, F.: 1986, *Astron. Astrophys.* **168,** 197.
Stetson, P.B.: 1987: *Publ. Astron. Soc. Pac.* **99,** 191.
Tarrab, I.: 1982, *Astron. Astrophys.* **109,** 285.
Yoshii, Y., Saio, H.: 1986, *Astrophys. J.* **301,** 587.

The Nebular Stage of Nova GQ Muscae: Physical Parameters from Spectroscopic Observations

J. KRAUTTER, Landessternwarte Heidelberg-Königstuhl, F.R. Germany, and
R.E. WILLIAMS, Cerro Tololo Inter-American Observatory, La Serena, Chile

Nova GQ Muscae 1983, a classical nova which had its maximum in January 1983, might already be familiar to the readers of the *Messenger*, since it was already twice the subject of articles in this journal. E. Oliva and A. Moorwood (1983, *The Messenger* **33,** 30) reported on infrared CVF spectrophotometry carried out within the first four weeks after maximum. J. Krautter, K. Beuermann, and H. Ögelman (1985, *The Messenger* **39,** 25) described the results which were obtained from coordinated observations from X-rays to the infrared regime carried out in 1983 and 1984. Apparently, these authors had some foreboding, since they closed their article with the words ". . . This, *at present,* concludes the story of Nova Muscae 1983." In fact, that was not the end of the story of Nova GQ Muscae: since then, exciting results of new observations of GQ Muscae have been obtained which provide the justification to again write an article about this nova for the *Messenger.*

Before we discuss our new observations, we want to shortly summarize the most important results from the early phases. GQ Muscae, which had a visual brightness V ≈ 7.0 mag at maximum, is a moderately fast classical nova: t_3, the time for a decrease by 3 magnitudes from maximum brightness, was about 40 days. The outburst amplitude was more than 14 mag, one of the largest outburst amplitudes ever observed for novae. The lightcurve was somewhat unusual for a fast nova, since the visual magnitude remained nearly constant at a level of 3.5 mag below maximum brightness for a period of about 11 months (April 83 to March 84). It should be mentioned that no indication for dust formation, which quite often happens in novae of this type, was found.

The spectroscopic observations during the early phases showed a pronounced overabundance of nitrogen relative to carbon and oxygen, and there was an indication of a He/H overabundance. However, no abundance of any metal relative to H or He could be determined. The line profiles were very complex; during the early phases the usual P Cygni absorption systems (principal, diffuse enhanced, and Orion system) with velocities of the absorption components up to −2000 km/sec were found as well as up to 4 emission components. The distance was found to be D = 4.8 ± 1 kpc. This allowed a lower limit for the luminosity around maximum of about one Eddington luminosity to be derived, assuming a 1 $M_\odot$ white dwarf.

Of special interest were the X-ray observations carried out with EXOSAT, since GQ Muscae was the first classical nova from which X-ray radiation was observed during the outburst or decline from outburst. Since no spectral energy distribution could be determined, two

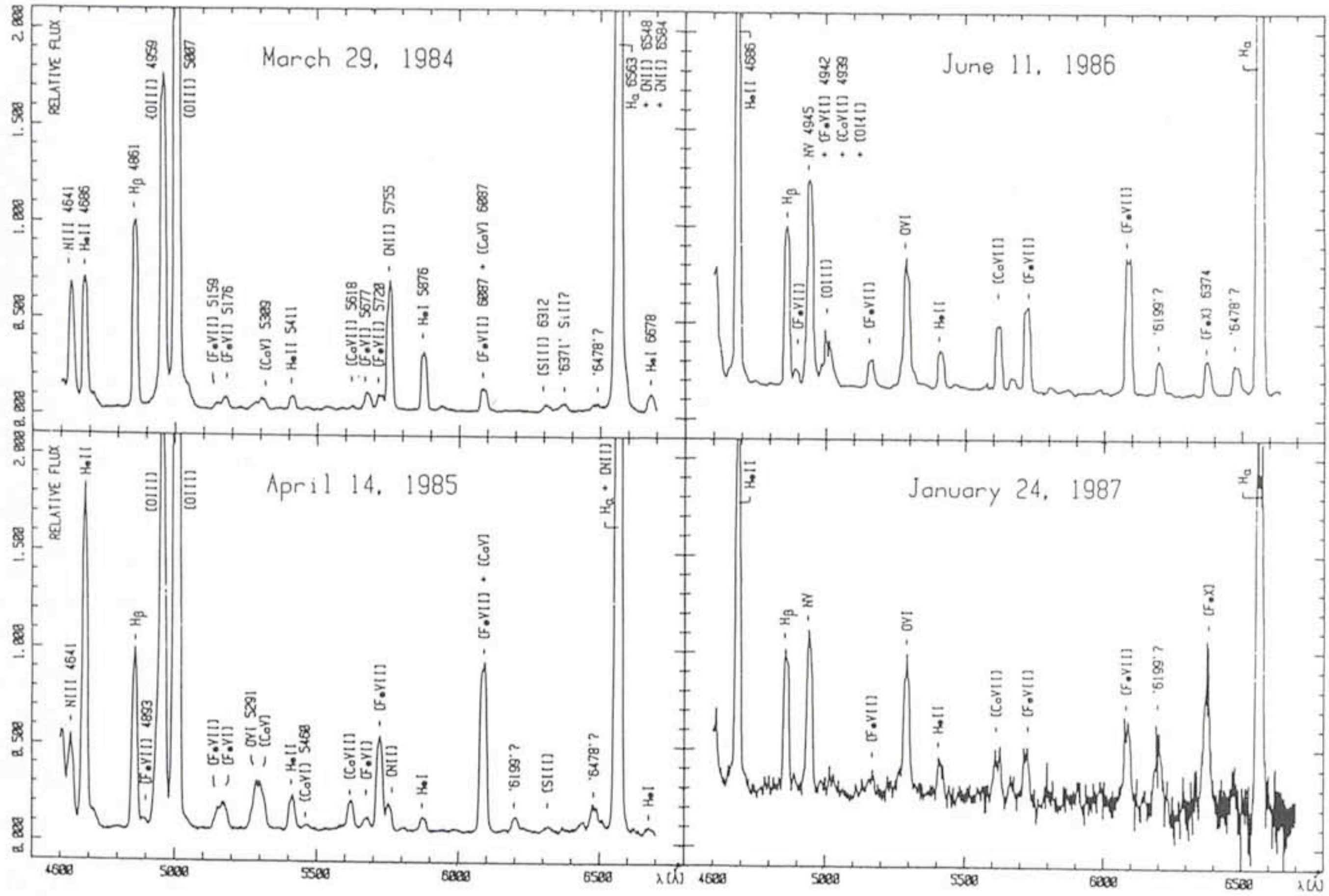


Figure 1: *A series of spectra of Nova GQ Muscae 1983 from March 1984 to January 1987. The fluxes are given in relative units. The strongest lines are not shown in full intensity. From Krautter and Williams (submitted to* Astrophys. J.*).*

possible explanations were given at the time: either a shocked shell of circumstellar gas emitting 10^7 K thermal bremsstrahlung radiation or a white dwarf remnant emitting blackbody radiation of several hundred thousand K at about one Eddington luminosity. However, there were arguments which strongly favoured the latter mechanism (Ögelman, Krautter, Beuermann, 1987, *Astron. Astrophys.* **177,** 110).

We shall come back to the X-ray emission mechanism at the end of this article.

Spectroscopic Observations During the Nebular Stage

We now turn to our spectroscopic observations, carried out in irregular intervals during the nebular phase from 1984 to 1988. Most observations in the optical spectral range were performed using the ESO 1.5-m, 2.2-m, and 3.6-m telescopes on La Silla. Low and medium resolution spectrograms were obtained with the Cassegrain Boller & Chivens spectrographs and recorded with IDS or CCD detectors. Two spectra were obtained with the 1-m and 4-m telescopes of the Cerro Tololo Inter-American Observatory and recorded with a 2D-frutti photon counting detector. UV spectra were obtained with IUE using, in all cases, the facilities of the ESA Villafranca satellite tracking station.

Figure 1 shows a representative series of low resolution ($\Delta\lambda \approx 7$ Å) spectra taken in March 1984, April 1985, June 1986, and January 1987. The spectra are displayed in the range 4600 Å–6700 Å, and the fluxes are given in relative units. Note that the strongest emission lines are not shown in full strength; they have been cut in order to show weak lines on a reasonable scale.

The spectrum from March 29, 1984 (upper left) is shown in full scale in Krautter et al. (1985, *The Messenger* **39,** p. 29).

The general character of the spectra did not change during this period; they are dominated by strong emission lines superposed on a weak continuum. However, since the emission line fluxes continuously decreased while the continuum flux remained about constant, the average equivalent widths decreased from 1984 to 1988. All lines are very broad and have half widths at zero intensity of about 800 km/sec which reflect the velocity of the expanding envelope. Due to the low resolution, only two emission components can be distinguished.

High Resolution Observations

When we finally obtained in April 1985 (two days before the second spectrum in Figure 1) high resolution spectra ($\Delta\lambda \approx 0.2$ Å) using the Echelle spectrograph CASPEC attached to the 3.6-m telescope, we were rather surprised by the line profiles we saw. As an example, Figure 2 shows a tracing of the [O III] $\lambda\lambda$ 4959, 5007 emission lines: as many as at least 22 different emission components can be distinguished! All the small peaks in the emission lines are real emission components and not noise, since they show up in both [O III] lines. The line profiles of the other emission lines in the CASPEC spectra have the same general structure, i.e., the same line width and the same radial velocities of the individual components. There are, however, variations in the relative fluxes of the emission components: For instance, in the [O III] the blueshifted components are on the average stronger than the redshifted ones, whereas the Balmer and the [Fe VII] lines have a more symmetric structure. These line profiles clearly show that the ejection of the expanding envelope of GQ Mus was anything but spherically symmetric. The individual emission components appear to be emitted by individual blobs of

TABLE 1: T_e *and* n_e *at different dates.*

Date	T_e [K]	log N_e
Apr 1984	14500	7.5
Apr 1985	18000	6.9
Jan 1986	17500	6.6
Jan 1987	≤25000	6.0

material. Such "blobs" can be seen on direct images of old nova shells which are close enough to be spatially resolved. Nice examples are presented in a recent article by H. Duerbeck (1987, *The Messenger* **50,** 8). Because of its larger distance (4.8 kpc) the shell of Nova Muscae should now have an apparent diameter of only 0.3 arcsec and cannot be spatially resolved. The minor differences in the emission characteristics of different lines may be due to different excitation conditions and/or slightly different chemical abundances in the individual blobs.

We should not forget to mention that the high resolution spectra allowed us to determine the wavelengths of the emission lines with a much higher accuracy than is possible from medium or low resolution spectra. On the basis of the CASPEC spectra we could remove some uncertainties in the line identifications; for instance, we are now sure that coronal lines like [FeX] λ 6374 were not present in April 1985 (more about coronal lines later).

Element Abundances and Physical Parameters in the Expanding Shell

Emission line ratios can be used to derive physical parameters of the expanding shell, particularly n_e, T_e, chemical abundances, and the mass of the shell. One has to keep in mind, however, that the derived numbers are mean values for the entire expanding shell. As we have seen, there could be slight variations from blob to blob. Unfortunately, only a limited number of lines can be used for diagnostic work. Because of the large line widths many lines are heavily blended with other lines and, hence, no reliable fluxes can be determined. Striking examples are the [NII] λλ 6548, 6584 lines, which are hopelessly merged with the strong Hα line. Since the line profiles are very complex and vary from one species to the other one, deconvolution procedures can be applied in a limited way only. Table 1 shows T_e and n_e for those epochs at which the (quasi-)simultaneous UV and optical data allowed us to derive numbers for these quantities. The kinetic temperature T_e at the gas in the expanding shell was determined using the line ratio of NV λ 1240/NIII λ 1719, both in the UV range. These lines are formed by different processes – NV by collisional excitation, NIV by dielectric recombination – and have, therefore, different temperature dependences. In order to calculate the electron density, we used the line ratios of the collisionally excited forbidden [OIII] λλ 4363, 4959, 5007 lines which are found in the optical spectral range. The relative intensities of these lines depend on T_e and n_e. Using T_e as calculated from the UV spectra, we obtain a unique value for n_e. In January 1987 (and later on) both NIV λ 1719 and the [OIII] lines had become too weak to be used for diagnostic work. Hence, we extrapolated n_e from the earlier values and determined an upper limit for the temperature from [FeVII] line ratios.

Of special importance is the knowledge of the chemical composition of the shell. In order to understand why, we have to shortly review the basic ideas of the 'thermonuclear runaway model' (hereafter TNR model) which very successfully describes the general features of the nova outburst. For those readers who are interested in more details of this model we refer to reviews by e.g. Starrfield and Sparks (1987, *Astr. Spac. Sci.* **131,** 379) or Truran (1982, in: *Nuclear Astrophysics,* ed. Barnes, Clayton, Schramm, Cambridge) who have done the basic work of the TNR model.

It is now generally accepted that a nova outburst occurs on the white dwarf component of a close binary system in which the secondary is transferring mass through the inner Lagrangian point into an accretion disk and ultimately onto the white dwarf. The build up of the hydrogen envelope on the white dwarf continues to some critical value, whereupon hydrogen burning via the CNO cycle starts and the thermonuclear runaway begins. One of the predictions of the TNR model was that the energetics of the outburst should depend on the abundance of the intermediate mass elements C, N, and O. Fast novae, which undergo a more violent explosion than slow ones, should have strong CNO overabundances. In fact, no fast nova could ever be (theoretically) produced with solar CNO abundances. Therefore, the CNO abundance should be a very critical observational test of the TNR model.

TABLE 2: *Element abundances in the ejecta of GQ Mus (mass fractions). For comparison purposes the solar values are also given.*

Element	GQ Mus	Sun
H	0.42	0.77
He	0.38	0.21
C	0.004	0.0034
N	0.12	0.0013
O	0.07	0.0083
"Z"	0.20	0.018

Up to now, reliable abundances for only a handfull of novae (≈ 9) have been available. For the determination of the element abundances in the ejecta of GQ Muscae we used emission lines from both the optical and UV spectral range. The He/H abundance was calculated from recombination lines in the optical spectral range, whereas UV lines were used for the N/He ratio. The mass fractions are given in Table 2, where for comparison purposes the solar values are also shown. He is overabundant with

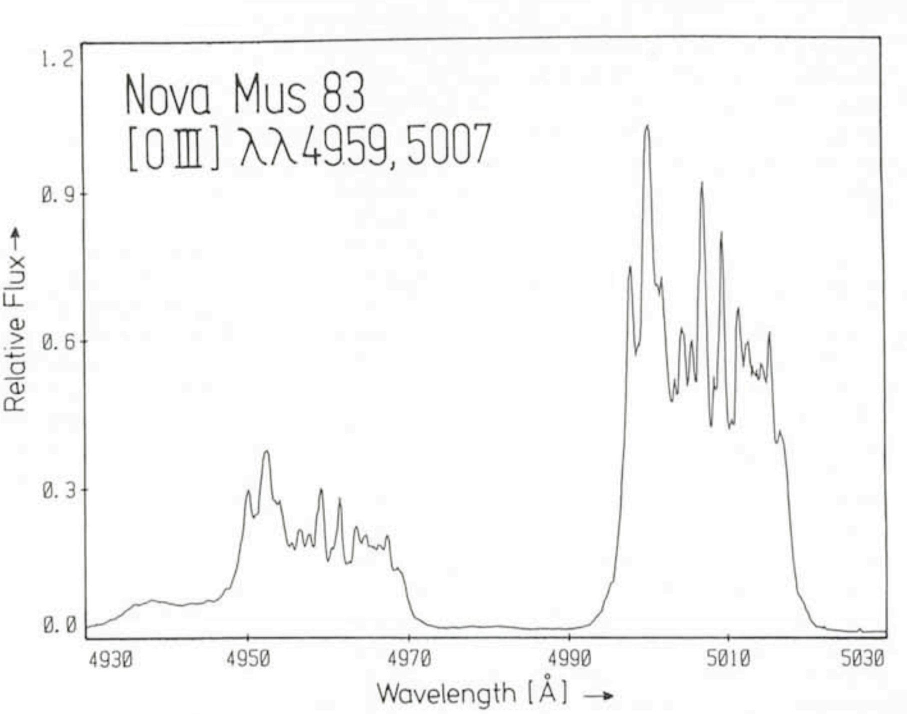


Figure 2: *High resolution line profiles of the [OIII] lines of GQ Muscae taken with CASPEC.*

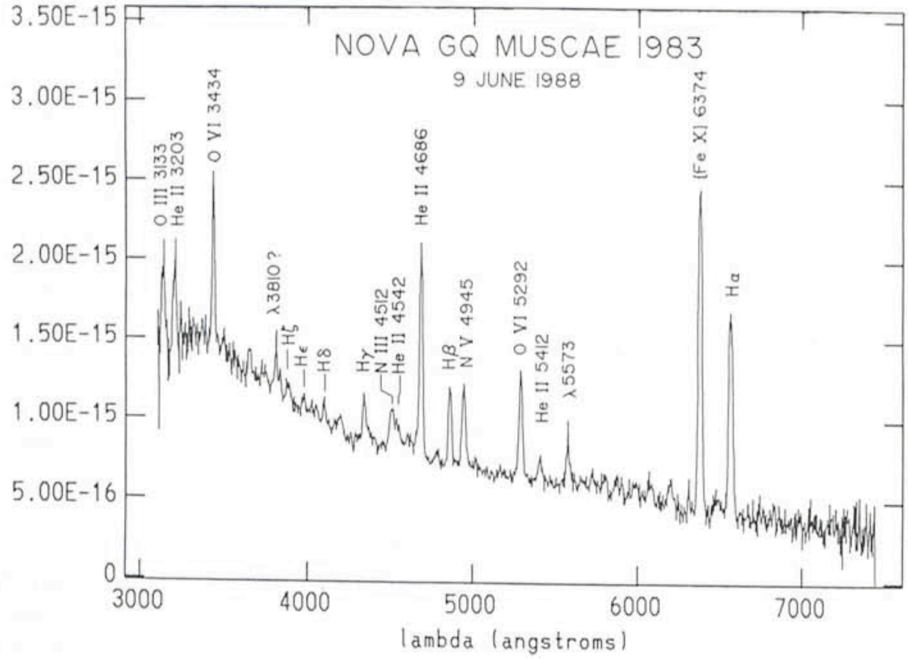


Figure 3: *Spectrum of GQ Muscae taken with the CTIO 4-m telescope and recorded with a 2D frutti photon counting detector. The red [FeX] λ 6374 coronal line is the strongest line in the spectrum which has – to our knowledge – not been found yet in any other astronomical object. From Krautter and Williams (submitted to* Astrophys. J.*).*

respect to H by more than a factor of two. Of the heavy elements, N and O are strongly overabundant, whereas C has about solar abundance. "Z" is about 0.20. We would like to note that the CNO abundances are preliminary numbers only; the final numbers might be subject to slight changes. However, the result is obvious: GQ Mus has a CNO overabundance, just as the TNR model requires for a fast nova.

The Increase of the Ionization of the Optical Spectrum

A very interesting feature of the spectral evolution of GQ Muscae is the continuous increase of the ionization from March 1984 to June 9, 1988 (the date of our last spectrum). Already in March 1984, 14 months after maximum, the general ionization is rather high (upper left part of Figure 1). Apart from the hydrogen Balmer and the He I recombination lines, all other lines of neutral elements had disappeared at this time. On the other hand, emission lines of rather highly ionized species like [FeVI], [FeVII] and [CaVII] are found. One year later, in April 1985, the ionization had increased. Lines of higher ionization have increased in strength relative to e.g. Hβ, whereas lines of lower ionization like [NII] λ 5755 have decreased. A striking example is the line ratio of [NII] λ 5755 vs. [FeVII] λ 5721. In 1984 [NII] was much stronger, whereas in 1985 the situation was reversed. Also the HeII/HeI ratio had considerably increased. Another 14 months later, in June 1988, the spectral appearance had changed even more: the [OIII] lines had become rather weak, and the [NII], HeI, and even [FeVI] lines had disappeared. On the other hand, the red [FeX] λ 6374 coronal line was present as a relatively strong line. The first sign of this line was found in a spectrum taken 10 months earlier, in August 1985 (not shown in Figure 1). In January 1987, [FeX] was as strong as Hβ and stronger than [FeVII] λ 6087. This increase of the ionization continued for at least 17 more months until June 9, 1988, the date of our last spectrum (Figure 3). [FeX] λ 6374 is now the strongest line in the spectrum – even stronger than Hα. This is extraordinary, as we are not aware of any other astrophysical object which has an [FeX] or any other coronal line of comparable strength!

In order to understand this spectral behaviour, a crucial question must be answered: what is the source of the ionization, collisional ionization or photoionization? The movement of the ejected envelope through the interstellar medium might produce a shock front giving rise to temperatures sufficient to cause very highly ionized species like [FeX]. There are, however, many arguments which exclude any significant shock contribution to the formation of the highly ionized species:

- The kinetic temperature T_e in the ejecta is low at all times (≤ 25,000 K).
- The post-shock temperature of $1.9 \cdot 10^7$ K for an expansion velocity of 800 km/sec would require [FeXIV] λ 5303 to be more intense than [FeX] λ 6374. However, [FeXIV] could not be identified in the spectrum.
- The increase of the ionization state requires a shock whose strength increases with time. There is no plausible explanation, however, why a shock should develop that way.
- The range of ionization is very narrow. In the case of collisional ionization one would expect a much broader range in the ionization.

Taken together, all these arguments lead to the conclusion that the ionization must be due to photoionization from a hot source. The increase of the ionization indicates an increase of the temperature T_* of the ionization source. To get a more quantitative estimate of T_* we have used the HeII/HeI line ratios in order to calculate Zanstra temperatures. We obtained $T_* = 3 \cdot 10^5$ K, $8 \cdot 10^5$ K, and $\geq 1.5 \cdot 10^6$ K for 1984, 1985 and 1986, respectively. These values are approximate and represent upper limits because we have assumed a radiation-bounded sphere. This is still approximately fulfilled in 1985 as the presence of [NII] shows, but in 1986 the deviations might be larger.

For the interpretation of these results we consider the phase of 'constant bolometric luminosity' of the TNR model of the nova outburst. The hydrodynamical calculations show that, during the early hydrodynamic phase, only part (anywhere from 10% to 90%) of the material accreted on the white dwarf has a velocity high enough to be ejected as an expanding envelope. The velocity of the remaining material quickly drops and a hydrostatic equilibrium is established. We now have a configuration with the white dwarf core, an inert He shell and the hydrostatic envelope with a radius of 10^{11}–10^{12} cm (the size of a red giant!). On top of the degenerate core, where the temperature is high enough, the hydrogen burning continues hydrostatically at a constant level of roughly one Eddington luminosity. The effective temperature of the whole system exceeds 10^5 K.

In the further evolution, the mass of the envelope decreases. Hydrogen is used up by the thermonuclear reactions and material is ejected by radiation pressure-driven mass-loss. The radius of the envelope decreases. On the other hand, there is a constant production of energy from the shell hydrogen burning which continues as long as some material is left in the envelope. As a result, the effective temperature T_* of the remnant increases with decreasing radius.

But that is exactly what we observe in the case of GQ Muscae! The photoionizing source is the white dwarf remnant whose temperature increases. Of course, the high temperature of the white dwarf also easily explains the X-rays from GQ Muscae. Unfortunately, after the termination of the EXOSAT mission, for several years no X-ray satellite sensitive to soft X-ray radiation has been available for some time and none will be available until the launch of ROSAT. Only very little observational material on the late phases of the classical nova outburst is available yet. Many crucial questions remain: How long does the hydrogen shell burning really last? When does a nova turn off? In the case of GQ Muscae, we have demonstrated how long-term observations of novae in the optical spectral range can help to improve this situation. The observations appear to constitute an important verification of the TNR model of the classical nova outburst.

Violent Activity in the Bright Quasar 3C 273

T. J.-L. COURVOISIER, Observatoire de Genève, Sauverny, Switzerland

Observations of the optical variability in the bright quasar 3C 273 date from long before this source has been found to be a quasar. Almost a century of (mostly photographic) data are available (Angione and Smith, 1985) and display variations on many timescales longer than ~10 days. In more recent years, a programme of multi-frequency observations of the quasar from the radio domain to the X-rays has been conducted. The first results of this programme have been described in the *Messenger* No. 45 (September 1986). In summary, we found variations by a factor ~2 in most observable spectral domains. The typical variability timescale was of the order of one month. The different components of the source varied at different epochs, showing little correlation between them. This complex variability pattern allowed to identify distinct components and showed that most of them must be emitted in regions not larger than about one light-month.

This multi-waveband campaign of observations started in late 1983 and has been pursued during each observing season (December to July) since then. Until now, different types of variability behaviour have been observed each year. Figure 1 illustrates this by showing the V band flux as a function of time since January 1985, when the Swiss telescope on La Silla joined in the programme with regular and precise photometric measurements. A slow flux increase can be seen in 1985, followed by a year of very small variations in 1986. During the observing season which started in December 1986, the UV flux (measured with IUE) decreased by ~40%, the decrease was much less important at longer wavelengths but can still be seen in the figure. The most striking feature of the figure, however, is the change of the behaviour of 3C 273 in February 1988. At this time, which is well within the observing season, the source changed from a state characterized by relatively slow changes to a state of rapid and recurrent flares. The characteristic times were then not of the order of an month as during the previous years, but rather of the order of a day. This violent activity in 3C 273 came at a very appropriate time, when our collaboration was well established and could react rapidly to the observed changes. We were thus able to observe very frequently, even daily for part of the time, in the optical and infrared domains. The observations were performed at the ESO 1-m telescope, the ESO/MPI 2.2-m telescope, the 70-cm Swiss telescope on La Silla, the UK infrared telescope (UKIRT) in Hawaii and with the mm telescope SEST at ESO and JCMT in Hawaii. The results of these observations have been published (Courvoisier et al. 1988). Even with the temporal and spectral sampling that we were able to obtain during the flares, the flux variations were so fast that we could not resolve them satisfactorily.

The period of violent activity lasted from February to April 1988. During this interval, we observed 5 optical maxima separated on average by ~15 days, although 2 of the maxima are separated by 2 days only (Fig. 2). The amplitude of these maxima is of about 30%. The fastest change we observed was a flux decrease of ~15% in 24 hours. This flux decrease corresponds to a change in luminosity in the source of about $-6 \cdot 10^{40}$ erg s^{-2} or to the switching off of ~10 million suns per second for 24 hours (assuming a distance to 3C 273 based on a cosmological model with H_0 = 50 km s^{-1} Mpc^{-1} and a source emitting isotropically).

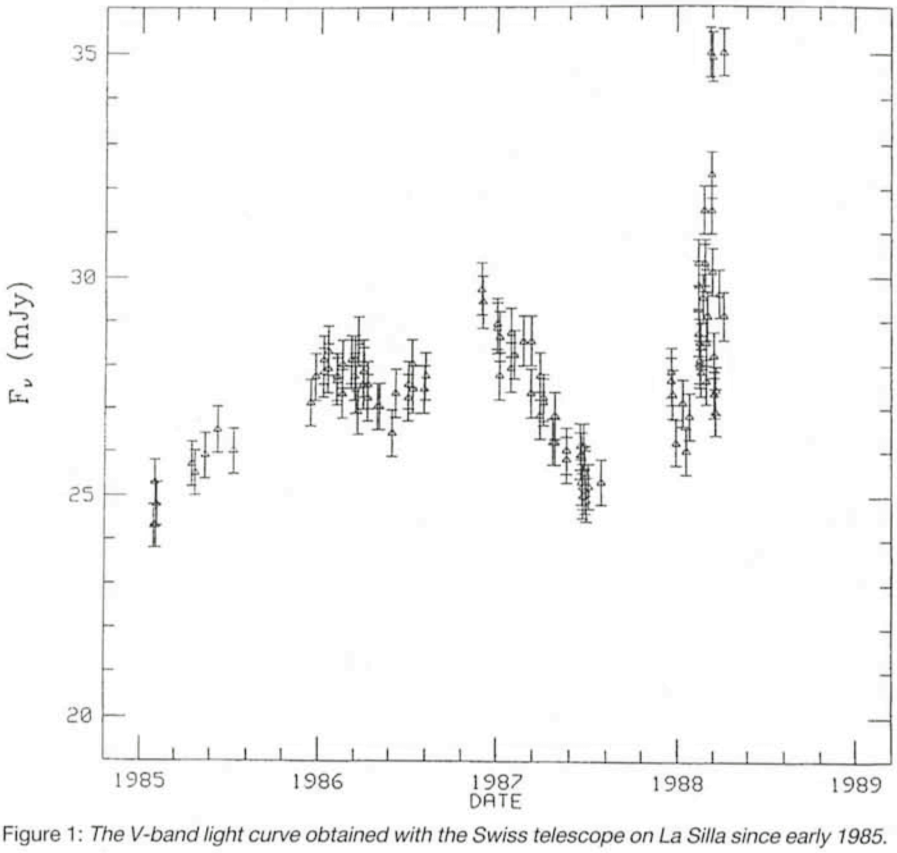


Figure 1: *The V-band light curve obtained with the Swiss telescope on La Silla since early 1985.*

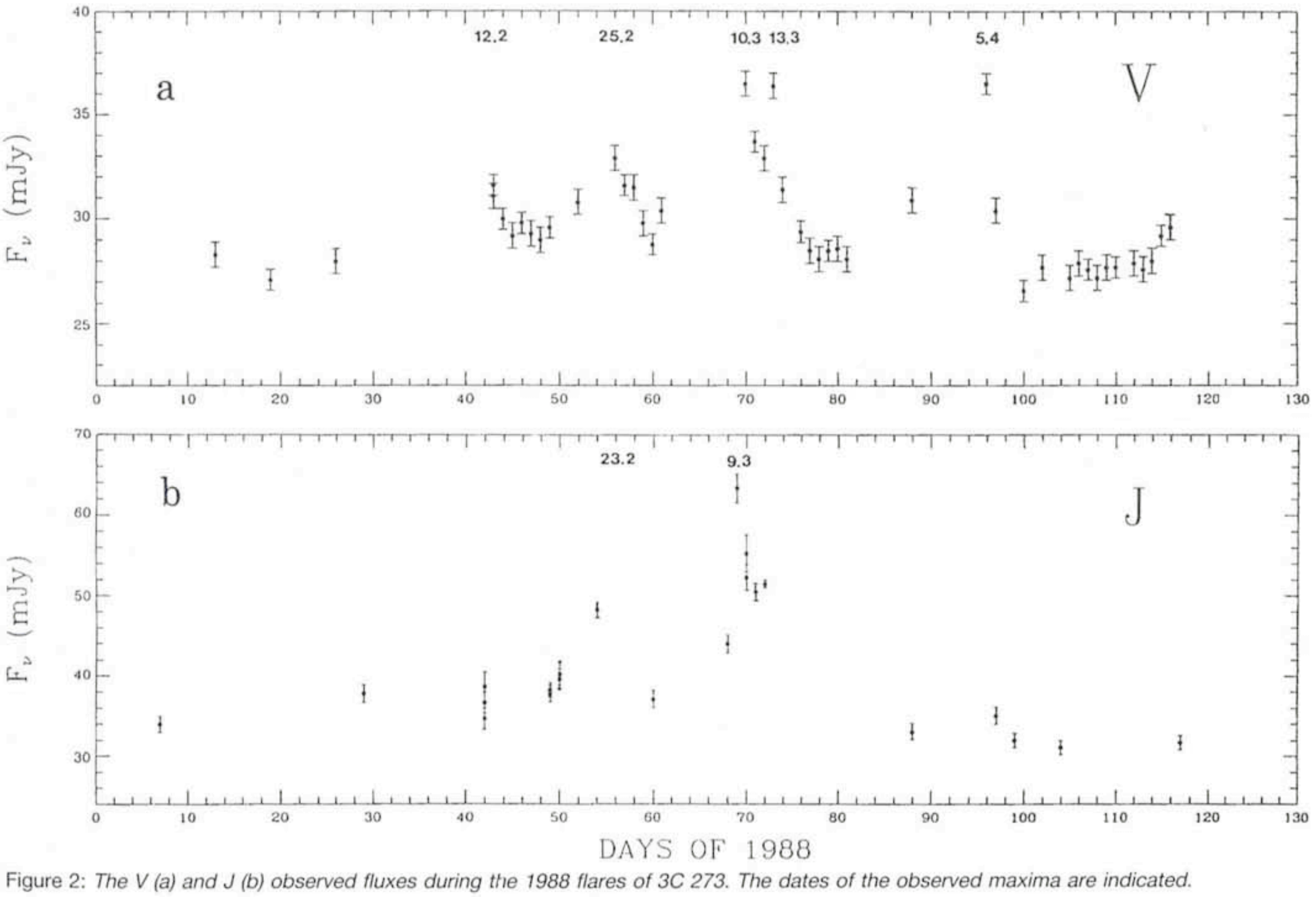


Figure 2: *The V (a) and J (b) observed fluxes during the 1988 flares of 3C 273. The dates of the observed maxima are indicated.*

In the infrared domain, we also observed repeated flares, but only 2 maxima have been seen (Fig. 2), coincident with two of the visible maxima. The amplitude of the maxima with respect to the "quiescent" emission measured the previous year was larger than in the visible and amounted to roughly a factor 2. The fastest change in the observed infrared flux was by $\sim 40\,\%$ in 24 hours, it was a flux increase rather than a decrease. This change in the infrared flux corresponds to a change in the luminosity of $\sim +6 \cdot 10^{40}$ erg s^{-2}, i.e. to the switching on of about 10 million suns every second for 24 hours. It can be seen on Figure 2 that the fastest measured flux variations need not be the fastest source variations, because the sampling of the light curve is not sufficient to resolve the variability.

Infrared and optical daily observations around the March 10th flare allowed to follow the spectral evolution around this date. In general it was seen that the spectral energy distribution became steeper as the flux decreased. This type of behaviour is characteristic of synchrotron emission, the radiation of relativistic electrons in a magnetic field. The steepening of the energy distribution happens because the electrons emitting the higher frequency photons loose their energy faster than the others. The observation of a decay time for the flare (about 2 days) allowed the estimation of the magnetic field in the emission region. This was found to be ~ 0.7 Gauss, about the same field as is existing on the Earth. This estimate of the magnetic field is important as it is free of the large uncertainties normally linked with measurements based on the overall shape of the synchrotron emission.

The polarization of the incoming flux was also observed daily for a week in late February. The polarization was found to be about ten times more important than normally in 3C 273, and to vary significantly from day to day.

The observed properties of the 3C 273 flare component as described here are very similar to the typical behaviour of another type of active galactic nuclei: the BL Lac objects. These latter objects are well known for their rapid variations and for the night to night changes in their (high) polarization. Their emission is also usually ascribed to synchrotron emission. BL Lacs and quasars differ however in many respects: BL Lacs have no prominent "blue bump", which dominates the optical UV emission of quasars (and of 3C 273 in particular), BL Lacs do not show emission lines, which are also a prominent feature of quasars (and 3C 273), and BL Lacs usually are highly polarized, whereas 3C 273 in its normal state has a very low level of polarization. Our observations show therefore that the same processes can be at work occasionally in quasars as are normal in BL Lacs, although both are very different types of sources. We also know that the BL Lac like behaviour of quasars is a relatively rare event, because we observed it only once in several years of monitoring.

One of the optical flares, the last on April 5, seems to have had quite different properties, its maximum amplitude was not in the V band but at higher frequencies, further in the blue. This indicates that it was not an infrared flare, as is also suggested by the appearance of the infrared light curve at this epoch. If interpreted in terms of synchrotron emission, this last event must have been caused by a very peculiar population of electrons, in which the more energetic electrons are more numerous than the less energetic ones. This type of distribution is very unusal. Which other emission process could explain the energy distribution and the very fast variations is not clear yet.

Very fast variability is often a (distance independent) indication of relativistic motion in the source. The argument is that the high energy electrons in a synchrotron source also scatter the infrared synchrotron photons and give them some of their energy, shifting them thus to the X-ray domain. This combined process is called synchrotron self-Compton emission and is a function of the source size: smaller sources have a larger self-Compton component compared to the synchrotron component. Sources for which the luminosity and size are such that the brightness temperature is in excess of $\sim 10^{12}$ K should emit much more in the X-rays than in the synchrotron branch. This is known as the Compton catastrophe, and is not observed in active galactic nuclei. In quasars, the source size is estimated using the variability timescale of the source, and if the brightness temperature calculated with the infrared or radio flux and variability timescale is in excess of the Compton limit, one can deduce that the true source luminosity is smaller than what can be calculated from the observed flux using an isotropic emission geometry. The simplest anisotropy is that the source is moving relativistically towards the observer, thus boosting the synchrotron flux in the direction of the observer.

In 3C 273, the observations described here imply a brightness temperature well below the Compton limit. However, we have some observations at longer wavelength close to the February infrared maximum, and these observations indicate that the flux continues to rise towards the longer wavelengths, so that, if the spectrum of the March 10 event is similar to the February 25 maximum or if rapid variability also occurred around February 25 (both are probable but neither can be established with our spectral and temporal sampling), then the brightness temperature is in excess of the Compton limit. Further evidence along these lines comes from the mm observations performed this year: Preliminary results (Robson et al., in preparation) indicate very rapid variations and therefore extremely high brightness temperatures, well in excess of the Compton limit. It is therefore possible that the source of the flares is moving at relativistic speeds towards the observer.

The evidence for a brightness temperature in the flares of 3C 273 well in excess of the Compton limit, and thus of relativistic bulk motion of the flare source, is important as it suggests that the emission region is associated with the superluminal jet observed with VLBI (Cohen et al. 1987). This jet is highly structured with new knots appearing at more or less regular intervals and moving away from the source at very high velocities. The flares could then well be the first signs of a new knot appearing in the jet.

The very rapid variations observed during the flare of the bright quasar 3C 273 cast some doubt on the observations of previous flares in this source. It is clear that observations with a less dense temporal sampling would have missed most of the structure we observed and led to quite different conclusions. Also the very structured nature of the flares may be somewhat discouraging for observers, as it indicates that daily observations at least are required to study this type of events. However, this structure also indicates that there is a wealth of information to be obtained on the source geometry, on the acceleration of electrons to relativistic energies and on emission processes. This information will certainly prove important to constrain detailed models of the emission region. Future observations will have to find the relationships between the flaring activitiy and the other properties of the quasar and try to find what triggers the beginning of a flare, and so maybe help understand the nature of the superluminal jet.

We could obtain a dense spectral and temporal sampling of the 3C 273 flares only with the help and assistance of many rapid reactions to our requests at ESO and in Hawaii.

References

Angione R. J. and Smith H. J., 1985, *Astron. J.* **90** (12), 2474.

Cohen M. H., Zensus J. A., Biretta J. A., Comoretto G., Kaufmann P. and Abraham Z., 1987, *Astrophys. J.* **315,** L89.

Courvoisier T. J.-L., Robson E. I., Blecha A., Bouchet P., Hughes D. H., Krisciunas K. and Schwarz H. E., 1988, *Nature* **335,** 330.

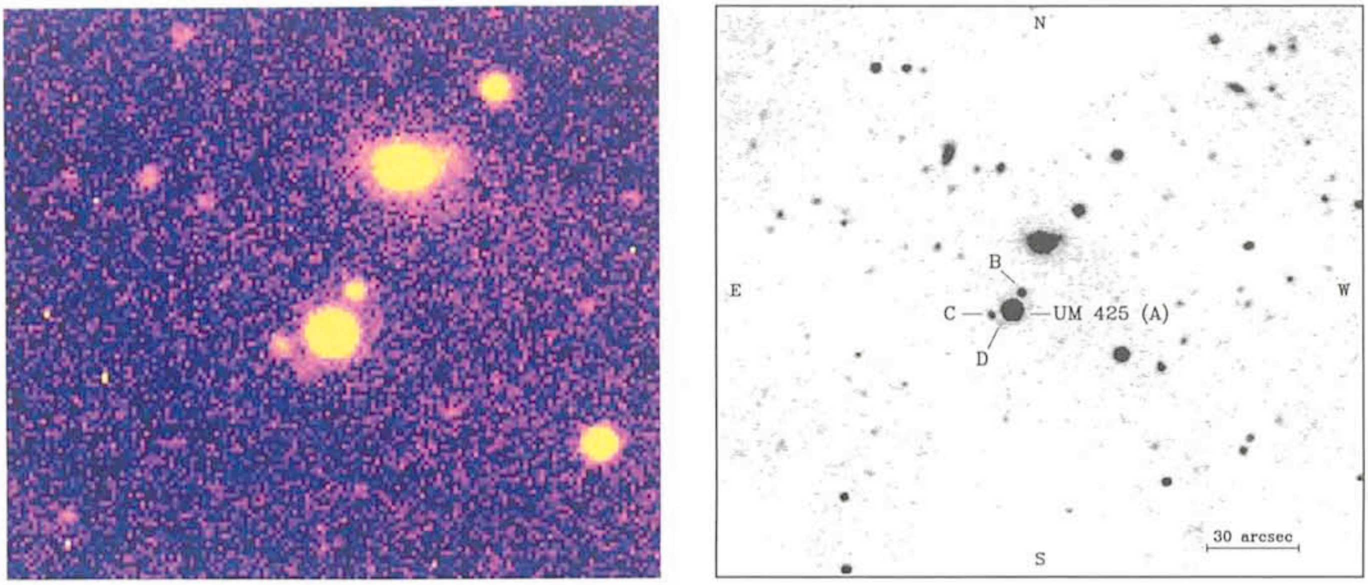
UM 425: a New Gravitational Lens Candidate

G. MEYLAN, ESO, and S. DJORGOVSKI, CalTech, Pasadena, USA

I. Introduction

Since the first theoretical discussions more than 50 years ago on the phenomenon of light rays bent by intervening mass in the universe (Eddington 1920, Einstein 1936, Zwicky 1937 a, b), gravitational lensing has steadily grown to become one of the most active fields of research in extragalactic astronomy today. There are numerous theoretical investigations (Refsdal 1964, 1966, Turner et al. 1984, Blandford and Narayan 1986, Blandford and Kochanek 1987 a, b), but the observations of good gravitational lens candidates are still rare. It is only during the last decade that a few quasar systems have been found in reasonable agreement with the gravitational lensing interpretation, viz., 0957+561 (Walsh et al. 1979), 1115+080 (Weymann et al. 1980), 2016+112 (Lawrence et al. 1983), 2237+030 (Huchra et al. 1985), 0142−100 (Surdej et al. 1987), and 1413+117 (Magain et al. 1988). In other possible cases, e.g., 2345+007 (Weedman et al. 1982), and 1635+267 (Djorgovski and Spinrad 1984), there has so far been no detection of lensing galaxies, and thus they should possibly be considered as genuine pairs of interacting quasars, similar to the probable binary quasar PKS 1145−071 (Djorgovski et al. 1987). Recently, so-called giant luminous arcs have been observed in a few clusters of galaxies. They are interpreted as segments of Einstein rings, created because of an almost perfect alignment of the lensing cluster potential well with the lensed background object (Soucail et al. 1988, Lynds and Petrosian 1988). Blandford and Kochanek (1987) provide the most comprehensive and updated review on these subjects.

To improve our knowledge on the phenomenon of gravitational lensing, we are conducting an optical imaging survey for lensed quasars, with a spectroscopic follow-up for the promising cases. The quasar UM 425 = QSO 1120+019 (MacAlpine and Williams 1981) is one of the objects selected as potential lens candidates on the basis of two criteria: a large apparent optical luminosity ($M_V \leq -28$), and a relatively large redshift ($z \geq 1.5$). These simple criteria, chosen to reflect possible gravitational magnification (luminosity) and to provide a large intercept length (redshift), increase the a priori probability that a quasar selected from a magnitude-limited sample is lensed. The efficiency of such simple criteria is demonstrated by the present case, by a few other candidates from our survey which are still awaiting confirmation,



Figures 1a and 1b: *Central part (Fig. 1a in false colours and Fig. 1b in grey scale) of an image of the quasar UM 425 (digital stack of V and R frames) obtained with a charge-coupled device (CCD) and the Cerro Tololo Interamerican Observatory (CTIO) 1.5-m telescope, on UT 1987 March 2. The high luminosity quasar is resolved into at least four images. Two quasi-stellar images, the main component A and its brightest companion B, separated by 6.5 arcsec, have V = 16.2 mag and V = 20.8 mag, respectively. The C component (V = 21.8 mag) and the even fainter D component are similar to the numerous nonstellar objects in the field, suggestive of a rich foreground (z ≃ 0.6?) cluster of galaxies.*

and by the two cases published by the Liège group (Surdej et al. 1987, Magain et al. 1988). More comprehensive results concerning UM 425 are to be published in *Ap. J.* Letters.

II. Observations and Results

Because of weather conditions, six observing runs, spread over more than 15 months, were necessary in order to unveil completely the interesting character of the QSO UM 425. Our first charge-coupled device (CCD) imaging observations of this object were obtained with the Cerro Tololo Interamerican Observatory (CTIO) 1.5-m telescope, on the night UT 1987 March 2. The conditions were photometric with a seeing FWHM ≃ 1.7 arcsec. Exposures of 600 sec in V and 500 sec in R were obtained, with an additional 1000 sec B exposure on UT 1987 March 5. The images were processed using standard techniques. Figure 1a shows, in false (computerized) colours, the digital stack of the V and R frames. Three close faint companions, labelled B, C, and D (in decreasing luminosity) on the grey scale image displayed in Figure 1b, encircle the bright image of the quasar (A). Our preliminary photometry indicated that the companions B and C have similar or identical colours to the brightest image, A. There is a large number of V ~22 mag galaxies in the field, suggesting a rich foreground (z ~0.6 ?) cluster. Thus, the initial optical imaging data were consistent with gravitational lensing.

Because of the promising character of these images, snapshots were kindly taken by Dr. R. Perley with the Very Large Array (VLA) radio telescope in September 1987. The system was not detected at 20 cm and 6 cm.

The follow-up spectroscopy, in marginal weather conditions, with the Mt. Palomar 200-inch telescope, on the night UT 1988 March 8, and with the Las Campanas 100-inch telescope, on the night UT 1988 April 7, indicated inconclusively possible similar emission lines in spectra of components A and B, and possibly also C.

The convincing observations were obtained with the ESO Faint Object and Spectrograph Camera (EFOSC) at the ESO 3.6-m telescope, on the 3 nights UT 1988 May 15, 16, and 17. The weather conditions were nonphotometric with a mean value of the seeing FWHM ≃1.4 arcsec. Several direct imaging exposures were obtained, with 60 sec integration with the B filter (ESO # 552), 45 sec with the V (ESO # 553), and 30 sec in the R (ESO # 554). The data were processed and added using standard techniques. These reasonably good-seeing images suggest that the component C is somewhat diffuse (nonstellar) in appearance.

The separation between the quasar image A and its brightest companion B is:

$$\Delta\alpha_{A-B} = +3.1 \pm 0.1 \text{ arcsec}$$
$$\Delta\delta_{A-B} = -5.7 \pm 0.1 \text{ arcsec},$$

which corresponds to a separation of 6.5 arcsec in the direction PA = −29°. The separation between the images A and C is:

$$\Delta\alpha_{A-C} = -6.6 \pm 0.1 \text{ arcsec}$$
$$\Delta\delta_{A-C} = +1.8 \pm 0.1 \text{ arcsec},$$

which corresponds to a separation of 6.8 arcsec in the direction PA = +105°.

The spectrophotometric magnitudes of the QSO (A), 16.5 B mag, 16.2 V mag, and 15.7 R mag, are uncertain by a couple of tenths of a magnitude, because of the poorly determined zero point, which also plagues our direct imaging. The spectrophotometric colours are much better determined, since the zero-point uncertainties cancel: we obtain $(B-V)_A$ = 0.33, and $(V-R)_A$ = 0.49, with the uncertainty of a couple of per cent. However, differences between magnitudes in a given bandpass can be accurately determined from our direct imaging. We obtained a relative photometry of the components A, B, and C by using the point-spread function fitting programme for stellar photometry in DAOPHOT. For the components A and B, we obtain:

$$\Delta B_{A-B} = -4.68 \pm 0.15$$
$$\Delta V_{A-B} = -4.61 \pm 0.08$$
$$\Delta R_{A-B} = -4.42 \pm 0.12,$$

giving 21.2 B mag, 20.8 V mag, and 20.1 R mag for the component B. Using the spectrophotometric colours of the image A as the zero-point, we derive $(B-V)_B$ = 0.40, and $(V-R)_B$ = 0.68. The colours of the component B derived from our spectrophotometry are $(B-V)_B$ = 0.36, and $(V-R)_B$ = 0.67, uncertain by a few per cent, and thus in excellent agreement. For the components A and C, the differences in magnitudes are:

$$\Delta B_{A-B} = -6.05 \pm 0.25$$
$$\Delta V_{A-C} = -5.56 \pm 0.15$$
$$\Delta R_{A-C} = -5.77 \pm 0.15,$$

giving 22.6 B mag, 21.8 V mag, and 21.5 R mag, with $(B-V)_C$ = 0.8, and

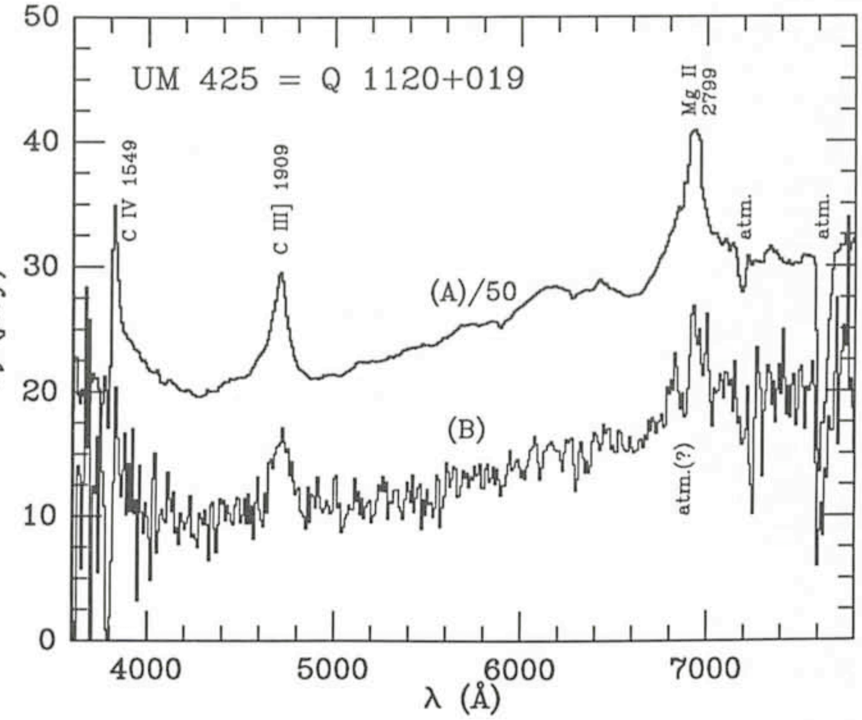


Figure 2: *Spectra of the quasar UM 425 (A and B), obtained with the Faint Object and Spectrograph Camera (EFOSC) at the European Southern Observatory (ESO) 3.6-m telescope, on the 3 nights UT 1988 May 15, 16, and 17. Because of the large difference in luminosity between the two components, the spectrum of A is divided by a factor of 50 for display purposes. The spectra are similar in shape and show the same emission lines (C IV 1549, C III] 1909, and Mg II 2799) at the same redshift.*

$(V-R)_C = 0.3$. These colours have uncertainties of about 0.3 mag. The component D, clearly a nonstellar object, is too faint and too close to the bright image A to obtain any reliable measurements. It is about 4–5 arcsec away in the direction PA $\simeq +150°$.

Given the measurement errors, these results are consistent with constant colours of the three components, but with two hints: (i) B may be slightly redder than A, perhaps by the presence of an underlying (lensing?) galaxy; (ii) C may be redder than A in (B–V), but bluer in (V–R), and in view of its apparently nonstellar appearance, it could be (as well as the component D) a member of a faint foreground cluster of galaxies.

During the same 3 nights of May 1988, the spectra of the components A and B were obtained with the B 300 and R 300 grisms of EFOSC. The final usable range in wavelength runs from 3600 to 8000 Å, with a resolution of ~7 Å/pixel. The data confirmed immediately that both objects A and B have quasar spectra, with the same emission lines at apparently the same redshift. The resulting spectra for components A and B are displayed in Figure 2. These two spectra are the result of 7 exposures of 1,800 sec in each of the B 300 and R 300 grisms, giving a total of 14 exposures, or 7 hours of integration. The usual strong emission lines are present in both spectra, viz., C IV 1549, C III] 1909, and Mg II 2799. The spectra are very similar in the overall shape, and the equivalent widths of the emission lines are quite comparable: 63.2 and 69.1 Å in the case of C III] 1909 lines, and 74.1 and 70.8 Å in the case of the Mg II 2799 line, for A and B components, respectively.

The comparison between the two spectra is hampered by the strong difference in magnitude between the components, giving very different signal-to-noise ratios: e.g., $(S/N)_B \sim 6$ when $(S/N)_A \sim 350$. The Mg II line appears to be asymmetric, with a possible absorption in its blue side. However, the comparison of the spectra is made difficult by the presence of the B band, which we can remove only partly. Some absorption feature could also be present in the blue side of the C IV line. Data with a higher S/N ratio are needed before the situation is clarified. Consequently, the redshift of the quasar A was obtained by using only the C III] line, the only "clean" emission line in our spectra, and equals $z_{A,1909} = 1.465 \pm 0.005$. From the C IV line, we obtain $z_{A,1549} = 1.469$, and from Mg II line, $z_{A,2799} = 1.476$.

We looked for a possible difference in redshift between the two spectra (A and B), using the cross-correlation technique. The different measurements were done by varying the limits of the wavelength range used (from ~4000 to ~7200 Å) and giving mean value of the redshift difference $\Delta z_{A-B} = (-1.5 \pm 2.0) \times 10^{-3}$, corresponding to the rest-frame

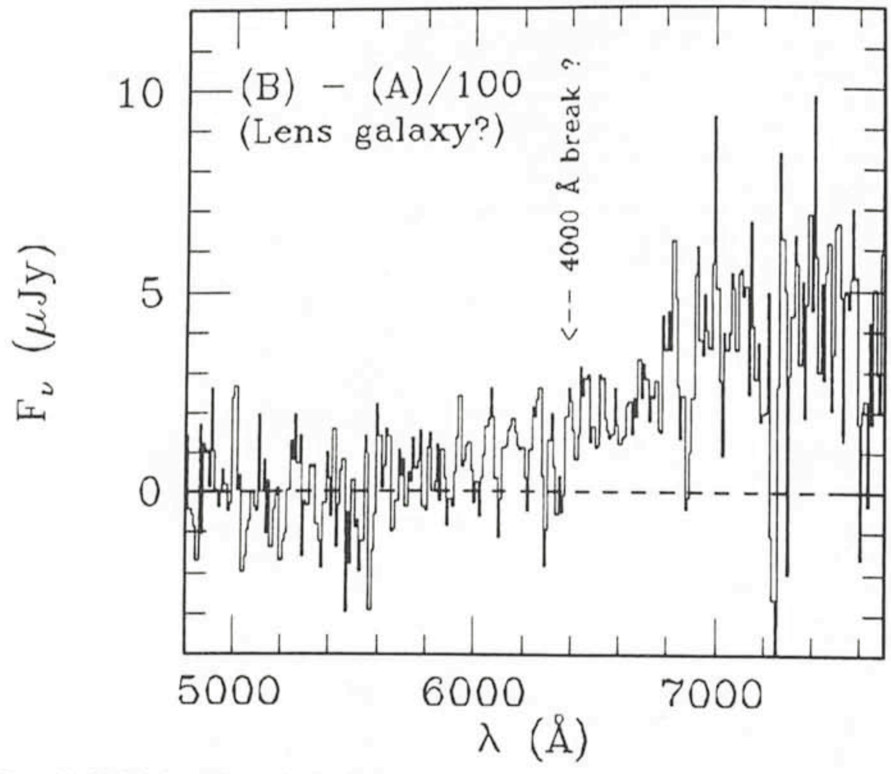


Figure 3: *Residual spectrum obtained after dividing the spectrum of the component A by 100 and subtracting it from the spectrum of the component B. Each original spectrum corresponds to 3.5 hours of integration time in each grism. The residual spectrum difference is reminiscent of an early-type galaxy spectrum at a redshift z ~0.6, if the continuum rise at ~6400 Å is attributed to the 4000 Å break.*

velocity difference $\Delta v^{rf}_{A-B} = -180 \pm 240$ km s^{-1}, and a median value $\Delta z_{A-B} = (+1.3 \pm 2.0) \times 10^{-3}$, or $\Delta v^{rf}_{A-B} = +160 \pm 240$ km s^{-1}. These very preliminary measurements are then consistent with a zero velocity difference between the components A and B, to within ~ 300 km s^{-1}. Additional data are needed in order to improve on this measurement.

The result of the division of the two spectra (B/A) is fairly constant in the blue part (3600–6400 Å), and a slight but significant increase in the red part (6400–8000 Å), which is equivalent to the slight difference in colour, noted above. It is possible to consider the apparent reddening of the component B as a contribution from a foreground galaxy which could be a part of the gravitational lens itself. We divided the spectrum of the component A by 100 (very close to the flux ratio from the division), and subtracted it from the spectrum of the component B. The resulting spectrum, shown in Figure 3, is reminiscent of an early-type galaxy spectrum at a redshift $z \sim 0.6$, if the continuum rise is attributed to the 4000 Å break (see Surdej et al. 1987 for a similar investigation). The rough R magnitude of this component is $\sim 23 \pm 0.5$ (about 7^m fainter than A and 2^m fainter than B), comparable to what is expected of a luminous elliptical galaxy at $z \simeq 0.6$ (Guiderdoni and Rocca-Volmerange 1987). The large number of other faint galaxies in the field is also consistent with the presence of a rich foreground cluster at that redshift. Finally, it is possible that the companion D (and perhaps even C) are other members of this hypothetical lensing cluster along the line of sight to UM 425. The brighter ($V \simeq 17.8$) galaxy just NW from UM 425 is at $z = 0.1265$, and probably unrelated to the system.

III. Conclusion

It is worth mentioning that it is a generic feature of gravitational lensing that the closer the component separation, the greater the similarity of their relative intensities, and vice versa. In the present case, because of the relatively large image separation (6.5 arcsec), a large difference in brightness is expected and observed (almost a factor of 100). Furthermore, in simple geometry model, the lensing galaxy is expected to be closer to the faint image B than to the bright image A. However, in the case of UM 425, the lensing potential is probably fairly complicated, and we postpone any modelling of the system to a future, more comprehensive paper.

The very similar spectra and colours, the presence of a possible lensing galaxy and/or a cluster, and the luminosity and redshift bias used to select the object in the first place, argue in favour of the gravitational lens hypothesis. It is regrettable that the system is not detected in the radio, as the comparison of the optical and radio images can be used as a powerful test for lens candidates (Djorgovski et al. 1987). Further data are needed in order to tighten the measurements presented here, and establish the nature of the components C and D.

It is a pleasure to thank the staff of all observatories involved, and especially H. Pedersen and J. Miranda at ESO, J. Bravo and M. Navarete at CTIO, W. Kunkel and P. Schecter at Las Campanas, and J. Carrasco at Palomar. Many thanks also to R. Perley for obtaining and reducing the VLA snapshots.

References

Blandford, R.D., and Narayan, R. 1986, *Astrophys. J.*, **310**, 568.
Blandford, R.D., and Kochanek, C.S. 1987, in *Dark Matter in the Universe*, Jerusalem Winter School for Theoretical Physics, eds. Bahcall, J., Piran, T., and Weinberg, S. (Singapore: World Scientific), p. 133.
Blandford, R.D., and Kochanek, C.S. 1987, *Astrophys. J.*, **321**, 658 and 676.
Djorgovski, S., and Spinrad, H. 1984, *Astrophys. J.*, **282**, L1.
Djorgovski, S., Perley, R., Meylan, G., and McCarthy, P. 1987, *Astrophys. J.*, **321**, L17.
Eddington, A.S. 1920 *Space, time, and Gravitation*, Cambridge: Cambridge University Press.
Einstein, A. 1936, *Science*, **84**, 506.
Guiderdoni, B., and Rocca-Volmerange, B. 1987, *Astr. Astrophys.*, **186**, 1.
Huchra, J., Gorenstein, M., Kent, S., Shapiro, I., and Smith, G. 1985, *Astron. J.*, **90**, 691.
Lawrence, C., Schneider, D., Schmidt, M., Bennett, C., Hewitt, J., Burke, B., Turner, E., and Gunn, J. 1983, *Science*, **223**, 46.
Lynds, R., and Petrosian, V. 1988, *Astrophys. J.*, in press.
MacAlpine, G.M., and Williams, G.A. 1981, *Astrophys. J. Suppl.*, **45**, 113.
Magain, P., Surdej, J, Swings, J.-P., Borgeest, U., Kayser, R., Kühr, H., Refsdal, S., and Rémy, M. 1988, *Nature*, **334**, 325.
Refsdal, S. 1964, *Mon. Not. R. Astr. Soc.*, **128**, 307.
Refsdal, S. 1966, *Mon. Not. R. Astr. Soc.*, **132**, 101.
Soucail, G., Mellier, Y., Fort, B., Mathez, G., and Cailloux, M. 1988, *Astr. Astrophys.*, **191**, L19.
Surdej, J., Magain, P., Swings, J.-P., Borgeest, U., Courvoisier, T.J.-L., Kayser, R., Kellerman, K.I., Kühr, H., and Refsdal, S. 1987, *Nature*, **329**, 695.
Turner, E.L., Ostriker, J.P., and Gott, J.R. III 1984, *Astrophys. J.*, **284**, 1.
Walsh, D., Carswell, R.F., and Weymann, R.J. 1979, *Nature*, **279**, 381.
Weedman, D.W., Weymann, R.J., Green, R.F., and Heckman, T.M. 1982, *Astrophys. J.*, **255**, L5.
Weymann, R.J., Latham, D., Angel, J.R.P., Green, R.F., Liebert, J.W., Turnshek, D.A., Turnshek, D.E., and Tyson, J.A. 1980, *Nature*, **285**, 641.
Zwicky, F. 1937a, b, *Phys. Rev.*, **51**, 290 and 679.

Binary Nuclei of Planetary Nebulae

A. ACKER, G. JASNIEWICZ, Equipe "Populations Stellaires", Observatoire de Strasbourg, France

Introduction

About ten planetary nebulae have late-type central stars, which are too cool to ionize the nebula. This implies either the presence of a warmer companion (the true central star), or an unstable central star which was hotter in the past.

These two phenomena – binarity and intrinsic variability –, which are physically very different, may give rise to apparently very similar variations: same behavior for the radial velocity curve and/or for the light curve. In addition, in both cases, spectral peculiarities can be observed, such as stellar emission lines, which can be explained by chromospheric activity of the star or by mass exchange in a close binary system.

The true interpretation is possible only if coordinated observations are conducted.

Observations

At La Silla we used various tools:

– Radial velocity scanner CORAVEL mounted on the Danish 1.5-m telescope (observations taken by Prévot from Marseille):
– Differential photometer P7 of the Geneva Observatory mounted on the Swiss 70-cm telescope:
– Spectrograph B & C (CCD detector) mounted on the ESO 1.52-m telescope.

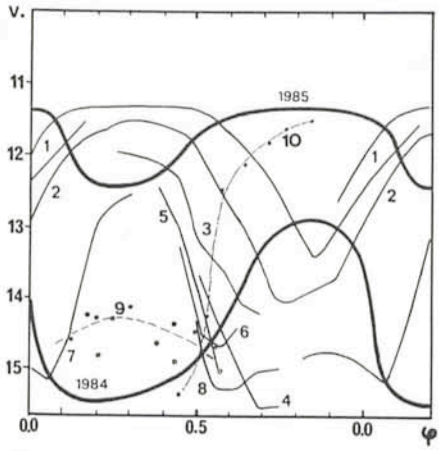


Figure 1: *Evolution of the light curve of NGC 2346 (central star). 1 to 8 are taken from Mendez et al. (1984). 1 = Kohoutek, 1982 Jan. – Feb.; 2 = Gathier, 1982 Mar. – Apr.; 3 = Claria, 1982 Nov.; 4, 5 = Van Driel, 1982 Dec.; 6 = Mendez, 1983 Jan.; 7, 8 = Kohoutek, 1983 Jan.; 9 = Kohoutek and Celnik, 1984 Feb.; 10 = Schaeffer, 1985 Feb. The two thicker lines correspond to our observations: 1984 Sept. – Oct.; 1985 Sept. (taken from* Astron. Astrophys. **160,** *L1–L3 (1986).*

Results

Since 1978 we have observed in particular four cold nuclei of planetary nebulae: FG Sagittae (spectral type K), LoTr5 (G5 star), NGC 2346 (A5 star) and Abell 35 (GB star). Here we report briefly on the two southern objects, NGC 2346 and Abell 35.

NGC 2346

According to Mendez et al. (1982), the central star is an SB1 and its photometric variations (detected in 1981) are due to the passage of a dust cloud in front of the binary system. Infrared observations of Roth et al. (1984) and IUE observations of Feibelman and Aller (1983) have allowed to confirm the dust cloud interpretation.

The optical observations of NGC 2346 during the eclipses, taken all together, were especially informative. The comparison (see Fig. 1) of our photometric observations Sept.–Oct. 1984, Sept. 1985) with the previous one have shown a phase difference, and new properties of the clumpy shell have been suggested (Acker and Jasniewicz, 1985: Jasniewicz and Acker, 1986). In particular the end of the eclipses has been suspected and confirmed in 1986.

Abell 35

Simultaneous spectroscopic and photometric observations of BD 22°3467, the GBIII central star of Abell 35, have been performed at La Silla, in order to elucidate the origin of the light variations and of the Hα emission stellar line shown by Jasniewicz and Acker (1988). Binarity is probably responsible for these variations: this assumption is confirmed by recent IUE observations reported by Grewing and Bianchi (1987).

We have conducted the following observations:

– 43 measurements have been done from February to April 1988 using the P7 differential photometer mounted on the Swiss telescope (mean probable error on the V magnitude 0.008):

– 48 spectra, taken with an exposure time of 25 minutes each, have been collected from 20 to 24 April 1988, using the spectrograph B & C + CCD, mounted on the ESO 1.52-m telescope. The dispersion was 58 Å/mm; all the spectra were centred around the Hα line; the final resolution was 1 pixel = 1.7 Å.

The spectra were reduced using the IHAP procedure. Preliminary results should be given (see Fig. 2).

The faint Hα emission line is double peaked and variable. The spectroscopic variations seem to occur within a range of 20 hours, and thus are in agreement with the photometric period P = 0.765 d. found by us in 1986 and 1987.

The hypothesis related to an accretion disk in a binary system will be

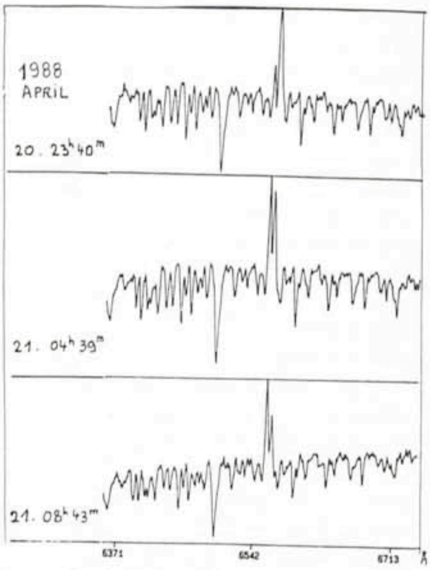


Figure 2: *Spectroscopic variations on the Hα line for the central star of Abell 35 (ESO 1.52-m telescope, B & C + CCD).*

tested and discussed after full processing of the data (to appear in *Astron. Astrophys.*).

For other cold nuclei, data were collected using the CORAVEL system; but the central stars of planetary nebulae are very faint objects, and the radial velocity variatons we detected in three cases must be confirmed by new series of observations.

References

Acker, A., Jasniewicz, G.: 1985. *Astron. Astrophys.* **143,** L1.
Feibelman, W.A., Aller, L.H.: 1983, *Astrophys. J.* **270,** 150.
Grewing, M., Bianchi, L.: 1987, IAU Symp. No. **131,** Mexico.
Jasniewicz, G., Acker, A.: 1986, *Astron. Astrophys.* **160,** L1.
Jasniewicz, G., Acker, A.: 1988, *Astron. Astrophys.* **189,** L7.
Mendez, R.H., Gathier, R., Niemela, V.S.: 1982, *Astron. Astrophys.* **116,** L5.
Roth, M., Echevarria, J., Tapia, M., Carrasco, L., Rodriguez, L.F.: 1984, *Astron. Astrophys.* **137,** L9.

Brey 73: a Multiple Wolf-Rayet Star

G. TESTOR, Observatoire de Paris, Section de Meudon, France, and
A. LLEBARIA, B. DEBRAY, Laboratoire d'Astronomie Spatiale, Marseille, France

1. Introduction

Detailed observations of several of the most luminous stars in the LMC show that these stars often are multiple systems (Walborn, 1977; Feitzinger et al., 1980; Prevot-Burnichon et al., 1981; Lortet et al., 1986). Most of these stars really are tight clusters where different types of stars are mixed. Moreover, very accurate observations of R 136 by speckle interferometry (Weigelt and Baier, 1985) and of Sk −6641 under very good seeing (Heydari-Malayeri et al., 1988) have revealed eight and six components respectively in a field of about 4 × 4 arcsec². The existence of supermassive stars in the LMC is now ruled out, and we must interpret extragalactic young stellar associations very cautiously.

Therefore, being interested in the

population of massive stars in the LMC we are currently carrying out a new spatial high resolution observing programme of all bright Wolf-Rayet stars whose image seems slighty larger than a stellar profile in hitherto published photographs.

Apparently composite objects discovered by spectroscopy as the Wolf-Rayet Brey 18 = HD 269227 = R 84 (Allen and Glass, 1976; Cowley and Hutchings, 1979) will be studied later, when spatial resolution has been improved (less than 1 arcsec) or by speckle interferometry.

A good example of such a large and bright Wolf-Rayet is Brey 73. This star, of integrated magnitude V = 12.2 (Breysacher, 1981) and of type WN 4.5 + OB, is located in the OB association LH 99 (Lucke, 1972) of N 157B (Henize, 1956) a supernova remnant 7 arcminutes South-West of 30 Doradus. In 1979 Azzopardi and Breysacher reported that this star had a diffuse image and in 1980 Walborn's observations at the RC focus of the CTIO 4-m telescope showed that Brey 73 consisted of two components separated by only 1.5 arcsec. He noticed that the eastern component was slightly brighter, but he did not identify the Wolf-Rayet star. The visual examination of our CCD frames also reveals that Brey 73 is indeed a multiple star.

Even though the seeing was only 1.6 arcsec, thanks to the highly sampled CCD images and using the CAPELLA package for photometry in crowded regions (Debray et al., 1988), developed at the LAS in Marseille, we have been able to resolve and measure no less than eleven components.

2. Observations

The observations were obtained using the UV coated GEC CCD camera attached to the 2.2-m telescope at La Silla in October 1987. The chip has 385 × 576 pixels, each pixel 22 μ × 22 μ, corresponding to 0.26 × 0.26 arcsec^2 on the sky. The field of Brey 73 (Fig. 1), containing two other Wolf-Rayet (W-R) stars, Brey 71 and Brey 70a = MGWR 4 (Morgan and Good, 1987), was imaged with a 60 Å continuum filter centred at λ 4794 Å and a narrower one of 50 Å centred on the 4686 Å HeII emission line, in order to enhance the HeII brightness excess of the W-R. The exposure times were 3 minutes and 2 minutes for the HeII and continuum frames respectively. The CCD images were reduced (flat fielding, cleaning, etc. . .) using the MIDAS/VAX image processing system.

3. Reduction

Before applying the CAPELLA programme, we used two reduction programmes in the context of MIDAS:

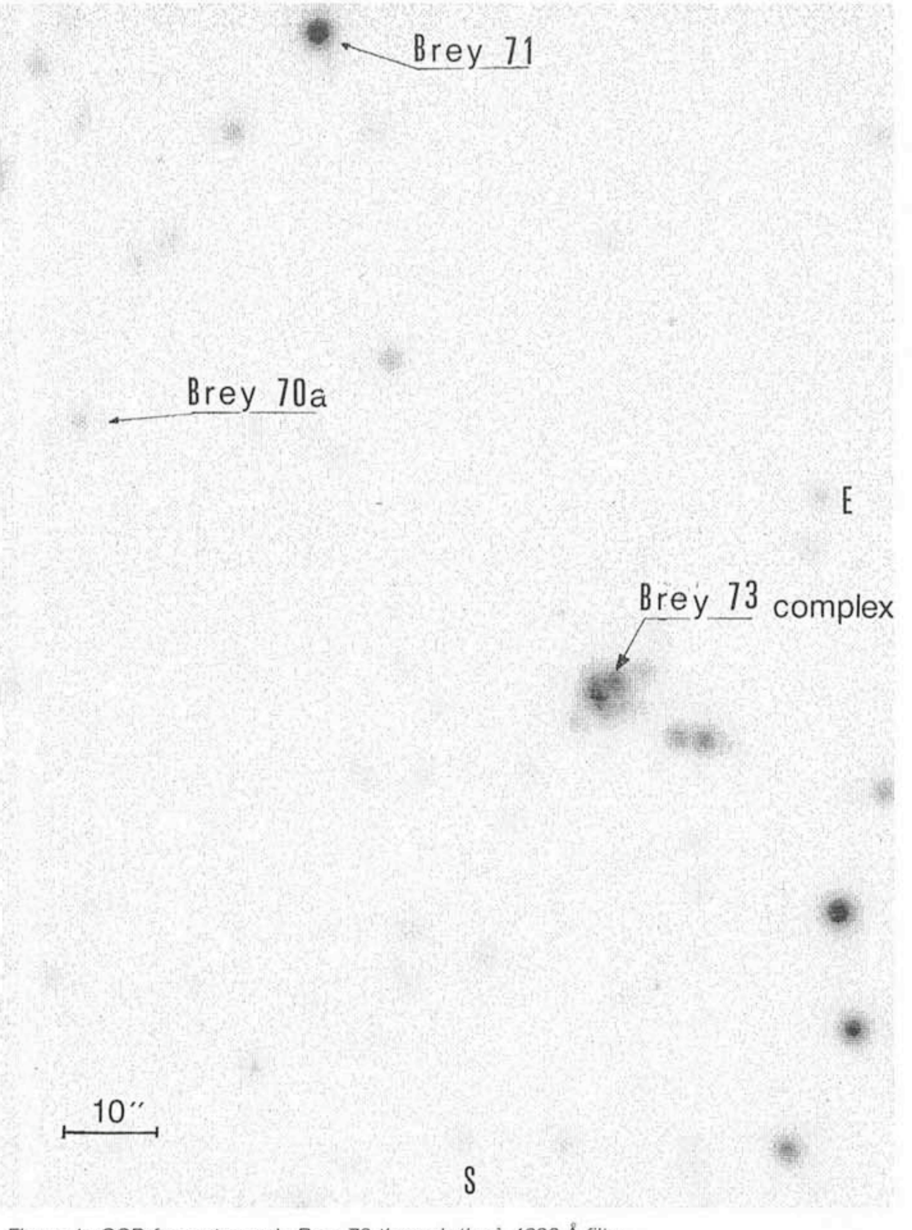


Figure 1: *CCD frame towards Brey 73 through the λ 4686 Å filter.*

– DAOPHOT, a very well adapted programme for crowded fields but non-interactive (Stetson, 1987).

– BIDIM which includes the following steps: Measurement of the slippage between the two frames to a tenth of a pixel, alignment of one image on the other one, determination of standard coefficients, difference after normalization.

In both cases, the W-R was detected in the association (Fig. 2) but could not be accurately located and its photometry could not be carried out either.

The CAPELLA package

The HeII and continuum frames have been treated individually and independently following the same operating sequence.

The standard reduction procedure for CCDs (correction of the dark current, of the cold columns, response uniformity, and so on) having been applied for both frames, the image taken in the HeII line has then been corrected for local defects (hot pixels, cosmic rays, etc.) with a special "erosion-healing" procedure made by Llebaria (bidimensional package in MIDAS) which restores defective pixel intensities by means of local interpolation from the surrounding area in an extension proportional to the dimensions of the defects.

Stars are then measured using a profile fitting photometry software called CAPELLA (Debray et al., 1988). An experimental point spread function (PSF) is determined from isolated stars which are interactively chosen in the same field. Stars are recentred to a common grid and are averaged together. Pixels intensities which are too far away from the mean value of relevant pixels intensities in the other stellar images are rejected from the computation of the mean. No modeling being used, it is

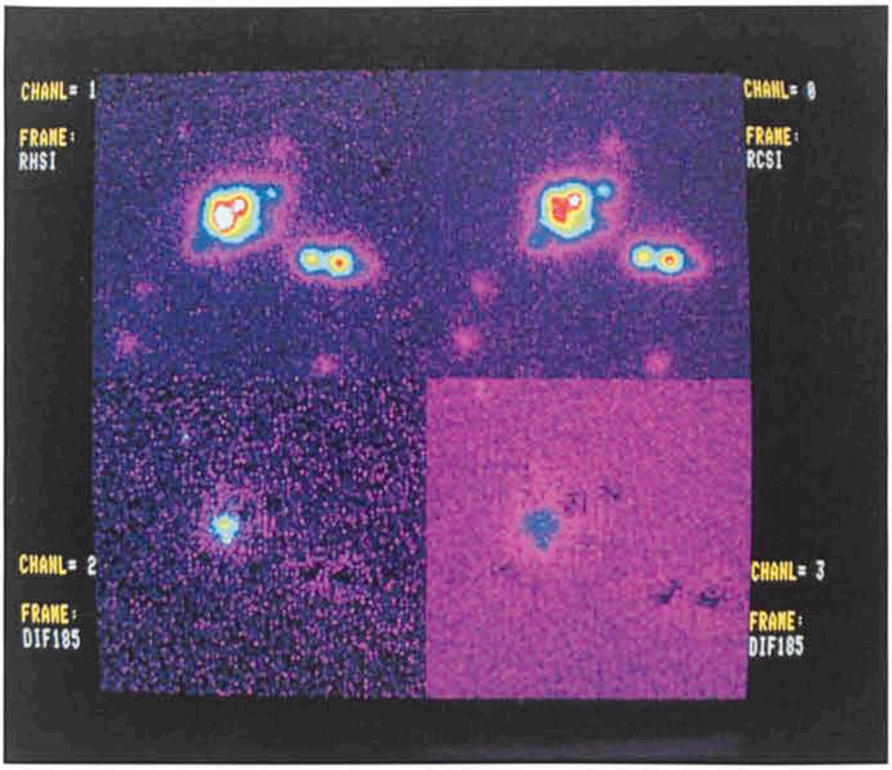


Figure 2 *(Upper left): HeII frame of Brey 73 association. (Upper right): Continuum HeII frame. (Lower left): Difference after scaling and rebinning using the BIDIM package. The Wolf-Rayet star appears in the middle. (Lower right): Enhancement of residuals due to differences between the two PSF.*

possible to work as in our case with slightly oval, or irregular PSF. Finally, relative fluxes of all stars are measured using linear regression fit with the PSF.

Stars are detected using convolution of the frame with a Laplacian adapted to the PSF FWHM. Detected stars are removed by subtraction of the recentred and scaled PSF. A new detection is performed over the field of residuals and detected objects are added to the previous list.

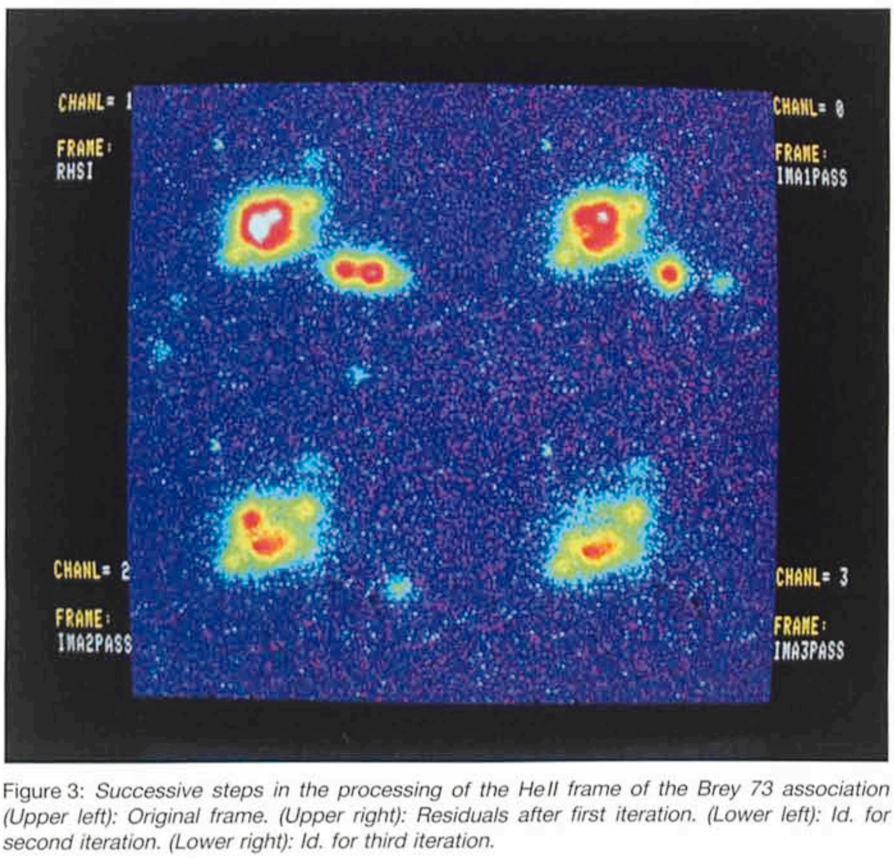


Figure 3: *Successive steps in the processing of the HeII frame of the Brey 73 association (Upper left): Original frame. (Upper right): Residuals after first iteration. (Lower left): Id. for second iteration. (Lower right): Id. for third iteration.*

For each detection, a contamination coefficient quantifies local blending due to nearby stars. This quantity is proportional to cross-correlation of the star with surrounding stars and inversely proportional to the auto-correlation value. As the fitting procedure runs, it is adapted with respect to the coefficient value.

Fairly contaminated stars (typically field stars which are out of the Brey 73 association) are measured using unblended parts of the stellar images for the linear regression fit with the PSF. Two possibilities may occur for very crowded stellar images. If the star is fainter than its immediate neighbours, star measurement is postponed to a next iteration until brighter neighbouring stars have been measured and subtracted. If the star is brighter than its immediate neighbours, they are first evaluated after rough subtraction of the star to be measured, in order to remove them from the wings of the star to be measured using an "up-and-down" procedure. In the case of very blended stars of the Brey 73 association, This "up-and-down" procedure must be iterated at its turn for the correct evaluation of the neighbouring stars.

In the present case, it has been necessary to perform nine successive iterations because of the large overlap of the stellar images in Brey 73 (Fig. 3 and 4). The photometric reduction step required one day of interactively assisted work for each image on a VAX 780, with a Deanza IP 8400 station and CAPELLA in MIDAS.

4. Results and Discussion

Our work reveals that Brey 73 is in fact an aggregate of 11 components (Fig. 5) including the Wolf-Rayet star at a resolution of at least 1.3 arcsec with an effective seeing of 1.6 arcsec.

Apparent magnitude

Figure 6 shows all the stars of the field. Triangles refer to the stars of the Brey 73 association.

It immediately appears that the W-R star Brey 73 is of similar magnitude (at λ 4794 Å) as Brey 71, though the magnitudes quoted for these two stars in the literature are very different.

The calibration of the W-R component in the Brey 73 association was made on the one hand thanks to the single stars Brey 71 (WN 7) and Brey 70a (WN 3–4) of magnitude v = 13.76 (Breysacher, 1986) and 17.64 (Morgan and Good, 1987) respectively, in the u'ubvv' photo-

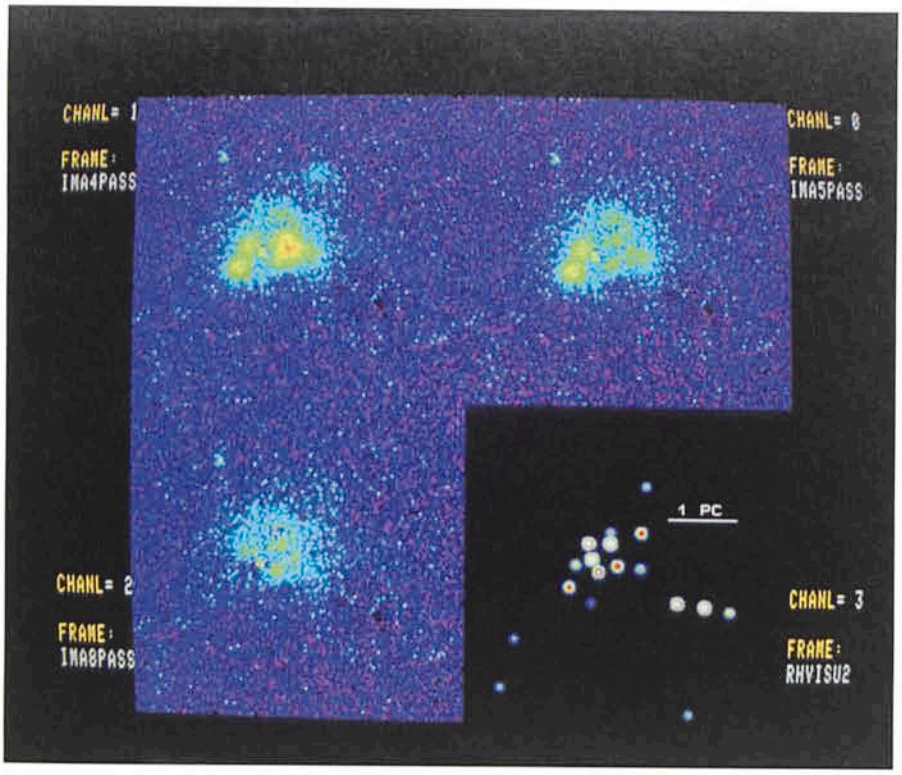


Figure 4: *Successive steps in the processing of the HeII frame of the Brey 73 association (continuation). (Upper left): Residuals after fourth iteration. (Upper right): Residuals after fifth iteration. (Lower left): Id. for eighth (the last one) iteration. (Lower right): 0.25 arcsec reconstitution of Brey 73.*

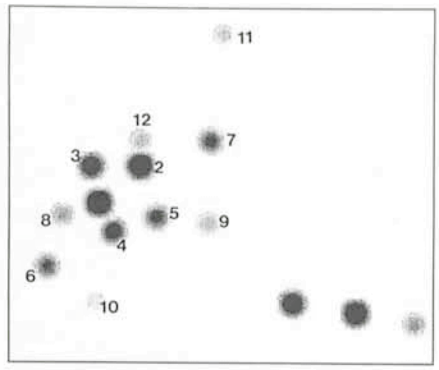


Figure 5: *0.25 arcsec reconstitution of Brey 73 showing stars detected in the association.*

metric system avoiding the W-R emission lines described by Smith (1968), and on the other hand thanks to the integrated magnitudes V = 12.11 of the Brey 73 association and V = 13.96 of Brey 71 in the UBV current photometric system, obtained by Feitzinger and Isserstedt (1983) through an 18 arcsec diaphragm. The difference in magnitude v between the UBV and narrow band u'ubvv' system is determined by the relation v-V = 0.20 for WN 4.5 and v-V = 0.08 for WN 7 stars (Breysacher, 1986). We have checked elsewhere that v (λ 4794 Å) and V are well correlated with the slope 0.97, for stars not redder than 0.4. The correlation v (λ 4794 Å), v (Smith) is expected to be even better with a slope closer to 1.

Table 1 gives different magnitudes v of the W-R in the Brey 73 association. Its calibration from the magnitude v and V of Brey 71 gives two different magnitudes v = 13.74 (column 3) and v = 14.04 (column 4) respectively. The latter value is in good agreement with the magnitude v = 13.99 (column 5) extracted from the integrated magnitude V of the Brey 73 association. From the faint Brey 70a we derived a magnitude v = 13.43 (column 2), the excess in brightness could be due to the nebula. Finally we adopted v = 14.01 as the mean magnitude deduced from the V magnitudes of Brey 71 and Brey 73. The brightest star in the aggregate besides the W-R has a mean magnitude v of about 13.76.

Absolute magnitude

Adopting a LMC distance modulus of 18.5 (Westerlund, 1974) the visual absolute magnitude of a star is given by the relation $M_v = v - A_v - 18.5$ where v is the apparent magnitude, $A_v = R_1 E_{b-v}$ the total absorption in the v band (Lundström and Stenholm, 1984). Adopting $E_{b-v} = 0.12$ and $R_1 = 4.2$ (Breysacher, 1986), we found a magnitude $M_v = -4.99$ instead of -6.7.

This value draws Brey 73 towards the right of the WN 4.5 absolute magnitude histogram (Breysacher, 1986 – Fig. 1) strengthening Breysacher's hypothesis that the mean magnitude of this subclass is not very different from that of WN 3 and WN 4, about −4.2.

As a conclusion, CAPELLA is an excellent help, well adapted for the study of stellar aggregates, even if a great number of intermediate frames must be used in its present status. In the case of Wolf-Rayet stars, the detection and treatment of multiple systems is of special interest as it is a necessary step for an accurate determination of the absolute magnitude of each star, which has far reaching consequences for our understanding of the evolution of massive stars. The comparison with results obtained in our Galaxy, of different chemical composition (Van der Hucht et al., 1988) will also be of great interest.

References

Allen, D.A., Glass, I.S.: 1976, *Astrophys. J.* **210,** 666.
Azzopardi, M., Breysacher, J.: 1970, *Astron. Astrophys.* **75,** 243.
Breysacher, J.: 1981, *Astron. Astrophys. Suppl. Ser.* **43,** 203.
Breysacher, J.: 1986, *Astron. Astrophys.* **160,** 185.

TABLE 1. *Magnitudes of the Brey 73 aggregate stars computed from the known measurements of Brey 70a, Brey 71, Brey 73.*

Stars of the Brey 73 aggregate	Magnitude (v) from Brey 70a (v = 17.64)	Magnitude (v) from Brey 71 (v = 13.76)	Magnitude (v) from Brey 71 (V = 13.96)	Magnitude (v) from Brey 73 (V = 12.11)
W-R	13.43	13.74	14.04	13.99
2	13.12	13.43	13.73	13.69
3	13.59	13.90	14.20	14.16
4	14.24	14.46	14.76	14.81
5	14.45	14.76	15.06	15.02
6	14.57	14.88	15.18	15.14
7	14.31	14.62	14.92	14.88
8	15.59	15.90	16.20	16.16
9	15.70	16.01	16.31	16.27
10	16.46	16.78	17.08	17.03
11	16.07	16.39	16.69	16.63
12	15.05	15.36	15.66	15.62

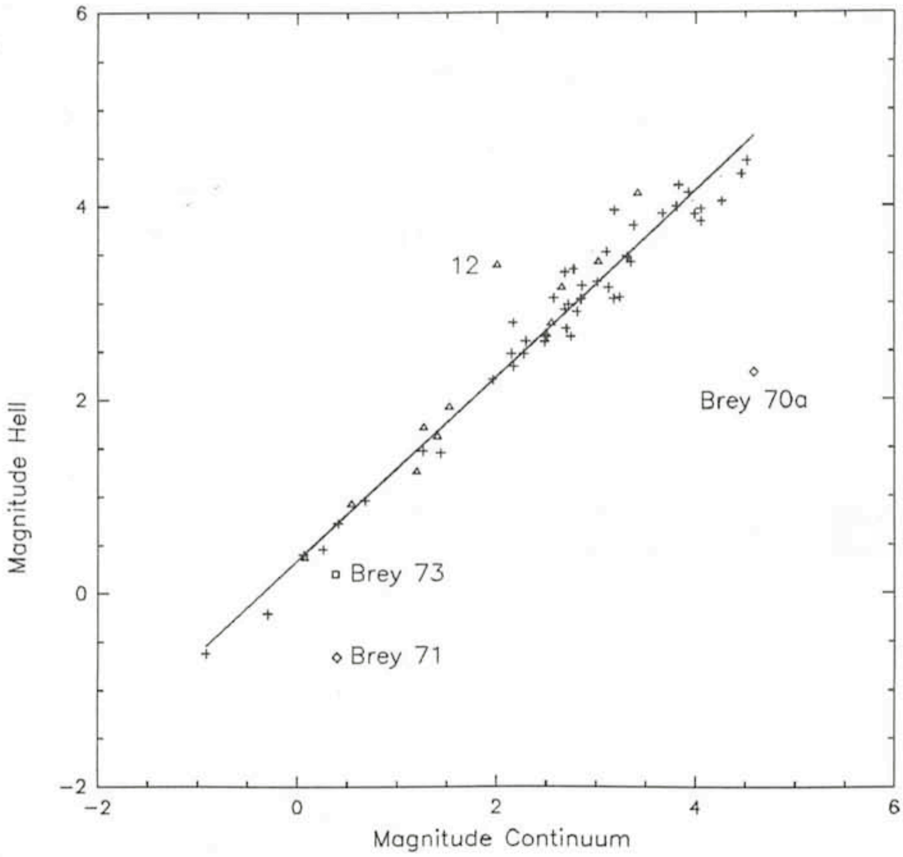


Figure 6: *Plot of the He II relative magnitudes versus the continuum magnitudes of all stars of the frame (90 arcsec × 140 arcsec). The known W-R stars Brey 70a, Brey 71 and the Brey 73 association show a conspicuous He II brightness excess. The stars belonging to the aggregate are represented by triangles. Most of the stars follow a close relationship* v (λ 4686 Å) = 0.96 v (λ 4794 Å) + 0.34 and with a σ rms of 0.22 magnitude after elimination of Brey 70a, Brey 71 and Brey 73. Star 12 is a faint star of the cluster, probably a red one which would need deep, good seeing B and V photometry.

Cowley, A.J., Hutchings, I.B.: 1979, *P.A.S.P.* **90,** 636.
Debray, B., Dubout, R., Llebaria, A., Petit, M.: 1988, *Astron. Astrophys.* (submitted).
Feitzinger, J.V., Schlosser, W., Schmidt-Kaler, Th., Winkler, C.: 1980, *Astron. Astrophys.* **84,** 50.
Feitzinger, J.V., Isserstedt, J.: 1983, *Astron. Astrophys. Supp. Ser.,* **51,** 505.
Henize, K.G.: 1956, *Astrophys. J. Suppl.* **2,** 315.
Heydari-Malayeri, M., Magain, P., Remy, M.: 1988, *Astron. Astrophys.* **201,** L 41.
Lortet, M.C., Heydari-Malayeri, M., Testor, G.: 1986, in *Luminous stars and associations in galaxies,* Proceed. IAU Symp. **116,** 401.
Lucke, P.B.: 1972, Ph.D. Thesis, University of Washington.
Lundström, I., Stenholm, B.: 1984, *Astron. Astrophys. Suppl.* **58,** 163.
Morgan, D.H., Good, A.R.: 1987, *MNRAS.* **224,** 435.
Prévot-Burnichon, M.L., Prevot, L., Rebeirot, E., Rousseau, J., Martin, N.: 1981, *Astron. Astrophys.* **103,** 83.
Smith, L.F.: 1968, *MNRAS.* **140,** 409.
Stetson, P.B.: 1987, *P.A.S.P.* **99,** 191.
Van der Hucht, K.A., Hidayat, B., Gunowan Admiranto, A., Supelli, K.R., Doom, C.: 1988 Preprint.
Walborn, N.R.: 1977, *Astrophys. J.* **215,** 53.
Walborn, N.R.: 1980 (Private communication).
Weigelt, G., Baier, G.: 1985, *Astron. Astrophys.* **150,** L 18.
Westerlund, B.E.: 1974, Proceedings of the first European Astronomical meeting in Athen, September 4–9, 1972, Volume 3. Springer, Berlin, Heldeberg, New York, p. 39.

Spectroscopic Identification of White Dwarfs in Galactic Clusters

D. REIMERS, Hamburger Sternwarte, Universität Hamburg, F.R. Germany
D. KOESTER, Department of Physics and Astronomy, Louisiana State University, USA*

The End Products of Stellar Evolution

The end products of the evolution of single stars are well known: low mass stars leave white dwarf remnants, massive stars undergo a supernova explosion with either a neutron star or a black hole as a remnant.

In a first approximation, it appears to be only the initial mass which determines whether a star ends its life peacefully as a white dwarf or undergoes a core collapse with a quasi instantaneous energy release of $\sim 10^{53}$ erg, visible as a supernova explosion.

Estimates of the maximum initial mass limit M_{WD} for formation of white dwarfs have been made by various techniques.

One possibility is to compare the supernova type II rate with the birth rate of massive stars in our galaxy. Since the former rate is extremely uncertain and can be observed only in external galaxies whereas the initial mass function can be measured only in the solar neighbourhood, the constraints on SN II parents are not stringent. An estimate of the local SN II rate (e.g. Tammann, 1974) tells us that all stars more massive than 5 to 10 $M_{\odot}$ must become supernovae, and Kennicutt (1984) found that SN II's in Sc galaxies come from stars with masses greater than 8 ± 1 $M_{\odot}$.

Since the fate of intermediate mass stars is mainly determined by mass loss in the red giant stage, the combination of stellar evolution tracks through the red giant stages with empirical red giant mass-loss rates also provides an estimate of M_{WD}. The difficulty of this approach is that while mass-loss rates in the normal red giant region are fairly well known and can be parametrized by semi-empirical interpolation formulae

* Formerly at Institut für Theoretische Physik und Sternwarte der Universität Kiel, F.R. Germany

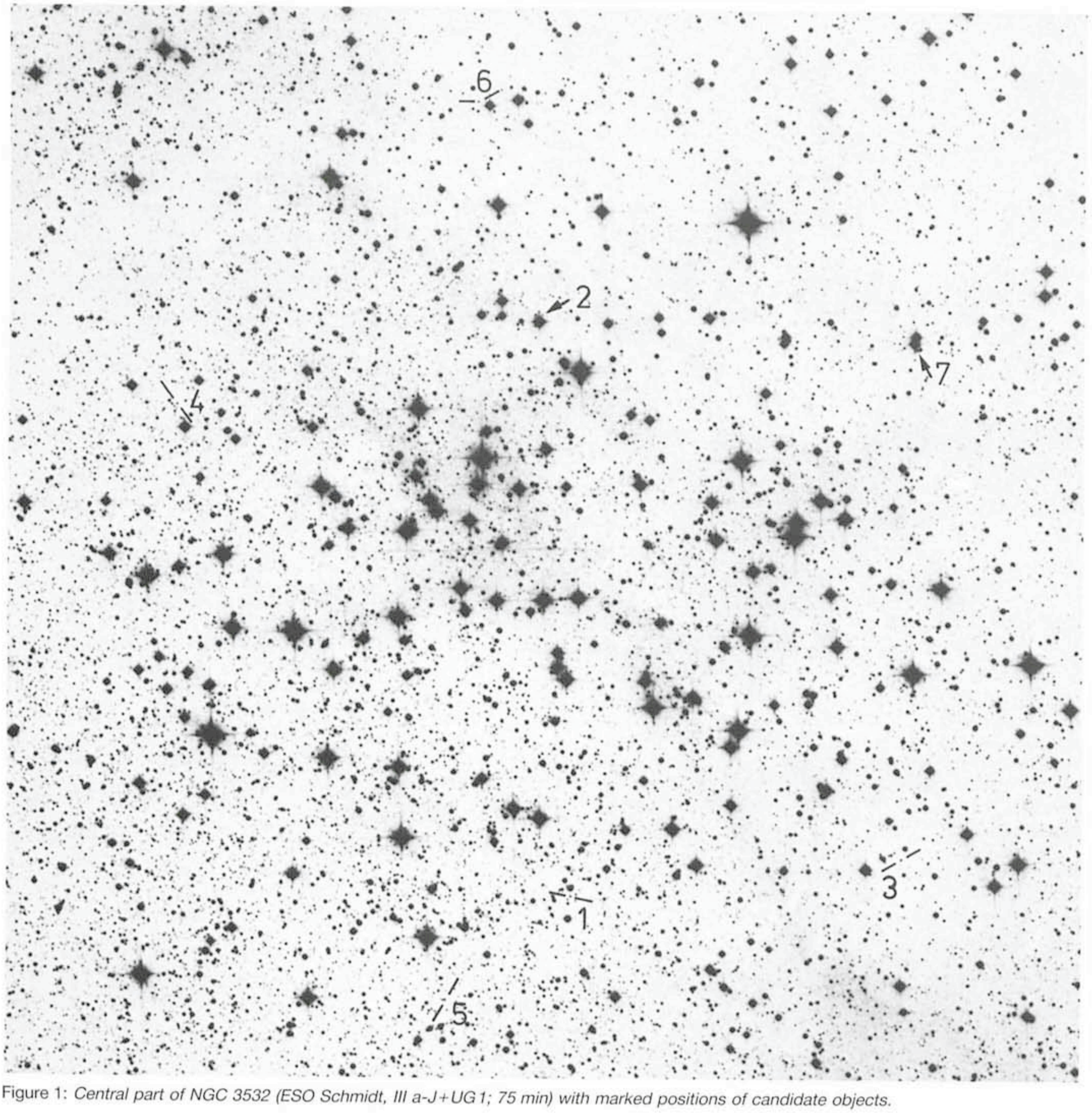


Figure 1: *Central part of NGC 3532 (ESO Schmidt, III a-J+UG 1; 75 min) with marked positions of candidate objects.*

(e.g. $\dot{M} \sim L/g \cdot R$, Reimers, 1975, 1987), an extrapolation to advanced red giant phases (e.g. OH-IR stars) where most mass is lost is certainly not allowed. On the other hand, high mass-loss rates of advanced red giants as observed in thermal CO lines or in OH maser lines cannot easily be linked to stellar evolution calculations, since for these stars masses and evolutionary stages are poorly known.

The only reliable method to determine M_{WD} seems to be the identification of white dwarf members of galactic clusters with turn-off masses $M_t \lesssim M_{WD}$.

The first attempt with this method was made by v.d. Heuvel (1975) for the Hyades. He found $M_{WD} = 4\ M_\odot$. However, with a turn-off mass of $\sim 2\ M_\odot$ the Hyades are not favourable for this method since according to the cluster luminosity function, their known six white dwarf members must have had progenitor masses only slightly higher than the turn-off mass.

Faint Blue Objects in Open Cluster Fields

A new attempt to determine M_{WD} from cluster white dwarfs was made by Romanishin and Angel (1980) who looked for a statistical excess of faint blue objects – relative to comparison fields – in a number of intermediate age northern clusters. Based on their findings, they concluded $M_{WD} \approx 7\ M_\odot$. However, the question remained whether the excess of blue objects in the cluster fields were really white dwarfs. Anticipating the results of our spectroscopic observations over the years 1980–88 from both La Silla and Calar Alto of all Romanishin and Angel's candidates, it finally turned out that only 6 out of 17 WD candidates in the four clusters NGC 2168, 2242, 2287 and 6633 are cluster members. This means that without time consuming spectrophotometry of the faint ($V \approx 19$ to 21) blue objects in the cluster fields, no safe

Confirmed white dwarf members of intermediate age clusters

Cluster (Paper No.)	Age log T	Turn-off Mass	White Dwarf	T_e [10^3 K]	V	Mass [$M_\odot$]	Progenitor Mass [$M_\odot$]
NGC 2516 (II)	8.0	4.75	−1 −2 −5	30 36 34	19.6 19.55 20.1	0.95 1.14 1.17	7.2 7.6 9.8
NGC 2451[4]) (III)	7.8	5.3	−6	31	16.75	0.6:	5.9
NGC 3532 (V)	8.3	3.6	−1 −5 −6	28 28 29	19.55 19.2 19.9	0.9 0.6 0.9	4.1 3.9 4.1
NGC 2168 (IV)	8.0	4.75	−3 −4	38 44	20.25 20.05	0.7 0.7	5.9 5.9
NGC 2287 (I)	8.25	3.9[1])	−2 −5	25 25	20.1 20.1	0.6 0.6	
NGC 6405 (VI)	7.9:	5.3:	−1[3])	82	18.1	1.18	6.5:
Pleiades	7.9	5.3	LB 1497			0.85	6.2[2])

[1]) According to Romanishin and Angel (1980).
[2]) Weidemann (1987).
[3]) Cluster membership uncertain, WD is ~1° from cluster centre.
[4]) NGC 2451 contains two more probable WD members (Paper III), if confirmed they have high masses and high progenitor masses; : denotes uncertain or preliminary values

conclusions are possible. The results of the first two observing years have been described briefly by Koester (1982).

Parallel to this activity we asked for deep ESO red and UV Schmidt plates of suitable southern intermediate age clusters with turn-off masses around 5 $M_\odot$. White dwarf members of clusters younger than about $2 \cdot 10^8$ years cannot have cooled down below about 25,000 K. Therefore one has to search for very blue faint objects in the cluster fields. With typical distance moduli of rich clusters between 8 and ≥ 11, hot white dwarfs are expected in the range V = 19 to 22.

The plates were blinked at Hamburger Sternwarte and we could identify further suitable candidates in the clusters NGC 2516, 2451, 3532, 6405, 6475, 6087 and IC 2391. Progress in follow up spectroscopy was slow, since due to the faintness of the objects only the 3.6 m + IDS was suitable in the years 1980–84, and the faintest objects as well as objects with relatively weak lines had to wait for EFOSC with its improved sensitivity. Our first observing run with EFOSC was conducted in April 88.

Cluster Membership

Even if a faint blue object within the cluster field turns out to be a white dwarf, it is not necessarily a cluster member. How can foreground and background white dwarfs be separated from cluster members? Besides the fact that extremely hot white dwarfs ($T_e >$ 30,000 K) are extremely rare in the general field and projection onto a cluster is therefore highly improbable, two criteria are applied: (i) the theoretically calculated cooling time, which depends on mass M and temperature T_e must be smaller than the cluster age and (ii) the distance modulus V-M_v determined from the observed apparent magnitude V and from effective temperature T_e and radius R has to be consistent with the observed cluster modulus. As Chandrasekhar's work, which won him the Nobel prize, has shown, degenerate stars obey a mass-radius relation which is approximately $R \sim M^{-1/3}$. The white dwarf radius R which is needed for cluster membership test is determined in the ideal case from gravity which can be measured from high-quality spectra by comparison with model atmosphere calculations. This was possible, e.g., in cases of NGC 2516 and NGC 3532. If gravity cannot be determined spectroscopically with sufficient accuracy, a typical WD mass is assumed in a first approximation. In most cases a decision about cluster membership is then possible since for a given effective temperature T_e the absolute magnitude varies as $M_v \sim R^2 \sim M^{-2/3}$ with mass, and assumptions about WD masses which have a narrow range anyway are not too crucial. As long as consistency with the cluster modulus is found for an assumed WD mass in the range 0.5 $M_\odot$ to 1.2 $M_\odot$, cluster membership is highly probable for a hot WD. Unfortunately, it will be difficult to measure proper motions of WDs in cluster fields at such faint magnitudes (~20^m) in the near future.

The Present Status

How many white dwarf members of intermediate age clusters (turn-off masses $\gtrsim 4\ M_\odot$) are known at present after the spectroscopic observations with the 3.6-m + IDS in the years 1980–84, the new start with EFOSC on fainter objects in 1988, and a few nights on the northern clusters NGC 2168 and NGC 6633 with the Calar Alto 3.5-m telescope? Altogether we have identified 12 (possibly 14) WD members of intermediate age clusters (Papers I–VI). Four were from Romanishin and Angel's (1980) candidate list (two in both NGC 2287 and NGC 2168). Eight (ten) hot DA white dwarfs (the hottest has 82,000 K!) have been discovered by ourselves on the ESO Schmidt plates taken for that particular purpose. Only one WD, the Pleiades member LB 1497 (e.g. Greenstein, 1974), was known to be member of an intermediate age open cluster before we started this project in 1980. ESO's superb equipment and dark sky has thus made possible an important contribution to an understanding of the final stages of stellar evolution.

Our first observing run with EFOSC and the 3.6-m telescope in April 1988 conducted by D.K. was highly successful. We identified 3 WD members of NGC 3532. Furthermore, we completed observations on several candidates in the clusters NGC 2422, 2516 and 2287 which had been too faint for an unambiguous identification with the IDS on the 3.6-m in earlier observing runs. The candidate in NGC 2422 could be proven to be a subdwarf, as suspected earlier (Paper I). The same applies to NGC 2516-4.

A highlight of the April 88 observations was the discovery of the extremely hot DA NGC 6405-1 (82,000 K, the hottest known DA?). While the star is ~1° outside the cluster centre, it has the same distance according to the model atmosphere analysis. One may suspect that the near coincidence of such an extremely rare type of star with a cluster is not just by chance.

A further surprise was that one of our faint blue candidates in NGC 6087 turned out to be a planetary nebula. It has a hot featureless continuum and nebular lines that extend ~14 arcsec in the direction of the spectrograph slit. A rough estimate shows that at the distance of the cluster (850 pc) this corresponds to a linear diameter of ~0.03 pc. This would imply a rather young PN with a central star of $M_v \approx -3$ to -4, inconsistent with the observed V magnitude of 19.3. Conclusion: Unfortunately, the PN is a background object.

M_{WD} and the Initial-Final Mass Relation

Data on the individual cluster white dwarfs identified by our spectroscopic observations and on the open clusters are compiled in the Table.

A major uncertainty for the determination of cluster turn-off masses, cluster ages and white dwarf progenitor masses has been recognized in recent years: the amount of convective overshooting for intermediate mass main sequence stars is not known. We have always assumed here an overshooting parameter $\alpha_C = 0.5$. For a full discussion of this point, in particular the influence of overshooting on the initial-final mass relation, we refer to Weidemann (1987).

The best case for determining M_{WD} is the rich southern cluster NGC 2516 (Reimers and Koester, 1982). Using the observed cluster luminosity function, the mass-interval above the cluster turn-off was estimated out of which the observed number of evolved stars has come. The result was $M_{WD} = 8^{+3}_{-2}\,M_\odot$. This statistical method, however, demands that no mass segregation has occurred within the cluster due to dynamical evolution. In cases where it is observed that the massive stars are more concentrated to the cluster centre than the low mass stars as in the case of the Hyades or NGC 3532, the statistical method can give only a lower limit to M_{WD} (Paper V), since for a sufficiently short relaxation time the white dwarfs can have a space distribution different from that of their progenitor stars or the upper main sequence stars respectively. An alternative approach is to try to estimate the WD progenitor masses by virtually placing the white dwarfs back onto the main sequence taking into account main sequence and red giant lifetimes and the WD cooling ages. For details we refer to Weidemann (1987). Thus obtained progenitor masses (Table) yield both an initial-final mass relation (Fig. 3) and an estimate of M_{WD}. Notice in Figure 3 that the initial-final mass relation may well be a strip with a finite width, which could be explained by differential mass-loss in the preceding red giant stage. Clearly more stars and more accurate data are needed, so, e.g., the accuracy of WD masses (via radii) depends on the accuracy of distance moduli and reddening corrections of open clusters!

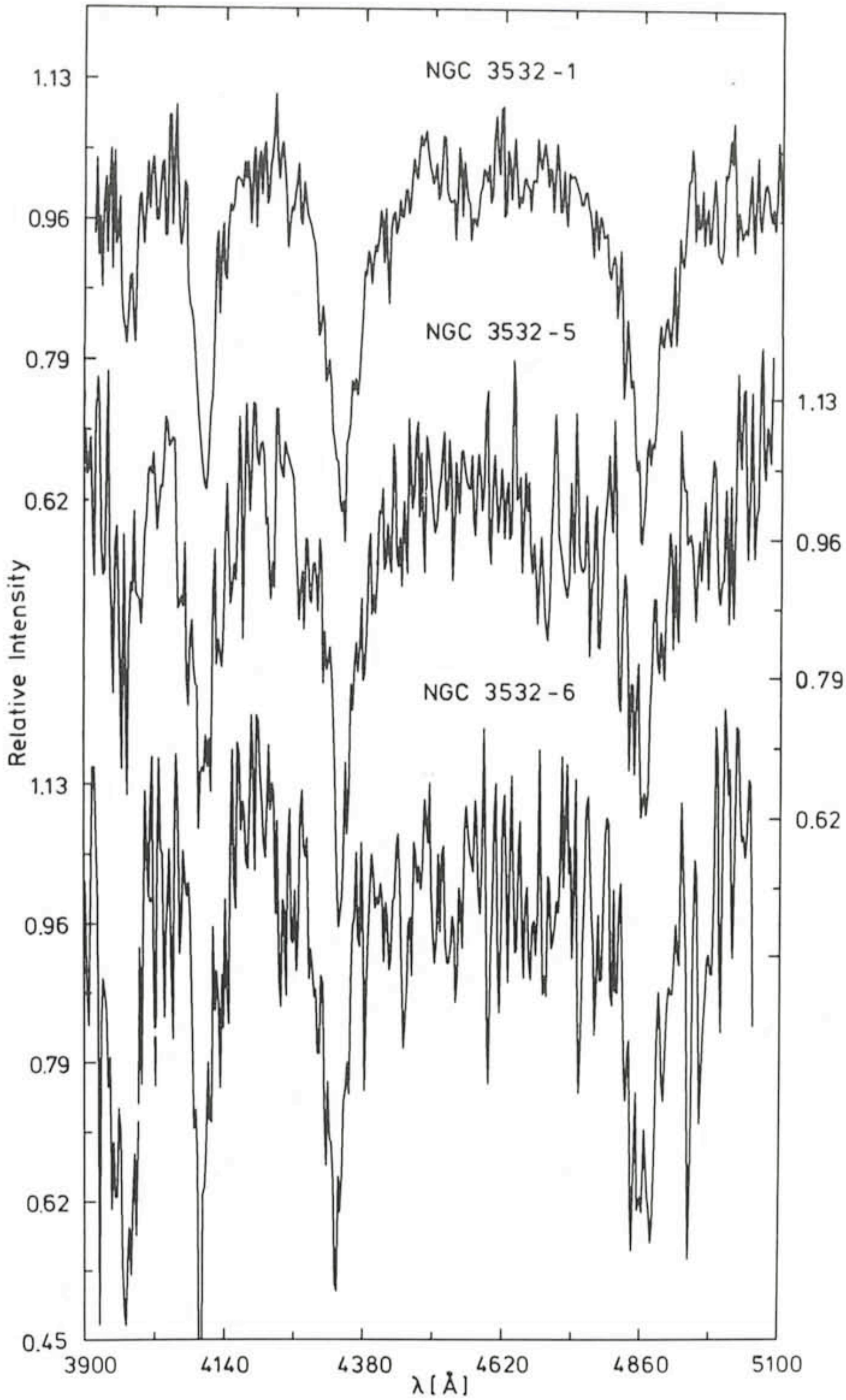


Figure 2: *EFOSC spectra of DA white dwarf members of NGC 3532.*

The Future

We clearly need more WD members of rich open clusters with turn-off masses above $5\,M_\odot$. One of the best known examples is NGC 6067, also called the "jewell box" because of its concentration of blue main sequence stars and red giants. It contains ~ 10 red giants and Cepheids. Due to its extreme richness and a turn-off mass of $\sim 6\,M_\odot$ we expect about 15 hot white dwarfs in the cluster, however, at $V \sim 23^m$. Our attempt to find candidates with deep CCD exposures with the Danish 1.5-m telescope has so far been unsuccessful mainly due to the concentration of bright stars which caused severe CCD overflows. Due to the higher resolution of the CCD, EFOSC images look better.

Follow-up spectroscopy of 23^m candidates at a sufficient S/N for gravity determination using the model atmosphere technique will be a promising task for the VLT.

Acknowledgements

This work would have been impossible without the efficient support of

staff astronomers and skillful night assistants on La Silla.

References

Greenstein, J.L., 1974, *Astron. J.* **79,** 964.
Kennicutt, R.C., 1984, *Astrophys. J.* **277,** 361.
Koester, D., 1982, *The Messenger* **28,** 25.
Koester, D., Reimers, D., 1981, *Astron. Astrophys.* **99,** L8 (I).
Koester, D., Reimers, D., 1985, *Astron. Astrophys.* **153,** 260 (III).
Koester, D., Reimers, D., 1989, *Astron. Astrophys.* Letters, in prep. (VI).
Reimers, D., 1975, *Mem. Soc. Roy. Sci. Liège* **8,** 369.
Reimers, D., 1987, in *Circumstellar Matter,* IAU Symp. **122,** 307.
Reimers, D., Koester, D., 1982, *Astron. Astrophys.* **116,** 341 (II).
Reimers, D., Koester, D., 1988, *Astron. Astrophys.* **202,** 77 (IV).
Reimers, D., Koester, D., 1989, *Astron. Astrophys.* (V).
Romanishin, W., Angel, J.R.P., 1980, *Astrophys. J.* **235,** 992.
Tammann, G.A., 1974, in Supernovae and Supernova Remnants (C.B. Cosmovici, ed.) D. Reidel, p. 155.
v.d. Heuvel, E.P.J., 1975, *Astrophys. J.* **196,** L121.
Weidemann, V., 1987, *Astron. Astrophys.* **188,** 74.

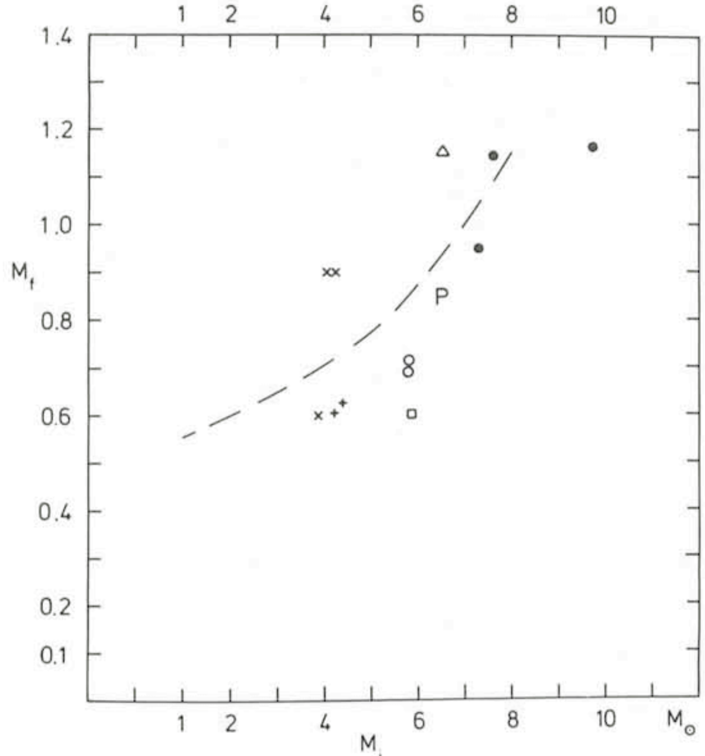


Figure 3: *Initial-final mass relation for intermediate-mass stars according to cluster white dwarfs identified in the course of this programme. Symbols: ○ NGC 2516, + NGC 2287, x NGC 3532, ° NGC 2168, □ NGC 2451, △ NGC 6405, P Pleiades. The broken line is the relation adopted by Weidemann (1987).*

New Results About SB0 Galaxies

D. BETTONI, Osservatorio Astronomico di Padova, Italy, and
G. GALLETTA, Dipartimento di Astronomia, Università di Padova, Italy

We discuss here the preliminary results of a long term project on kinematics and photometry of SB0 galaxies begun at ESO in 1983 and not yet fully completed. Beginning this study, we were particularly interested in analysing the mark of triaxiality that the bar induces in otherwise symmetrical galaxies, by perturbing and stretching out the stellar orbits. But we did not imagine that, progressing in this almost unexplored land, so many new and not yet fully explained features would be discovered. Now, we feel it would be interesting to resume here before the completion of the search the main results so far obtained.

1. A Bit of History

SB0 galaxies are good candidates for this study because of the low, but not negligible, quantity of gas and dust present in them. But despite the large number of theoretical models of bars, and the several works on gas kinematics, stellar motions were in the past very little studied. A systematic attempt to analyse the kinematics of SB0s (Kormendy 1982, 1983) was never completed and practically only one galaxy, NGC 936 (Kormendy 1983, 1984), was studied in detail (photometry, stellar velocity field and velocity dispersion field) before 1987. Similar projects at other observatories followed the same course, with observations never completed or results never published. Probable reasons for this were the difficulty of supporting for many years a project requiring many observing nights against the idea that in the melting pot of billions of stars moving within the bar it should be impossible to distinguish between "families" of orbits and, last but not least, against the occasional misunderstanding of some (too human) time commissions. But with some vicissitudes and a little bit of luck, observations of SB0s continued at ESO telescopes, demonstrating that we can look inside the stellar and gas kinematics with good hope of progressing toward its complete understanding. In recent years, therefore, new data on stellar kinematics have become available for eight more SB0s (Galletta 1987, Bettoni and Galletta 1988, Bettoni et al. 1988, Jarvis et al. 1988, Bettoni 1988). The observational techniques used in our observations reflect the improvement of ESO instrumentation in these years: starting with the 3.6-m telescope with the Boller & Chivens spectrograph and the 3-stage EMI image tube, the observations continued at the ESO-MPI 2.2-m telescope with RCA CCDs when these detectors became available. Parallel to this study, the inner photometry of the selected galaxies has been performed using the ESO-Danish 1.52-m telescope.

2. Observations and Data Reduction

Our sample includes 15 SB0 galaxies brighter than the 12th magnitude and

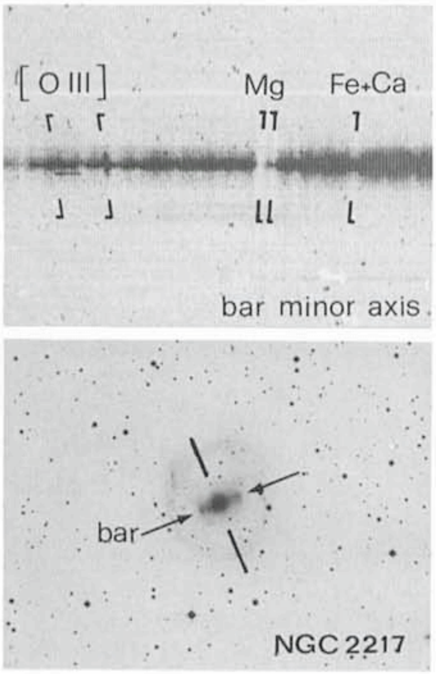


Figure 1: *The almost face-on SB0 NGC 2217 (bottom), and its spectrum along the bar's minor axis (top) showing the opposite tilt of emission and absorption lines. This is the second case of counterrotation between gas and stars found in SB0, after NGC 4546 (Galletta 1986).*

visible for a whole night in the allotted observing period. We selected these galaxies in an effort to have systems with all possible orientations of the bar, from side-on to end-on, and with all possible inclinations of the galaxy disk, from edge-on ($i = 90°$) to face-on ($i = 0°$). Among these, 10 systems have already been observed in the previous runs at La Silla and 7 of these have been fully reduced.

A number (from 4 to 7) of long slit spectra at different P.A. were taken for each galaxy, with exposure times ranging from 60 to 120 minutes, in order to map as much as possible the velocity field. The spectral region observed at the 3.6-m telescope ranged from 3500 to 4500 Å, including Ca II H and K, G-band and the eventually present λλ 3727-29 [O II] doublet. The spectral region selected at the 2.2-m ranged from 4800 to 5800 Å, due to the different spectral response of the RCA CCDs adopted, and includes Mg I, Fe and many other bands. When present, Hβ and λλ 4959-5007 [O III] doublet were also measured. In addition, the spectrum of some giant stars of low rotational velocity were recorded each night, for use in the reductions as template stars of zero velocity dispersion. All the spectra have been reduced by means of the ESO-IHAP procedures and analysed using the FQ method (Sargent et al., 1977) modified as in Bertola et al. (1984) to produce the stellar velocity and velocity dispersion curves. The emission lines eventually present have been interpolated by fitting gaussian profiles, obtaining the gas velocity curve and the equivalent velocity dispersion σ_{gas} = FWHM/ 2.53.

The photometric analysis has been performed on frames recorded in band V, I and at wavelengths around Hα on the 1.5-m Danish telescope, with exposure times ranging from 10 to 30 minutes. They have been reduced with the standard ESO-IHAP procedures. The photometric zero point of V band has been obtained using the magnitudes reported by Longo and de Vaucouleurs (1983), while the isophote interpolation has been performed using the INMP programmes (Barbon et al. 1975).

3. Results

The main properties of the SB0 galaxies observed until now are resumed in Table I, where in addition to the galaxies present in our sample we added NGC 936 (Kormendy 1983, 1984) and the four galaxies studied by Jarvis et al. (1988).

We could resume the more interesting findings:

3.1 Velocity fields

Two galaxies were found where gas and stars rotate with similar but opposite streams. This is one of the more remarkable features found, and fully unexpected, which induces some interesting reflections on the nature of the gas in S0 galaxies. Observing NGC 4546, an apparently normal edge-on SB0, we detected the presence in the same spectrum of emission and absorption lines tilted because of the rotation but in opposite way (Galletta 1986, 1987). The amplitude of the observed motions between gas and stars is of the order of 400 km s^{-1} along the apparent major axis. This gas lies in a ~ 5 kpc wide disk not yet relaxed on the main galaxy plane. The second case is represented by NGC 2217, a galaxy with almost round disk isophotes where gas and stars again exhibit opposite motions, circulating around the bar major axis with velocities lower than in the case of NGC 4546, but not negligible (Fig. 1).

In these galaxies the presence of retrograde motions should be interpreted as a recent acquisition from outside, lacking reasonable mechanisms which allow such a clear decoupling between angular momenta of gas and stars having the same origin. They fit in the wider frame of S0s with recent interaction, like the polar ring galaxies (Schweizer et al. 1983) and confirm the idea that the gas in S0 galaxies has an external origin, as suggested for the HI by Wardle and Knapp (1986).

Differences between gas and star kinematics could enhance particular types of orbits. For instance, in the case of NGC 2217 the peculiarities observed could be explained if the gas moved on orbits belonging to the families of anomalous orbits (X-tube, see Van Albada et al. 1982), which appear retrograde when seen from the galaxy pole. This is actually the orientation at which, in an almost face-on galaxy such as NGC 2217, we observe the triaxial ellipsoid represented by its bar. These orbits were originally invoked (Van Albada et al. 1982) to explain the motions observed in the class of elliptical galaxies with minor axis dust lanes (Bertola and Galletta 1978) and represent a typical case where a single family of orbits should be discriminated from the heap of galactic orbits, as discussed in the introduction.

Another family of orbits that should be disentangled from the mass of the others, in the very special case of NGC 4546, is that of the retrograde Z-tube (Contopoulos and Papayannopoulos 1980, Heisler et al. 1982, Teuben and Sanders 1985). These orbits within the bar are elongated parallel to the bar intermediate axis, a direction perpendicular to the most part of the innermost

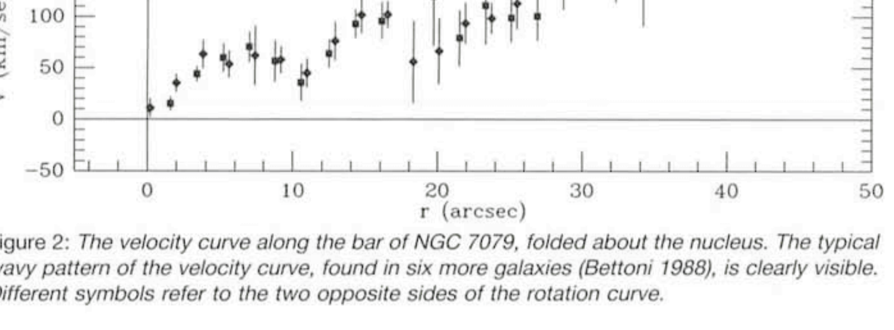


Figure 2: *The velocity curve along the bar of NGC 7079, folded about the nucleus. The typical wavy pattern of the velocity curve, found in six more galaxies (Bettoni 1988), is clearly visible. Different symbols refer to the two opposite sides of the rotation curve.*

Table I: *Properties of the SB0 galaxies studied. The main geometric characteristics of each galaxy, as the estimated inclination* i *with repect to the sky or the presence of ionized gas, are listed. In the following columns are also indicated: the presence of Z-motions (perpendicular to the galactic plane) for almost face-on galaxies; the symmetry of the bar velocity curve with respect to the galaxy nucleus; the presence in it of symmetric oscillations; the trend of the bar velocity dispersion. A question mark indicates data not yet fully reduced.*

Name	GEOMETRY		Ionized gas	BAR KINEMATICS				Ref.	Notes
	Bar-Disk P.A.	i		Presence of Z-motions	Presence of asymmetry	'Double wave' effect	σ_{bar}		
NGC 936	59°	49°	no	–	yes	yes	flat	1	
NGC 1543	–	0°	no	on both axes	no	no	~ flat	5	Double bar
NGC 1574	70°	28°	no	most on min. axis	yes	yes	peaked	5	
NGC 2217	–	24°	faint spiral arms	most on min. axis	?	?	?	7	Gas retrograde
IC 456	79°	48°	yes	–	yes	yes	flat	6	
NGC 2983	51°	47°	no	–	no	yes	peaked	4	
NGC 4371	70°	66°	no	–	?	?	?	7	
NGC 4442	10°	71°	no	–	?	?	?	7	
NGC 4477	58°	24°	no	on both axes	no	yes	flat	5	
NGC 4546	45°	71°	irregular disk	–	no	no	peaked	2	Gas retrograde
NGC 4643	–	0°	no	most on min. axis	yes	no	peaked	7	
NGC 4684	0°	75°	spiral arms, filaments	–	no	no	flat	7	
NGC 4754	60°	59°	no	–	yes	no	flat	5	
NGC 6684	61°	48°	no	–	yes	yes	flat	3	
NGC 7079	43°	43°	yes	–	no	yes	peaked	7	

References: 1: Kormendy (1983), 2: Galletta (1987) 3: Bettoni and Galletta (1988), 4: Bettoni et al. (1988), 5: Jarvis et al. (1988), 6: Bettoni (1988), 7: Bettoni and Galletta, in preparation.

stellar orbits, whose major axes lie on the bar's major axis. Since gas motions in NGC 4546 are retrograde with respect to the stars, the elongation of the isovelocity lines in the two velocity fields (gas and stars) appears at P.A. at almost 90° between them, confirming in this fortunate (and maybe unique) case the existence of this theoretically expected orbits.

Bar kinematics are sometimes asymmetric with respect to the whole galaxy. As generally performed in the reduction of rotation curves, the velocity curve derived from each spectrum was folded about the nucleus and the systemic velocity. In many cases the rotation curves close to the bar differ from the generally symmetric velocity field. In these galaxies, bar motions are actually symmetric, but with respect to a point not coincident with the galaxy nucleus, and independent of the apparent symmetry of the light distribution. This effect should reflect a real misalignment of the bar within the galaxy or the presence of dark and asymmetric matter. It is not yet clear which of these effects could be relevant.

A typical "wave pattern" of the bar rotation curve has been revealed in all the galaxies with intermediate inclination with respect to the sky so far observed. This effect, producing a "double wave" appearance of the unfolded velocity curves, was brought into evidence during the observations of IC 456 (Bettoni 1988) by comparing its bar velocity curve with that already published of the galaxies NGC 936 (Kormendy 1983, Fig. 4b, NGC 6684 (Bettoni and Galletta 1988, Fig. 5) and NGC 2983 (Bettoni et al. 1988, Fig. 4). Similar shapes were detected also in NGC 1574 and NGC 4477 (Jarvis et al. 1988), as well as in NGC 7079. In all these galaxies the velocities rise from the nucleus outward, then reverse their direction reaching minimum (or negative) values and turn back to increase their amplitude, reaching near the end of the bar the values of the general velocity field (Fig. 2). This velocity profile might oscillate around zero (systemic velocity) for galaxies with bar close to the apparent disk minor axis (e.g. NGC 6684) or might be superimposed to the main rotation, if the bar is closer to the major axis (e.g. NGC 936). This trend must not be confused with local minima of the rotation curve which appear outside the

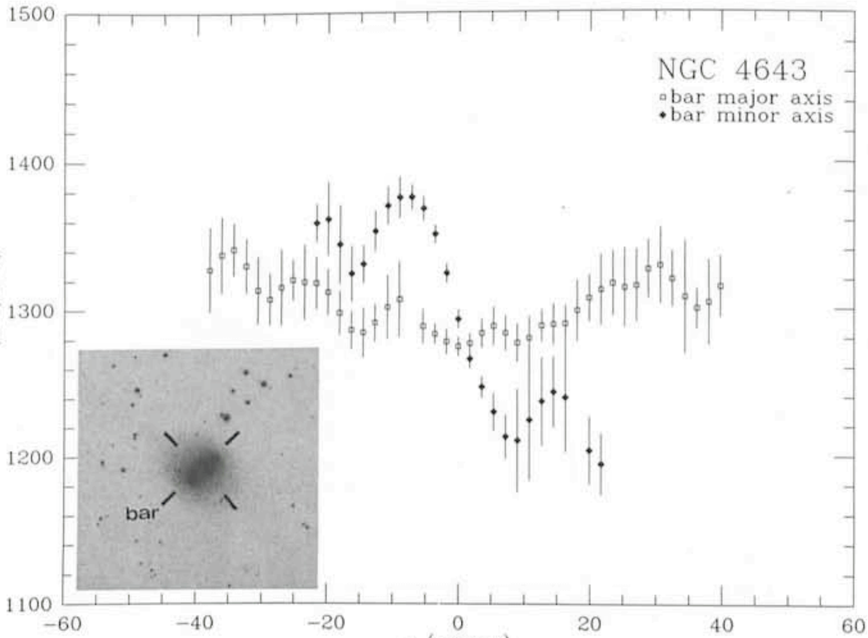


Figure 3: *Velocity curves for the face-on galaxy NGC 4643 (shown in the inset), after a gaussian smoothing of 2". Along the bar, only an asymmetric pattern is visible (open squares) with oscillations of ~ 40 km s^{-1}. On the contrary, the velocity increases as the spectrograph slit is twisted away from the bar going toward the minor axis (full diamonds). At this P.A., symmetric motions with an amplitude of 160 km s^{-1} are detected. Due to the orientation of the galaxy, these motions should be perpendicular to the galactic plane.*

bar where the bulge fades in the lens or in another component, as is the case of NGC 3945 (Kormendy 1982, Fig. 3) and NGC 2983 itself, where the two phenomena are present (Bettoni et al. 1988, Fig. 4).

On the contrary, no wavy trend around the systemic velocity was detected in NGC 4546 (Galletta 1987), in NGC 1543 and NGC 4754 (Jarvis et al. 1988) or in the two remaining galaxies of the sample so far reduced (see Table I). As an intrinsic feature, the observed wavy trend around the systemic velocity should be due to the presence of retrograde stellar streamings confined to some radii along the bar. A similar feature is expected in many models of barred galaxies which need some amount of retrograde motions. Among these the Freeman (1966a, b) homogeneous bar model, the N-body simulation by Zang and Hohl (1979) and the self-consistent model by Pfenniger (1984a, b). The last study suggests that three-dimensional stellar motions within a barred galaxy should periodically reverse the sense of rotation because of vertical instabilities. In addition, there is the possibility that these motions are produced by a combination of bar and disk streamings in some sectors of the galaxy plane, as suggested by L. Sparke (private communication) on the basis of the analysis of an N-body model of a barred galaxy (Sparke and Sellwood 1987). A more detailed analysis of this property is in progress, but a clear picture will be available only when (and if) the observations of a larger galaxy sample are performed. At this moment we can only say that this effect is observed only in galaxies with inclination between 28° and 53°, lacking in almost face-on or edge-on systems.

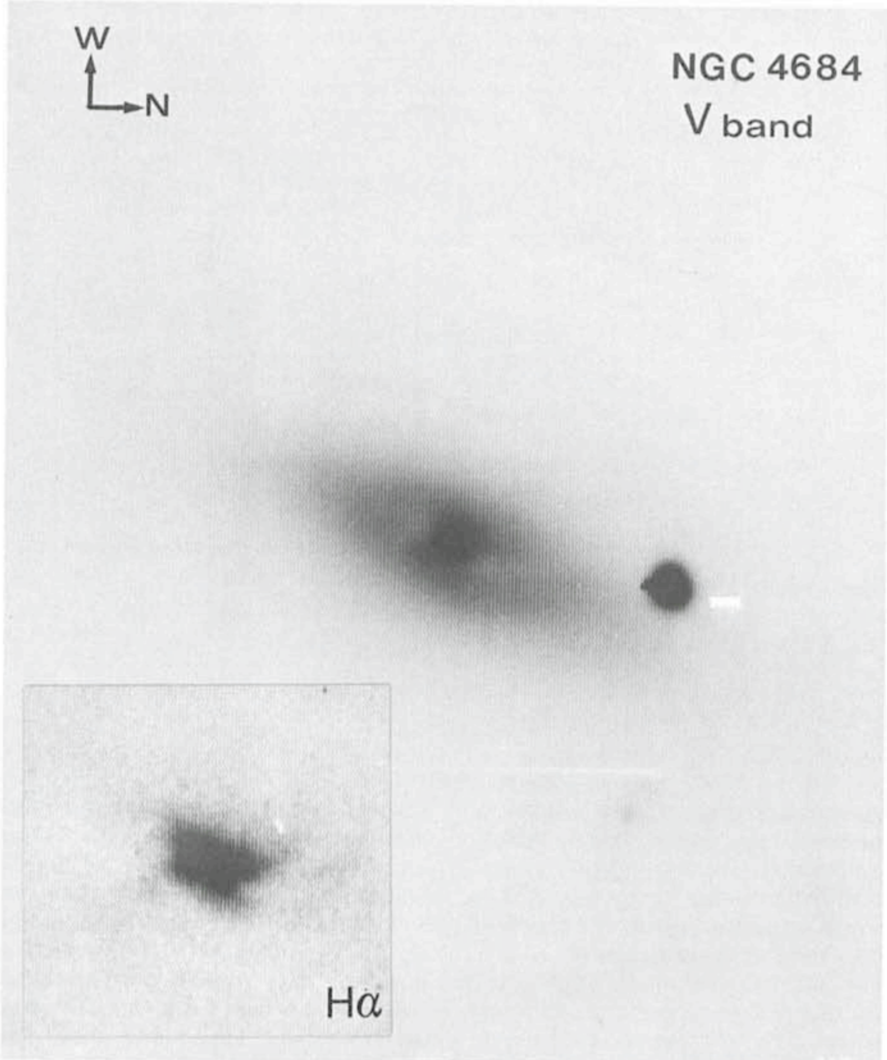


Figure 4: *The inner regions of NGC 4684, in a CCD frame (V band) taken at the 1.5-m Danish telescope. The bar is seen side-on, along the galaxy major axis. In the inset, the nucleus of the galaxy, at the same scale, observed in Hα light. The continuum near Hα has been subtracted. Dust lanes, spiral arms and filaments are visible.*

Stellar and gas streaming perpendicular to the galaxy plane was detected. This is another unexpected point, since it is generally believed that the main part of ordered motions takes place parallel to the main galactic plane. On the contrary, it has been observed in all the 6 almost face-on galaxies considered (see Table I). In the case of NGC 4643, for instance, the velocities along the bar are quite low (~ 40 km s^{-1}), while a wide rotation along the bar minor axis is present, with velocity differences of 160 km s^{-1}) (Fig. 3). A similar condition is present in NGC 1574 (Jarvis et al. 1988) and NGC 2217, while comparable amounts of rotation in both axes were detected in NGC 1543, and NGC 4477 (Jarvis et al. 1988). In some of these cases, this effect should be due to a not fully face-on orientation of the galaxy and/or to the fact that the bar's minor axis is close to the major axis of the disk. Looking at Table I, this could be the case of NGC 1574, NGC 4477 and may be NGC 2217, whose isophotal axial ratio is close to 0.9 (~ 27° of inclination for disks as flat as 0.25). But this hypothesis cannot explain the not negligible velocities found in NGC 1543 and NGC 4643, as well as the amplitude of that observed in the remaining galaxies.

As discussed previously, the gas in NGC 2217 should stream in one of the two possible families of anomalous orbits (see Schwarzschild, 1982), while this hypothesis is less plausible for the stellar motions, distributed in a wider range of energies and not streaming according to a specific orbit. It would be interesting to know if unbarred galaxies also share this property, but until now all requests for observing time on this problem have been rejected. In any case, this feature must be clarified also from the theoretical point of view, having interesting implications on the distribution of the angular momentum in a stellar system since its protogalaxy phase.

Many bars have flat velocity dispersion profiles. In 7 systems over 12 the bar velocity dispersion is characterized by a constant trend, with the peak of the bulge velocity dispersion eventually superimposed. An example of this effect is offered by NGC 6684 (Bettoni and Galletta 1988) or by NGC 4477 (Jarvis et al. 1988). This could indicate that the bars are uniformly hot. A more detailed analysis is necessary to answer this point.

3.2 Photometry and Hα imaging

Many systems have elongated or triaxial components. This agrees with the results of statistical works on rings and bulges (Kormendy 1979, Athanassoula et al. 1982, Buta 1986). A typical collection of these properties is represented by NGC 6684 (Bettoni and Galletta 1988). In this galaxy, the ring is elongated parallel to the bar, in a direction close to that of the line-of-sight. This gives the system the unusual aspect of a galaxy with a ring rounder than the disk. But the bulge also is triaxial. Its isophotes are not aligned at the same P.A. of the disk and the observed stellar motions appear to have a "kinematical line of the nodes" not coincident with the disk major axis, both typical signs of triaxiality. In addition, the bar appears displaced by $\sim 2''$ from the nucleus of the galaxy along its major axis. Off-centring of the bar (but along the bar's minor axis) is actually observed in some barred galaxies, but generally appears in late spirals, as NGC 4027 (Christiansen and Jefferys 1976, Pence et al. 1988). But with respect to the remaining galaxies of the sample, the offset of the NGC 6684 bar is quite a peculiar feature.

Short and smooth spiral arms, sometimes forming an incomplete ring, appear in some of the studied systems, such as NGC 2983, NGC 4546 and NGC 6684. This feature is brought into evidence by means of a decomposition of the images in the main galaxy components, performed by means of IHAP (see Bettoni et al. 1988). This procedure also indicates that in our sample the bars contain less than 20% of the total light.

The gas in the SB0s observed is concentrated in disks or in complex structures with spiral arms. The Hα imaging of some of the galaxies considered, which possess ionized gas (6 out of 11), indicates a spiral or a not relaxed structure. NGC 2217, for instance, has faint spiral arms in a structure that should be perpendicular to the bar's major axis. This structure recalls the gas in the warped plane which crosses the minor-axis dust-lane galaxies (Bertola and Galletta 1978) and seems to confirm the assumption made previously concerning matter in anomalous orbits. The more extended and complex structures observed in NGC 4546 and NGC 4684 (Fig. 4) represent two more cases of gas whose irregularity strongly suggests a recent acquisition from the outside. Again, as indicated by Wardle and Knapp (1986) for the neutral gas, there are indications of an external origin of most of the gas in S0 galaxies.

This work is dedicated to our daughter Anna, who decided to be born during the drafting of this paper.

References

Athanassoula, E., Bosma, A., Crézé, M., Schwartz, M.P., 1982, *Astron. Astrophys.* **107,** 101.

Barbon, R., Benacchio, L., Capaccioli, M., 1975., *Astron. Astrophys.* **51,** 25.

Bertola, F., Bettoni, D., Rusconi, L., Sedmak, G., 1984, *Astron. J.,* **89,** 356.

Bertola, F., Galletta, G., 1978, *Astrophys. J.,* **226,** L 115.

Bettoni, D. and Galletta, G., 1988, *Astron. Astrophys.,* **190,** 52.

Bettoni, D., Galletta, G. and Vallenari, A., 1988, *Astron. Astrophys.,* **197,** 69.

Bettoni, D., 1988, *Astron. J.,* submitted.

Buta, R., 1986, *Astrophys. J. Suppl. Ser.,* **61,** 609.

Contopoulos, G. and Papayannopoulos, Th., 1980, *Astron. Astrophys.,* **92,** 33.

Christiansen, J.H. and Jefferys, W.H., 1976, *Astrophys. J.,* **205,** 52.

Freeman, K.C., 1966a, *Mon. Not. R. Astr. Soc.,* **133,** 47.

Freeman, K.C., 1966b, *Mon. Not. R. Astr. Soc.,* **134,** 1.

Galletta, G., 1986, *The Messenger,* **45,** 18.

Galletta, G., 1987, *Astrophys. J.,* **318,** 531.

Heisler, J., Merrit, D., Schwarzschild, M., 1982, *Astrophys. J.,* **258,** 490.

Jarvis, B.J., Dubath, L., Martinet, R. and Bacon, R., 1988, *Astron. Astrophys.,* in press.

Kormendy, J., 1979, *Astrophys. J.,* **227,** 714.

Kormendy, J., 1982, *Astrophys. J.,* **257,** 75.

Kormendy, J., 1983, *Astrophys. J.,* **275,** 529.

Kormendy, J., 1984, *Astrophys. J.,* **286,** 132.

Longo, G., de Vaucouleurs, A., 1983, University of Texas Monographs, N. **3.**

Pence, W.D., Taylor, K., Freeman, K.C., de Vaucouleurs, G., and Atherton, P., 1988, *Astrophys. J.,* 134.

Pfenninger, D., 1984a, *Astron. Astrophys.,* **141,** 171.

Pfenninger, D., 1984b, *Astron. Astrophys.,* **134,** 373.

Sargent, W.L.W., Young, P.Y., Boksenberg, A., Shortridge, K., 1977, *Astrophys. J.,* **212,** 326.

Schwartzschild, M., 1982, *Astrophys. J.,* **263,** 599.

Schweizer, F., Whitmore, B.C., and Rubin, V.C., 1983, *Astron. J.,* 88, **909.**

Sparke, L.S. and Sellwood, J.A., 1987, *Mon. Not. R. Astr. Soc.,* 225, 653.

Teuben, P.J., and Sanders, R.H., 1985, *Mon. Not. R. Astr. Soc.,* **212,** 257.

van Albada, T.S., Kotanyi, C.G. and Schwarzschild, M., 1982, *Mon. Not. R. Astr. Soc.,* **198,** 303.

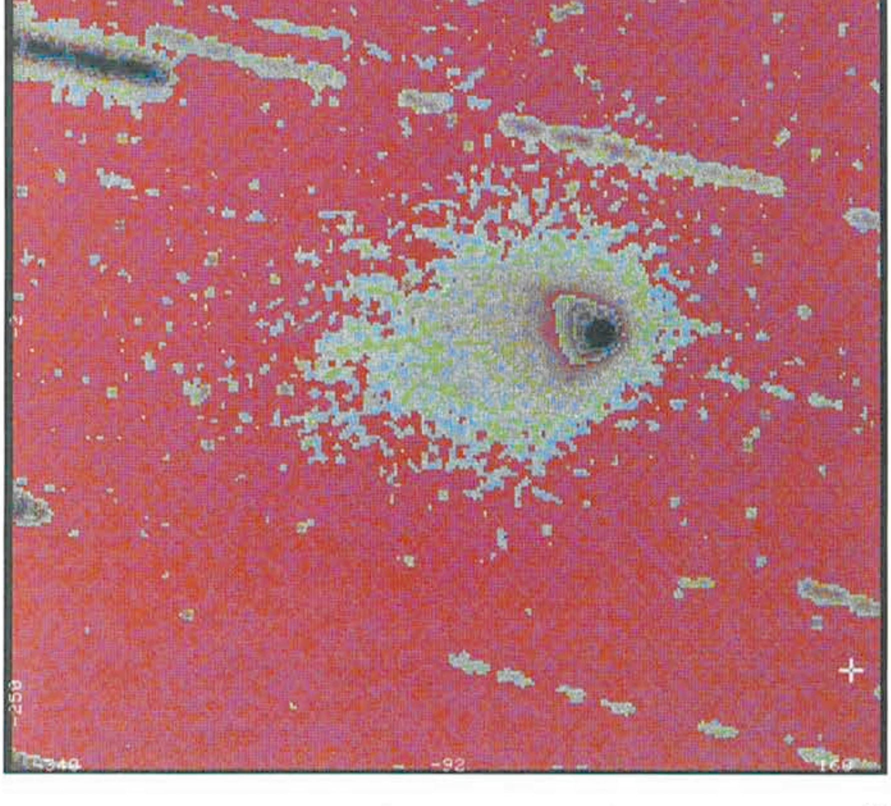
Wardle, M. and Knapp, G.R., 1986, *Astron. J.,* **91,** 23.

Zang, T.A. and Hohl, F., 1979, *Astrophys. J.,* **226,** 521.

Comet Tempel 2 Turns On

Earlier this year, observers all over the world began to observe Comet Tempel 2, a prime object for the NASA Comet Rendezvous Asteroid Flyby mission (CRAF) in 1993. This short period comet (P = 5.29 years) was first observed in 1873 and has since been seen at no less than 18 apparitions.

This time it was recovered already in December 1986, by Tom Gehrels and his collaborators with the Spacewatch camera. At that time the heliocentric



distance was over 4 Astronomical Units.

From earlier apparitions, it is known that the onset of activity is rather abrupt, normally about 60–80 days before perihelion, but at least once (in 1951) up to 100 days before. Since the perihelion would be passed on September 16.7, 1988 this time, it was expected that this turn-on would happen in June, or perhaps already in late May. This means that the cometary nucleus has been heated sufficiently to enable gas and dust to escape, so that a coma and a tail are created.

Observations from Kitt Peak on April 9–15, 1988 by D. Jewitt and J. Luu, still showed an stellar-like image of the comet nucleus. However, as can be seen on the picture, CCD images obtained on May 16 and 17 with the Danish 1.5-m telescope clearly show that the activity has started: the comet is surrounded by a diffuse coma, which extends over 1 arcmin or more. The active phase must therefore have started rather early this time, at least 104 days before perihelion.

The picture, which is a composite of eleven 10-minute exposures through a Johnson V filter on May 17, has a field of $\sim 2.0 \times 2.0$ arcmin^2. North is up and East is to the right. On this date, Tempel 2 was 135 million km from the Earth and the heliocentric distance was 278 million km. The magnitude of the central, bright part was about 17.

In the meantime, as reported by several journals (e.g. *Sky and Telescope*, September 1988, page 236), unfortunately no funding was received for CRAF in fiscal year 1989. This means that the launch will have to be delayed to the fall of 1994 and that therefore another comet will have to be targeted, probably Comet Wild 2. *R. M. WEST*

First Infrared Images with IRAC

A. MOORWOOD, G. FINGER and A. MONETI, ESO

Following its installation and first test in July, a second test of the new infrared array camera has just been completed at the 2.2-m telescope. Having returned after the official deadline we have not had time to prepare a very detailed article for this *Messenger*. We nevertheless wanted to take this opportunity to show a selection of images illustrating the kinds of results being achieved in the various camera modes and also to draw the attention of potential users to a problem with the detector which has developed since the Announcement for period 43 was issued.

As described in the June issue of the *Messenger* (**52,** 50) IRAC provides for infrared imaging in the standard J, H, K, and L filters and offers two novel features compared with existing common user cameras elsewhere – on line selection of four magnifications between 0.3 and 1.6 arcsec. per pixel and the provision of circular variable filters

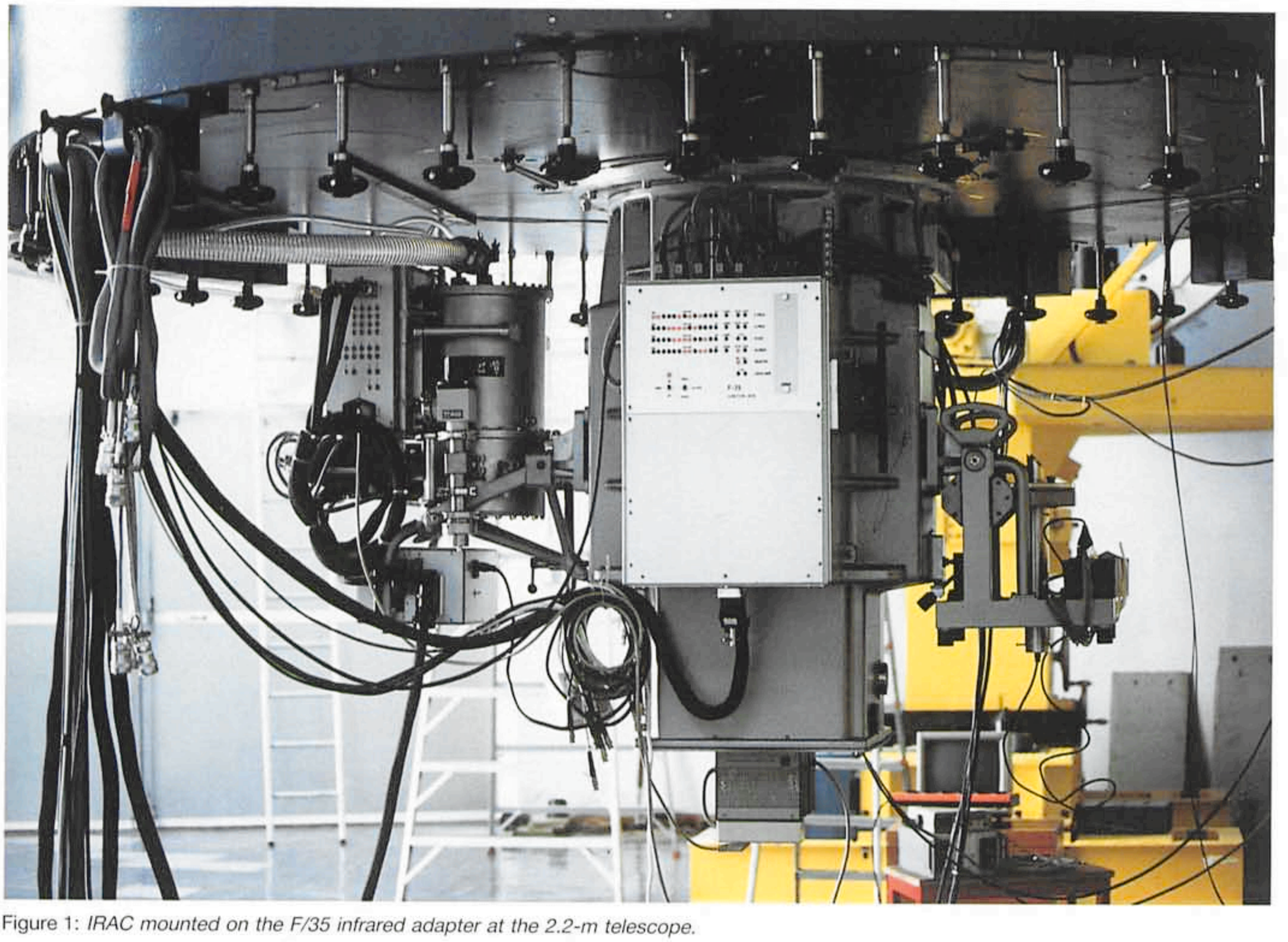


Figure 1: *IRAC mounted on the F/35 infrared adapter at the 2.2-m telescope.*

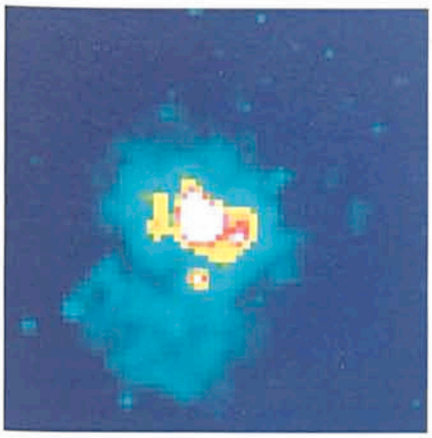


Figure 2: *The HII region G 333.6-0.2. K (2.2 μm) band; 0.8 arcsec/pixel; average of 10 40-s exposures; sky subtracted; median filtered.*

(CVF) for narrow band imaging at R ~ 50. No real problems with the camera itself or its associated electronics and software have been experienced so far. The detector used in July was a 64 × 64 pixel Hg : Cd : Te/CCD array (Philips Components) with a long wavelength cutoff around 4.7 μm, very good read noise (~ 400 e) and average dark current (~ 1000 e/s at 47 K) characteristics and a large well capacity ($7 \cdot 10^6$ e). Unfortunately, about 10 % of the pixels scattered over the array exhibit excess dark current and saturate after relatively short integration times spoiling the appearance of the raw images. They are rather easy to remove during image processing, however, either by median filtering or by combining two images shifted by a few pixels. This latter is quite straightforward using the lens wheel in IRAC which provides a more accurate (0.1 pixel) means of displacing the image than moving the telescope. With on-chip integrations of 10 minutes and equal numbers of alternate source and sky exposures the actual 3 σ detection limits achieved in 1 hour of observing time were J ~ 20.5, H ~ 20, K ~ 19.5 mag per pixel and the faintest sources actually measured were the components of the double quasar Q 1548+114 A, B at K ~ 17 and 17.5 mag (~ 1 % of the sky). As expected, the well capacity also proved sufficient for broad band imaging at L (3.8 μm) and even M (4.7 μm).

Unfortunately, by October this array was found to have mysteriously developed a new fault in the form of several lines of saturated pixels on alternate columns starting at one side and extending over about a quarter of the array. The rest was still useable but, as planned already in advance, this array was exchanged after a few nights for another with a 2.3 μm cutoff which it was of interest to test for future applications. This array exhibits a factor of 10 lower dark current and relatively few saturated pixels but is only 32 × 32 and cannot, of course, be used longward of the K band. The cause of the degradation of our 64 × 64 array is still not known although some type of surface contamination is a possibility, in which case its performance can probably be restored by a special cleaning technique.

As only very few of the October data have been reduced, the images shown here were all obtained with the 64 × 64 array in July except for Jupiter, observed with this array in October, and NGC 1097 (32 × 32). The only "cleaning" applied has been the application of

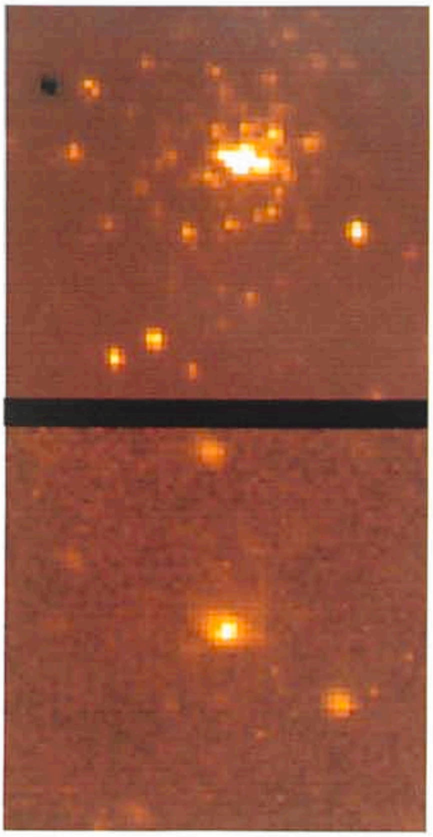


Figure 3: *The HII region NGC 3603. Upper panel – K band; 0.8 arcsec/pixel; average of 8 40-s exposures; sky subtracted; median filtered. N.B. the black spot is due to a star in the sky reference field. Lower panel – L (3.8 μm) band; 0.8 arcsec/pixel; average of 60 1-s exposures made with sky chopping at the F/35 secondary mirror.*

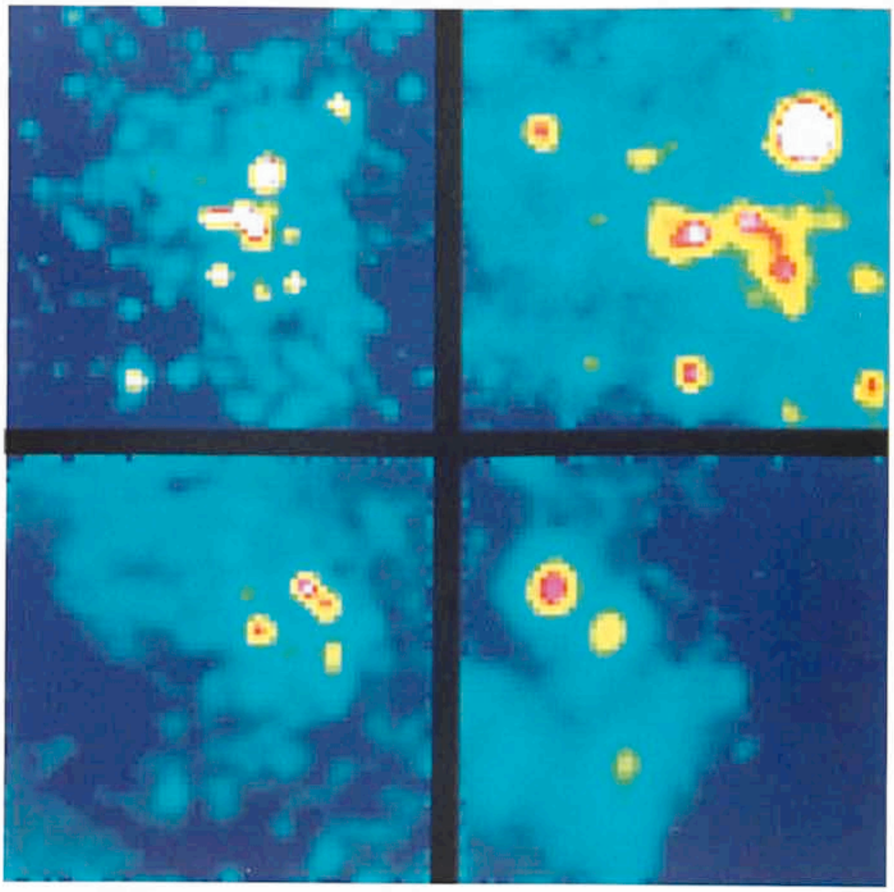


Figure 4: *The Galactic Centre. Upper panels – K band; 0.8 arcsec/pixel (left) and 0.3 arcsec/pixel (right) to show effect of zooming; combination of two 300-s exposures shifted by 3 pixels (see text); divided by sky. Lower panels – L band; same scales as upper panels but slightly displaced due to lack of co-centring between the differently coated lenses used at K and L. This can be avoided by using the same lens with a slight loss of efficiency in one of the bands; average of 125 1-s exposures without sky chopping; divided by sky.*

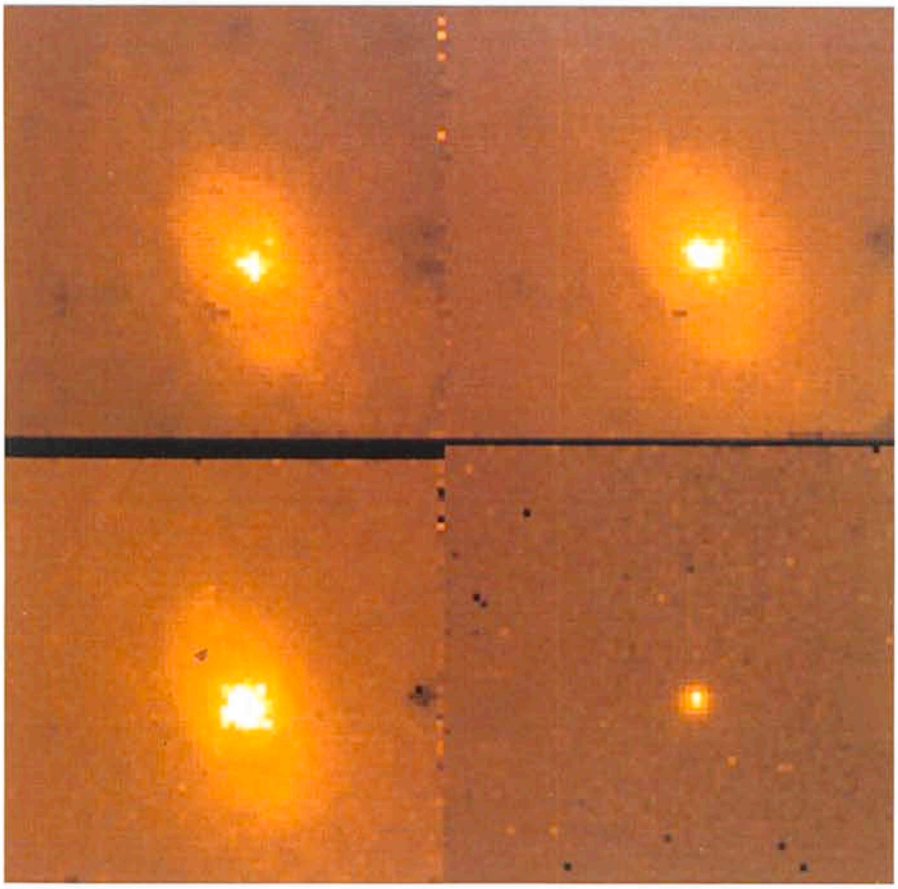


Figure 5: *The galaxy A 1409–65. J (1.25 μm) (upper left), H (1.65 μm) (upper right), K (2.2 μm) lower left); 0.8 arcsec/pixel; average of 4 40-s exposures; combination of images shifted by 3 pixels; sky subtracted. L band (lower right); 0.5 arcsec/pixel; average of 140 1-s exposures with sky chopping at the telescope secondary mirror. Note the point-like nucleus at L whose size has been estimated at 0.3 arcsec using 1 D speckle techniques at the 3.6-m telescope (Moorwood, Véron-Cetty and Perrier, in preparation).*

Figure 6: *Jupiter (Oct. 88). 0.8 arcsec/pixel; sky subtracted; median filtered with high threshold. Upper panel – K band. Middle panel – CVF at 2.07 μm. Lower panel – CVF at 2.12 μm showing effect of pressure induced absorption by molecular hydrogen in the planetary atmosphere. Note the appearance of a moon on the right side in the CVF images which were taken later than that in K.*

a median filter or the replacement of bad pixels using two images displaced by 3 pixels as described above. Some of the images have been flat fielded by ratioing with the sky while in others the sky has only been subtracted. The actual observing parameters and reduction procedure used in each case are specified in the figure captions.

Having offered IRAC in period 43 on the basis of the July test results we are now in the unfortunate position of not knowing exactly which array will be available at that time. The 64 × 64 array has to be returned to the manufacturers who have promised to do their best either to restore its performance by surface cleaning or to replace it with a detector of comparable performance. An improved array is also not excluded, depending on the results of a new Hg : Cd : Te production technique developed specifically to improve the uniformity and reduce the fraction of bad pixels.

At the moment therefore we remain confident of being able to offer our first Visiting Astronomers at least the performance as advertized and illustrated here.

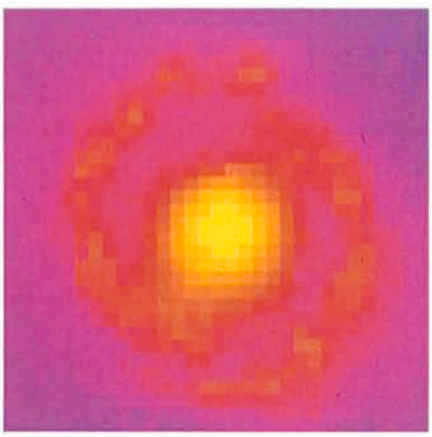


Figure 7: *Nuclear region of the galaxy NGC 1097. 32 × 32 array; K band; 0.8 arcsec/pixel; average of 5 60-s exposures; median filtered (but almost identical to raw image); divided by sky. Note that the "spiral arms" are composed of star forming regions within about 10 arcsec of the active nucleus.*

MIDAS Memo

1. Application Developments

The astrometric package is currently being developed. Coordinate transformations as well as usual coordinate projections can be performed on tabular format. The plotting package has been extended with commands to draw coordinate grids in different geometric projections. Also, some basic commands have been added to increase the flexibility of the package. For the same purpose the SET/PLOT command is enhanced: the user now has full control over the size of the plot symbols and can produce publication quality plots. In the ASSIGN/PLOT, SEND/PLOT and SET/PLOT an option has been built in to produce plots on a PostScript laser printer (see below).

The upgrade of ROMAFOT to the portable version of MIDAS is nearing completion. This includes several significant improvements of the package such as proper handling of undersampled images which is essential for EFOSC data and eventually also for HST images.

INVENTORY is now in the process of being migrated to the portable MIDAS and at the same time is being improved in a number of aspects.

2. Portable MIDAS

The 88NOV release of MIDAS is the first to support multiple operating systems namely, VAX/VMS and a long list of UNIX like systems. It has been implemented on machines from DEC, IBM, SUN, Apollo, Nixdorf, PCS, Stellar, Bull, Tektronix, and Masscomp. This first release contains almost all basic MIDAS commands although some of the application contexts are not yet available. This refers to a few very complex packages such as INVENTORY, ROMAFOT, CCD and Long Slit. They are expected to be ready for a minor MIDAS release 89FEB which will be sent out to sites that have the 88NOV version. This minor release will also resolve bugs and problems reported by users. The 88NOV release includes several improvements e.g. upgraded plotting routines, standard IDI routines, a terminal independent interface and a package for IRSPEC reductions.

The graphics commands use the portable version 3.2 of the Astronet Graphic Library (AGL) which supports a large variety of devices such as TEK 4010/14, VT 640, PostScript and X Window systems V 10.4 or V 11. Since we have only recently had access to version 11 of X Window, the 88NOV release only provides IDI routines for Gould IP8500 and X Window V 10.4. MIDAS will, however, support version 11 of X Window as a standard for work-stations. Institutes with other image display devices should upgrade their IDI implementation to the standard. Another component which varies significantly from system to system is the interface to magnetic tapes. This may have to be rewritten at the individual sites.

3. MIDAS Hot-Line Service

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

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

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

ESO Image Processing Group

MIDAS Benchmarks of Work-Stations

P. GROSBØL, K. BANSE, C. GUIRAO, D. PONZ, R. WARMELS, ESO Image Processing Group

1. Introduction

The number of computer systems on which MIDAS can be used has increased substantially with the introduction of the portable version. MIDAS is now available for both VAX/VMS and UNIX systems. This opens the possibility of using a large number of work-stations which offer many interesting features for astronomical image processing such as high performance per cost unit, integrated display options and good interactive response.

To improve the situation for interactive MIDAS users within ESO, it was decided to shift parts of the image processing from the VAX/VMS systems to work-stations. For this purpose, an early version of the portable MIDAS was implemented and tested on a wide variety of work-stations. A set of typical MIDAS applications were used to benchmark the performance of the different systems used in single user mode. These performance tests were done in the spring of 1988 and used to make a final decision for the purchase of image processing work-stations for ESO.

2. Work-Stations

A typical configuration of a work-station for interactive image processing with MIDAS consists of a 32-bit CPU with a floating point processor, 8 Mbyte main memory, 300 Mbyte disk, colour display with approx. 1000*800 8-bit pixels and an Ethernet interface. The software requirements are a UNIX or VMS operating system, X Window system for the display and standard compilers for Fortran-77 and C. A number of systems with roughly these specifications were tested. The systems are listed in Table 1 including their CPU type and operating system.

In addition to standard work-stations, a few larger systems were included for comparison e.g. VAX8600, Trace 14, Targon 35 and Alliant. MIDAS was implemented and tested on all the systems; the installations on the Trace 14 and the Alliant were done remotely over a modem line. The conditions for the benchmarks of these two machines were not well controlled and for this reason the results were omitted. For the IBM PC-RT 6150 system, only the basic installation and tests were performed, the actual benchmarks could not be made due to lack of time.

The tests were carried out at the vendor sites on demonstration models which meant that some variation in the actual configuration was unavoidable. The whole installation and tests were typically done in less than two days. For that reason it was impossible to spend time on optimizing the individual systems. It is estimated that differences in configuration and optimization may introduce up to 25% variation in the benchmark results.

3. Scope of Benchmarks

The benchmarks were made to measure the typical real time performance of interactive usage of MIDAS on single user work-stations. For this reason the tests included a number of actual, frequently used MIDAS applications. The important quantity for the user is how fast the different systems respond. This depends on the performance of the system in three main areas, namely:

1. scheduling of new application programmes,
2. speed of disk I/O operations, and
3. CPU power.

These quantities were measured with different MIDAS applications. Since MIDAS makes most calculations in single precision floating point, the CPU performance measured refers mainly to the operations with real values. The execution time of the benchmark procedures was measured in elapsed time since this indicated the interactive response of the system in single user mode.

It was not within the scope of these tests to derive absolute values for performance. The lack of optimization of the individual applications and general time constraints meant that the benchmarks could be used only as a relative measure of performance for the tested pre-release version of MIDAS. Better results can be achieved by tuning both the application programmes and systems parameters. The changes in the hardware configuration may also change the results in a non-linear manner. At the time of the tests, graphics and image display applications were not yet implemented. They were therefore not included in the benchmarks. The benchmark procedures will be further developed and improved to provide a standard performance test of MIDAS on computer systems. This implies that some tests may be modified in the future. Reference to the values presented here should therefore include the version number, i.e. MIDAS Benchmarks Version 0.9. The results cannot be used to estimate the performance of the systems with other packages than MIDAS due to differences in the usage of resources.

4. Benchmarks

Four of the 18 different benchmark procedures used are discussed here. They represent the general results of the benchmarks and indicate the performance of the systems with respect to CPU, I/O and scheduling. The four tests were:

1. Schedule. This procedure scheduled a simple MIDAS application which opened an image file and read a descriptor. This was repeated a total of 100 times. The execution of this test depends on the time it takes to schedule a new programme and access simple information in a file. This type of operation is done very frequently in MIDAS procedures and is therefore important to estimate how fast a system can perform long sequences of MIDAS applications. Since the actual task only accesses a single piece of information in the file, the elapsed time indicates the system overhead in executing applications and opening files.

2. Scaling. The scaling operation of an image involves access to the data, a multiplication and additions with constants, and finally the creation of a new file. A frame with 512*512 real pixels was used in this benchmark. This operation is used whenever an image is displayed. The speed of a simple arithmetic operation is in most systems so high that the performance is limited by the I/O rate of the disk. This test indicates the I/O bandwidth of a system which in turn shows how many data can be passed through in a given time.

3. Median. The median benchmark applies a median filter on a real image with 512*512 pixels. In contrast to scaling this task requires a significant number of operations per pixel and is thus limited by the CPU performance of the floating point unit. Although tasks of this type are executed less frequently in interactive sessions, it shows the basic speed with which any CPU demanding process can be executed.

4. Table. The benchmark performs a number of mathematical operations on a table with 13 columns and 10,000 rows. The calculations include arithmetic operations and trigonometric functions. Tables are often used during reduction of data in MIDAS. The efficiency of these functions is essential for the total through-put. Further, tables are used in the final analysis of data where the speed of interaction is crucial. Due to the size of the table used in the benchmark and the operation done, the time is set largely by the floating point CPU performance and only to a lesser extent by the I/O bandwidth.

The scaling and median tests were done also with larger images. For systems with main memory large enough to avoid swapping or paging, the elapsed times showed a linear increase. When this was not the case, a dramatic decrease in performance could be observed.

The benchmarks were, in most cases, executed several times and showed little variation. The results are given in Table 2 where the mean elapsed time in seconds is listed. Some values could not be obtained due to minor errors, time limitation and lack of disk space. Especially the I/O limited tasks (e.g. scaling) are sensitive to the fragmentation of the file system on which the data are located. This may introduce a systematic bias. Due to wrong compiler options in two tests (i.e. HP 350 and SUN 3/60) software floating point computations were used although hardware units existed. The Masscomp MC 5450 system can allocate contiguous files on disk which improves the I/O performance significantly. This option was not used since it is a real-time extension

TABLE 1: *Systems on which MIDAS has been implemented.*

Vendor-Model	CPU-type	Operating System
HP 9000-835	RISC HP-PA	HP-UX
HP 9000-350	MC 68020	HP-UX 6.0
Apollo DN 4000	MC 68020	Aegis
Apollo DN 590	MC 68020	Aegis
SUN 4/110	SPARC	SunOS 4/4.0
SUN 4/260	SPARC	SunOS 4/3.2
SUN 3/60	MC 68020	SunOS 3.5
Bull SPS 9/830	RISC-4	SPIX9 31.5
Tektronix TEK 4301	MC 68020	UTeK 2.4
Matra MS 1326	MC 68020	SunOS 3.4
Matra MS 1306	MC 68020	SunOS 3.4
Masscomp MC-5450	MC 68020	RTU
IBM PC-RT 6150-125	ROMP	AIX 2.1
Prime PXCL 5500	MIPS R2000	UNIX SysV 3.1
DEC μVAX II	VAX	Ultrix 2.0
DEC VAX 8600	VAX	VMS 4.7
DEC VAX 3500	VAX KA650	Ultrix 2.2
PCS Cadmus 9900	MC 68020	MUNIX 5.2
PCS Cadmus 9933/RC	MIPS R2000	MUNIX 5.2
Nixdorf Targon 35	RISC	UNIX SysV
Alliant FX/1	Alliant	Concentrix
Multiflow TRACE 14	WLIW	UNIX 4.3 BSD

to UNIX. The values for the VAX 8600 are given for comparison and were also obtained with a single user on the system.

5. Discussion

The results in Table 2 reflect the behaviour of the systems in three different aspects: Process scheduling in the first column, I/O bandwidth as scaling operation in the second column and floating point performance in the third column. The table operations included in the fourth column give an indication of both I/O bandwidth and floating point performances.

The times for process scheduling show a surprising spread with almost a factor of 10 between the fastest and slowest system. There is little correlation between the speed of starting a new task and general CPU performance. The Aegis and VMS operating systems have a significant lower performance than typical UNIX systems. This is especially odd in the case of VMS, since MIDAS executes application tasks differently for VMS and UNIX machines: In UNIX machines a child process is started and the task executed in the context of that subprocess. In VMS a subprocess is created only once, then, the applications are executed in the context of that subprocess. Therefore, the measured time for VMS is just the time for running an executable task in an existing subprocess, not for creating a child process as well.

The I/O bandwidth indicated by the scaling task depends on three major factors namely: physical speed of disk drive and interface, block size of the file system and implementation of hashing techniques. Due to the two latter factors, most BSD UNIX systems have at present a higher disk I/O performance than those based on SYS V. One of the exceptions is the Bull SPS9 system based on SYS V but using a very efficient disk controller. The SUN 3-4/260, VAX 8600, PCS and SPS9 used SMD type controllers with 8 inch disks which give higher performance than the SCSI or ESDI interfaces available on most other systems.

The single precision floating point performance is given by the median filter. It is interesting to see how the performance of relatively cheap work-stations slowly approaches that of machines like the VAX 8600. One may even argue that some work-stations have too high CPU performance compared to their I/O bandwidth when used for interactive image processing. The RISC machines usually have a much higher rate of executing instructions than CISC processors. This is not reflected in the benchmarks because they mainly measure the performance of the floating point co-processor.

For the evaluation of the total performance of the systems for interactive image processing the four quantities shown in Table 2 were used. The normalized performance for each test was defined as the median divided by the elapsed time given. The final rating was based on the mean of the normalized performances. This added more weight to the I/O performance than to CPU speed which is reasonable for interactive systems.

TABLE 2: *Benchmark results in seconds elapsed time.*

Vendor-Model	Schedule	Scaling	Median	Table	Remarks
HP 9000-835	33	13	33	34	
HP 9000-350	–	39	118	–	Software FP
Apollo DN 4000	167	14	–	47	
Apollo DN 590	142	13	–	50	
SUN 4/110	25	7	61	30	
SUN 4/260	30	8	41	22	
SUN 3/60	46	27	124	90	Software FP
Bull SPS 9/830	24	7	–	17	
Tektronix TEK 4301	97	15	–	46	
Matra MS 1326	40	11	–	32	SUN 3/260
Matra MS 1306	39	16	–	63	SUN 3/60
Masscomp MC-5450	73	20	–	79	Standard file system
Prime PXCL 5500	31	17	58	–	
DEC μ VAX II	115	30	157	89	
DEC VAX 8600	167	10	30	37	
DEC VAX 3500	38	11	51	44	
PCS Cadmus 9900	130	34	109	–	
PCS Cadmus 9933/RC	17	13	27	37	
Nixdorf Targon 35	39	10	45	15	

MIDAS Models Interstellar/Intergalactic Absorption Lines

M. PIERRE, D. PONZ, ESO

1. Introduction

Most of the current tools available in MIDAS, as well as in other image processing systems for Astronomy, are dedicated to the first step of data reduction which is to eliminate the instrumental signatures from the observations. This is clearly the main priority for such a system and continuous development is going on to support all the instruments available at La Silla. Very little effort has been dedicated to the complementary problem, the development of analysis tools to bring physical interpretation closer to the observed data. This article describes a new MIDAS context – CLOUD – that allows such an analysis, namely, to model the absorption of interstellar or intergalactic clouds as observed in spectroscopic data.

The programme models absorption features superimposed on a continuum which may also contain emission lines. The resulting output spectrum is computed at a given instrumental resolution and can therefore be used for a direct comparison with observations (provided the lines are resolved). This is particulary suitable for high resolution spectra, as observed by ESO instruments such as Caspec.

The main characteristic of the package is that, on the basis of astrophysical judgement and interpretation of results, the user can interactively determine the model parameters: the user elaborates on the model that will then be compared to the observations. No chi-square evaluation is performed by the programme which is then not to be considered as an extension of the fitting package.

The software will be available on an experimental basis in the next release of MIDAS and is also available in the portable version running under UNIX and VMS.

2. Description of the Method

The processes of formation of interstellar or intergalactic absorption lines can be simply described by atoms aggregated in discrete clouds along the line of sight, between the observer and an emitting source.

Each cloud is assumed to produce a single line whose position is determined by the mean velocity of the cloud and whose depth is related to the number of absorbers. Atoms within the same cloud have a certain velocity dispersion and therefore tend to broaden the line profile. In our case, we adopt a Maxwellian velocity distribution, purely thermal, so that $\sigma_v \alpha \sqrt{T}$. Moreover, because of the finite lifetime of the excited state of the corresponding atomic transitions, lines have also a natural intrinsic width. This phenomenon, while negligible with respect to thermal broadening for rather low column densities, tends to dominate when lines become saturated. The resulting absorption profiles are the so-called "Voigt profiles" and are those derived by the programme.

In addition to the commands which perform the calculations, the package contains:

- A catalogue of atomic constants, stored in a table which can be updated by the user.
- A table containing the user's guess for the cloud model; i.e., for each absorbing cloud: wavelength, column density, thermal width, atomic transition.
- A table containing parameters for possible gaussian emission lines to be added to the continuum.
- Coefficients for the continuum, assumed to be polynomial, and the definition of the sampling domain of the resulting images.

The modelling proceeds as follows:
1. Creation of the instrumental response (PSF), as a gaussian of given FWHM. It may be also any other experimental function supplied by the user.
2. Creation of a 1D image containing the continuum and possible emission lines.

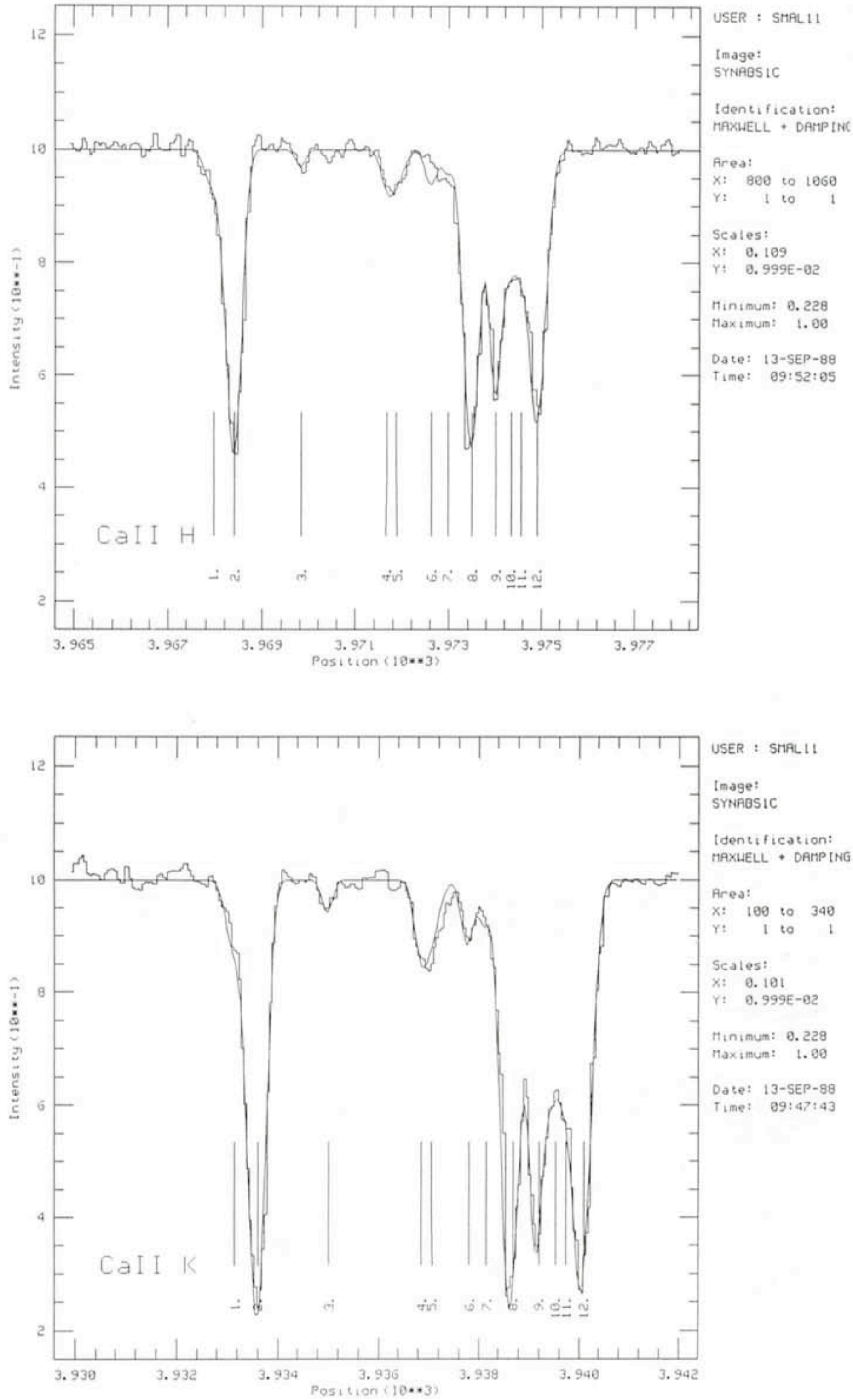


Figure 1 a, b: *Model (smooth line) for the H and K components compared with the observations (step function). The two components have been modelled simultaneously and corresponding line identifications are given in Tabel 1.*

3. Creation of absorption features on this image according to the cloud model table and convolution of this spectrum with the PSF.
4. Comparison of the resulting spectrum with observations. The user can then modify some of the input parameters and repeat the operations until the agreement is found to be satisfactory.

A complete description of the package is given in the forthcoming version of the MIDAS Users' Guide. An on-line tutorial, based on high resolution data, is also available.

3. An Example

As an example, we present here the modelling of the series of CaII absorption doublets in the spectrum of SN

1986 G in NGC 5128 observed with Caspec (D'Odorico et al. 1988).

The two images (components K and H of the doublet) have been pre-reduced so that the continuum is normalized to 1. Sampling is 0.05 Å per pixel and the instrumental resolution, 0.22 Å.

The final model consists of 12 absorption clouds (Table 1).

Figure 1 shows the resulting image convolved with a gaussian PSF of 0.22 Å FWHM, compared with the observations.

Comparison of these results with those derived by a similar package (STAR-LINK) shows complete agreement.

The example discussed here is also demonstrated in the MIDAS on-line tutorial.

TABLE 1. *Cloud model table.*

Seq. no.	VELOCITY	BVAL	N
1	−38.37775	13.00	0.5400 E+12
2	−4.395716	13.00	0.6600 E+13
3	+102.8715	5.000	0.1700 E+12
4	+241.7751	8.000	0.3000 E+12
5	+256.8906	15.00	0.5500 E+12
6	+313.5179	8.000	0.4000 E+12
7	+339.8785	7.000	0.2500 E+12
8	+379.1504	13.00	0.6300 E+13
9	+418.3698	11.00	0.4300 E+13
10	+443.2433	8.000	0.1300 E+13
11	+459.1050	4.500	0.8000 E+12
12	+486.2531	16.00	0.6300 E+13

Column 1: velocity of the clouds in km/s.
Column 2: broadening parameter ($\sqrt{2kT/m}$) in km/s.
Column 3: column density in number of atoms/cm^2.

Acknowledgements

The programme ALAS developed by M. Pettini was a source of inspiration during the design of our package.

We are indebted to S. D'Odorico for providing the data used in our example, and thank D. Baade for useful suggestions.

References

D'Odorico, S., di Serego Alighieri, S., Pettini, M., Magain, P., Nissen, P.E., Panagia, N.: 1988, submitted to *Astronomy and Astrophysics*. "A study of the interstellar medium in line to NGC 5128 from high resolution observations of the supernova 1986G."

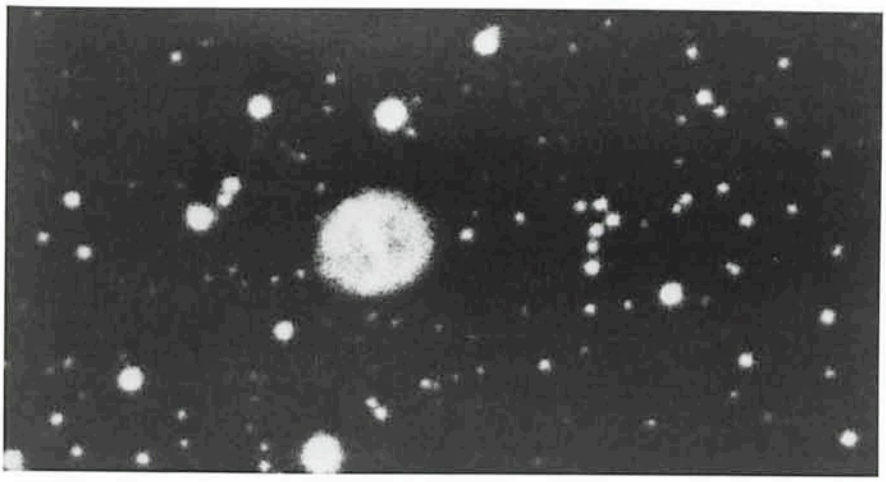
ESO Book Now Available in Five Languages

With the publication of French and Spanish versions now planned before the end of the current year, and a second edition in Danish – the first one was sold out in less than two months last year –, the ESO Book "Exploring the Southern Sky" will soon become available in five languages.

The publishers are: Danish (Rhodos; Copenhagen), English (Springer Verlag; Berlin, Heidelberg, New York), French (Les Editions de Physique; Paris), German (Birkhäuser Verlag; Basel, Boston), and Spanish (Equipo Sirius; Madrid).

TO ALL READERS

Please make sure that the card which accompanies this issue of the *Messenger* is returned, if you want to continue to receive the journal. *The editors*



A Celestial Riddle . . .?

Look at this picture, reproduced from one the ESO Schmidt plates obtained for the red half of the joint ESO/SERC Atlas of the Southern Sky. The bright, round object is the planetary nebula PK 274 +3°.1. The object to the right of it is . . . just some galactic stars.

Is somebody trying to tell us something?

STAFF MOVEMENTS

Arrivals

Europe:

PÉRON, Michèle (F), Astronomical Applications Programmer

SCHNEIDER, Karin (D), Secretary

SLATER, Roswitha (D), Accounts Clerk

VAN DE SPRENG, Jacob (NL), Project Control Officer

Chile:

GEMPERLEIN, Hans (D), Infrared Instrumentation Engineer

GUNNARSSON, Lars (S), Associate (Microwave Engineer SEST)

NYMAN, Lars (S), Associate (Telescope Scientist SEST)

Departures

Europe:

ARSENAULT, Robin (Canadian), Associate

IOVINO, Angela (I), Fellow

BUONANNO, Roberto (I), Associate

Chile:

MAUGIS, Michel (F), Electronics Technician

Christian Perrier Receives Award

On October 19, 1988 Christian Perrier received the "Prix DIGITAL – Societé Française des Spécialistes d'Astronomie" for his outstanding research in infrared interferometric imaging. The price is awarded to young scientists, less than 37 years of age, who have a record of scientific research of high quality and of international stature. Much of Perrier's work has been done with-in ESO. He spent three years at La Silla as a French Coopérant and ESO Fellow and one year thereafter at Garching putting into operation the ESO Infrared Specklegraph and its data reduction software. Several ESO *Messenger* articles have reported on his work. ESO is proud of Christian Perrier's success and congratulates him on this well deserved award. *J. BECKERS*

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where thirteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. A 3.5-m New Technology Telescope (NTT) will become operational in late 1988 and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, FRG. It is the scientific-technical and administrative centre of ESO, where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyze their data. In Europe ESO employs about 150 international Staff members, Fellows and Associates; at La Silla about 40 and, in addition, 150 local Staff members.

The ESO MESSENGER is published four times a year: normally in March, June, September and December. ESO also publishes Conference Proceedings, Preprints, Technical Notes and other material connected to its activities. Press Releases inform the media about particular events. For further information, contact the ESO Information Service at the following address:

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

The ESO Messenger:
Editor: Richard M. West
Technical editor: Kurt Kjär

Printed by Universitäts-Druckerei
Dr. C. Wolf & Sohn
Heidemannstraße 166
8000 München 45
Fed. Rep. of Germany

ISSN 0722-6691

Mi visita a La Silla

El Director General de la ESO, Harry van der Laan, me invitó a La Silla como consultor durante el período de la realuminización y el ajustamiento óptico del telescopio Schmidt de la ESO. Esta invitación me alegró mucho porque no sólo me dio la oportunidad de estar un tiempo en el telescopio Schmidt, sino también de encontrarme con muchos amigos en Chile. Ya en el aeropuerto de Tobalaba en Santiago, a la salida hacia la montaña, me encontré con algunos de mis antiguos colegas, Daniel Hofstadt y su esposa Sonia, Wolfgang y Suse Eckert, Erich Schumann, Nelson Labrín, Bernardo León y al astrónomo francés François Spite. Mientras viajaba desde el aeropuerto de Pelícano hacia La Silla en un confortable coche, mis pensamientos remontaron al año 1964 cuando demoraba 5 horas y media a caballo desde Pelícano hasta La Silla.

La Silueta de La Silla ha cambiado considerablemente con la instalación del SEST y del edificio para el NTT. Eché de menos el telescopio suizo y lo vine a descubrir más tarde cerca de mi dormitorio. Creo que los astrónomos suizos deben de gozar la cercanía al hotel.

Fue lindísimo trabajar nuevamente junto a Hans Schuster, Guido y Oscar Pizarro en el telescopio Schmidt. La mantención realizada por el personal técnico caminó sin problemas. El único obstáculo fue el tiempo; duró bastante tomar las placas necesarias para los distintos tests. Sin embargo, logramos con éxito un bastante buen ajustamiento del telescopio.

Durante mi estadía en La Silla fui por primera vez a Coquimbo y La Serena con Erich Schumann para presenciar la compra de los comestibles. Vi con sorpresa las impresionantes cantidades de comida que se transportan semanalmente a la montaña. Uno casi no se da cuenta del trabajo involucrado hasta que se encuentra la comida servida.

Deseo agradecer a todos aquellos que me proporcionaron una estadía tan agradable en La Silla.

ANDRÉ MULLER

Contents