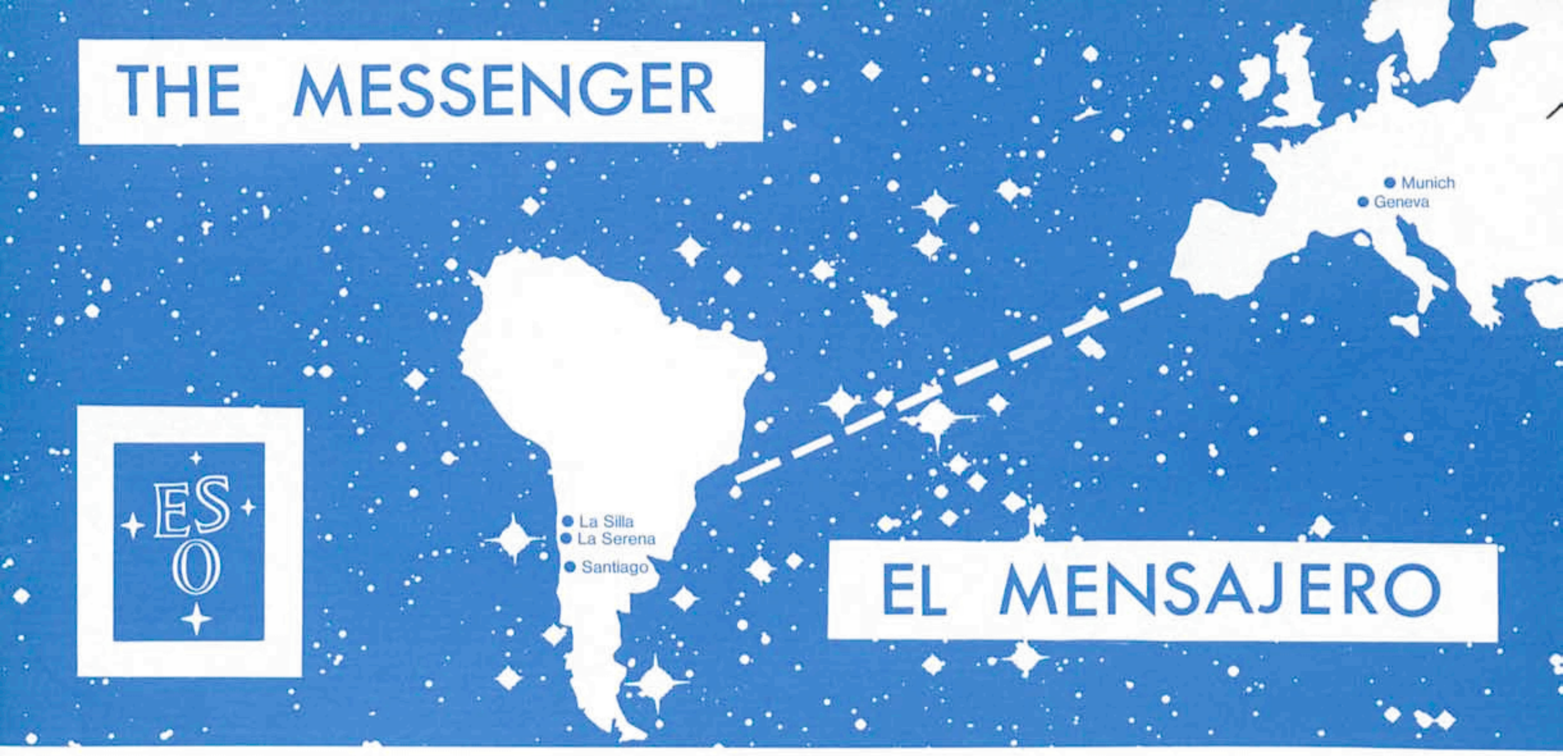

No. 18—September 1979

Radial Velocities of Visual Binaries

E. L. van Dessel

In addition to the initial chemical composition, the mass of a star is a fundamental parameter; it determines the life of the star from its birth, through its long or short period of luminous glory and to its inevitable end as a compact object. And yet, few stars have actually had their mass accurately measured. The programme that has recently been undertaken by Dr. Edwin van Dessel of the Royal Observatory in Brussels, Belgium, is therefore of particular importance. By obtaining precise measurements of radial velocities of stars in double or multiple systems, Dr. van Dessel expects soon to add new, well-determined stellar masses to the present, all to short list.

Observing visual binaries is one of the oldest arts in astronomy. Rather extensive series of observations of double stars have been published, e.g. by F. G. W. Struve (1837: Stellarum duplicum et multiplicium Mensurae Micrometriae, measures made at Dorpat; from 1839 on he observed in Pulkovo with a 15-inch refractor, then the largest in the world), by Mädler (also at Dorpat, Estland—now Tartu) or by Schiaparelli (1885, Milan). In his private observatory near Milan, later on in Gallarate, Baron Ercole Dembowski accumulated over 20,000 measures, published in collected form after his death (1881). Quite accurate measurements were performed with often very modest instrumentation.

With the observation of a double star we refer to the measurement of the position of the secondary star relative to the primary. The standard equipment has always been a filar micrometer attached to a long-focus refractor. The tradition is still being kept up, e.g. in Nice (Couteau, Muller, with two refractors of 74 cm und 50 cm aperture—the 74 cm has a focal length of 18 m), Washington (Worley, Walker—65 cm refractor), Sproul (Heintz—60 cm). Pairs separated by as little as 0.″10 have been measured.

The IDS catalogue of visual double stars contained some 64,000 stars when it was edited in 1963 by Jeffers and van den Bos; the discovery of visual pairs goes steadily on. For only about 800, however, enough observations have been collected to determine orbital elements.

As is well known, visual binaries are the only means of obtaining stellar masses, through Kepler's third law. The mass of a star being one of its basic parameters, it is clear that we would like to have as many of them determined as accurately as possible. Unfortunately, the formula which gives the total stellar mass

$$M_1 + M_2 = a^3/\pi^3 P^2$$

(*M* mass in solar units, *a* separation in arcsec, π parallax in arcsec, *P* orbital period in years) relies heavily upon the parallax. The observational parallax values are as a rule affected by too large errors to give a sufficiently precise mass determination. The quotient a^3/P^2 is in general much better determined, even if the observations do not cover an entire period (see e.g. Dommanget, 1971: *Astrophys. Space Sci.* **11,** 137). In most cases one resorts to statistical aid: the system is made to conform to the mass-luminosity relation; the corresponding parallax value is called the dynamical parallax. Individual masses M_1 and M_2 can be sufficiently well established, once the total mass is known, from the magnitude difference between the components. There is a way to obtain the complete set of information independently of statistical means, namely by combining visual and spectroscopic data.

All this is common knowledge, but there have been surprisingly few efforts so far to make spectroscopic observations of visual binaries and to acquire radial velocities of them with the aim of determining their mass. The main reason is probably that it is a rather ungrateful task, because of the slowness of orbital motion and consequently the long duration of such a programme. We may mention Victoria, Kitt Peak and, recently, Cambridge (England) as the most active observatories in the field.

The Programme: Mass Determination . . .

A programme of radial velocity observation of visual binaries was started by the author in 1977 at ESO. For practical reasons it would not be desirable to launch a programme that requires observations over one or more decades; but we shall try to show in the following that also on a shorter timescale (in the order of a few years time at a rate of 1 or 2 observing campaigns per year) very useful results may already be expected.

The ideal case is a binary for which the spectrum shows lines of both components. Even more ideal is the case where the star can be treated as a double-lined binary. There are but few examples—e.g. δ Equ or α Aur (Capella—actually a rather special case, because it ought to be called an interferometric binary rather than a visual one). However, for the purpose of mass determination one does not really need to cover the full radial velocity variation. If the visual orbit is known, one radial velocity value at the same instant for both components (or the radial velocity difference) suffices in principle to have an independent determination of the parallax and the total mass—but it pays, naturally, to have more measurements of the kind; the mass ratio between the components can be found independently from all other data if the velocity curves are well enough established to derive the amplitudes K_1 and K_2.

With the 152 cm telescope in coudé at a reciprocal dispersion of about 3 Å/mm, stars down to 6th–7th magnitude can be observed in a reasonable time. This gives us something like 10 double stars that ought to have, at present, a large enough radial velocity difference to be double-lined (Dommanget and Nys, 1967: *Catalogue d'Ephémérides,* Comm. Obs. Roy. Belg. No. B15; the new edition is expected in 1979). Some caution is indicated, because the predicted separation in radial velocity is based on the visual orbit; and of course the lines have to be sharp enough.

There are quite a number of visual binaries that during their orbital motion present a large radial velocity difference (Dommanget and Nys: 8 % has an amplitude $K > 20$ km/s). First of all the stars with relatively short period; typical values: P from 4 to 10 years, maximum velocity difference from 15 to 40 km/s. Another reason may be the large eccentricity: orbits with $e \approx 0.9$ are more common than is usually believed. Some stars have an uneventful radial velocity variation during decades and then go through a rapid phase near periastron. An example is shown in figure 1.

If the magnitude difference $\triangle m$ between the components is too large, say $\geq 0\overset{m}{.}8$, the binary will be single-lined. One then can still obtain the absolute dimensions of the system, combining the visual elements with the radial velocity measures, but the ratio M_2/M_1 will have to be derived from $\triangle m$ and the radial velocity variation one observes will be proportional to $M_2/(M_1 + M_2)$—i.e., will be small and hence subject to rather large relative errors. Our observing programme contains several systems going through a critical phase with peak radial velocity difference, as well as short-period pairs with marked radial velocity variation. These stars are observed at a reciprocal dispersion of 12 Å/mm, which is extremely well suited for accuracy and number of measurable lines.

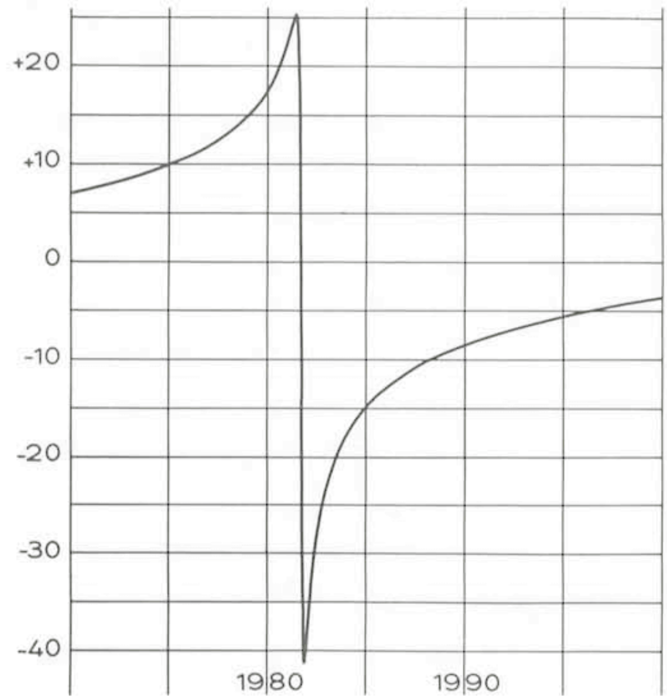

Fig. 1: *The radial velocity difference between the two components of the visual binary ADS 7662, which has an orbital period of 64.7 years and an eccentricity of 0.949 (Finsen, 1977).*

. . . and Related Problems

The actual programme is not aimed at a long-duration observation. If it were, one would be able to combine radial velocity and visual measurements and compute combined spectroscopic-visual elements. The computational techniques are available (e.g. Morbey, 1975: *P. A. S. P.* **87,** 689), but the observational material is still lacking.

There are other purposes, though, that may be served on a shorter timescale. One concerns the identification of the node: the visual orbital elements yield the node ☊ ± 180°. Given that the components are identified properly, a few radial velocity observations spaced sufficiently in time (and one can use older measurements for this purpose) may resolve the ambiguity in the plane of the orbit and allow us to decide whether the node is ascending or descending. This question may be of importance for statistical problems in our galaxy.

Another issue concerns the ambiguity that sometimes arises from visual measurements. Whenever the two components are of nearly equal magnitude, the visual observer is faced with an indetermination of quadrant and this frequently leads to two possible orbits. An example of such a case and the corresponding radial velocity curves are given in figure 2. It is clear that radial velocity observations ought to be able to decide between the two orbits.

Finally, there is an important subgroup among the visual binaries (of which we still consider only those with known orbital elements): those which are in fact triple or quadruple. In other words, visual pairs in which one component

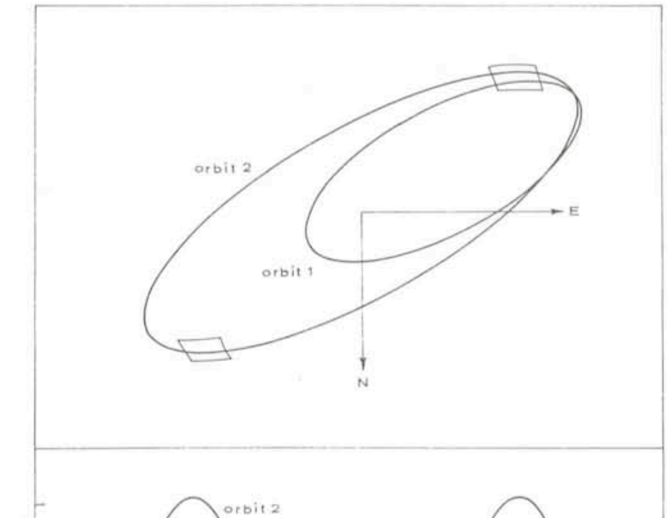

Fig. 2: *The case of B1909 (HR 108). Van den Bos calculated two equally possible orbits, the first with a period of 5.625 years (eccentricity 0.60), the second with a period of 11.25 years ($e = 0$). Both components are of magnitude 7.2. The two orbits as seen on the sky are shown in the upper part of the figure. A group of observations is indicated schematically by a quadrangle; because of the indetermination of quadrant (which star is the primary?) they are $\pm$ 180°. The relative radial velocity curves are shown in the lower part of the figure.*

or both are themselves spectroscopic binaries. These systems are interesting, because the statistics of their occurrence and their dimensions (mass and size) give us information about the formation of stars and stellar systems. In order to obtain a radial velocity curve for the visual pair, one has to determine the orbital elements, or at least v_0, of the spectroscopic binary at various epochs. In general, the systems are truly hierarchic ($P_{vis.} >> P_{spectr.}$), as is predicted by stability considerations. There are a few systems, though, that show lines of the three components and for which the hierarchy is less pronounced. The lines in such a case are intermingled in a complicated way. We have attacked two of those, which already have been described by Evans (see also Batten: Binary and multiple systems of stars), at a reciprocal dispersion of 3 Å/mm.

There are quite a number of systems with broad lines that are suspected of containing a spectroscopic binary, but the large scatter in radial velocity values will in many cases simply be due to the inevitable inaccuracy of the measurements. A few of the most striking cases have been added to the programme in order to bring, hopefully, some clarity.

All in all, the programme contains a rather large variety of interesting visual binary systems. The selection also has to count with the imminent putting to use of Coravel, i.e. radial velocity measurements by means of a mask. This method is faster, but there are certain limits to it (spectral type, angular separation of the components). On the other hand, the material of binaries for which visual data can be combined with radial velocities may well increase rapidly during the coming years. New, close pairs are discovered through occultation observations and can be measured with the speckle technique. Speckle observations can also deal with binaries that were hitherto only spectroscopic. We may at last be able in the coming years to arrive at a statistically significant number of stars with properly determined mass.

The plates are measured with the Grant machine of ESO, Geneva. It is a pleasure to compliment Jorge Melnick and Klaus Banse with the reduction facilities they have set up.

List of Preprints Published at ESO Scientific Group

June–August 1979

56. M. DENNEFELD and G. TAMMANN: Birthrate and Mass Function in the Magellanic Clouds. May 1979, *Astronomy and Astrophysics.*
57. O. M. KURTANIDZE and R. M. WEST: New Carbon Stars in Cygnus. May 1979, *Astronomy and Astrophysics.*
58. E. G. TANZI, M. TARENGHI, A. TREVES, M. C. W. SANDFORD, A. J. WILLIS and R. WILSON: Ultraviolet Observations of AM Herculis. June 1979, *Astronomy and Astrophysics.*
59. H. G. WALTER and R. M. WEST: Precise Optical Positions of Radio Sources in the Southern Hemisphere. June 1979, *Astronomy and Astrophysics.*
60. E. B. HOLMBERG, A. LAUBERTS, H.-E. SCHUSTER and R. M. WEST. The ESO/Uppsala Survey of the ESO (B) Atlas of the Southern Sky—VII. June 1979, *Astronomy and Astrophysics Supplement Series.*
61. I. SEMENIUK: Photometry of V 436 Centauri during the Superoutburst in May 1978. July 1979, *Astronomy and Astrophysics.*
62. N. VOGT, W. KRZEMINSKI and C. STERKEN: Periodic and Secular Variations in the Lightcurve of Dwarf Nova ex Hydrae. July 1979. *Astronomy and Astrophysics.*
63. N. VOGT and J. BREYSACHER: The Dwarf Nova BV Centauri, a Spectroscopic Binary. Submitted to *Astrophysical Journal.*
64. PH. VERON, P. O. LINDBLAD, E. ZUIDERWIJK, M.-P. VERON, G. ADAM: On the Nature of the so-called Narrow Line X-ray Galaxies. Submitted to *Astronomy and Astrophysics.*
65. M. TARENGHI, W. G. TIFFT, G. CHINCARINI, H. J. ROOD, L. A. THOMPSON: The Hercules Supercluster I. Basic data. Submitted to *Astrophysical Journal* (Dec. 15, 1979).
66. M. TARENGHI, G. CHINCARINI, H. J. ROOD, L. A. THOMPSON: The Hercules Supercluster II. Analysis. Submitted to *Astrophysical Journal.*
67. G. A. TAMMANN, A. YAHIL and A. SANDAGE: The Velocity Field of Bright Nearby Galaxies II. Luminosity functions for various Hubble types and luminosity classes. The peculiar motion of the local group relative to the Virgo cluster. August 1979, *Astrophysical Journal.*

H II Regions in NGC 5128

C. Möllenhoff

Among the many mysteries which nature has graciously presented to us in the southern hemisphere, the giant galaxy NGC 5128 is one of the greatest. It is a prodigious emitter of X-rays and radio waves and the origin of all this energy appears to be the nuclear region. In order to better understand this galaxy and the reason(s) for its peculiarity, many studies have recently been undertaken. One of these deals with the regions of ionized hydrogen, and the investigator, Dr. Claus Möllenhoff from Landessternwarte Heidelberg-Königstuhl, Fed. Rep. of Germany, here presents some of the most recent results.

The Galaxy NGC 5128

The peculiar galaxy NGC 5128 is one of the most remarkable astronomical objects in the southern sky. It is a very bright elliptical galaxy superimposed by a conspicuous equatorial dust lane (fig. 1). NGC 5128 is the optical centre of a strong and very extended radio source ("Cen A", with an apparent diameter of more than 8 degrees in the southern sky). NGC 5128 is the nearest giant radio galaxy (distance approximately 5 million parsecs = 16 million light-years), so it offers the opportunity of detailed optical observations. Our knowledge about this galaxy has strongly increased since the erection of serveral large telescopes in the southern hemisphere.

The most conspicuous feature in NGC 5128 is the big dust lane. It consists of a chaotic mixture of absorbing dust, light-emitting filaments of excited gas, and young blue stars. It is not yet clear if this dust lane is in reality a giant ring or a disk-like region penetrating the whole galaxy. Radial velocity measurements have shown that the dust lane rotates much faster than the galaxy itself.

This mixture of hot blue stars, dust, and gas is characteristic for regions where star formation takes place. The young blue stars excite and ionize the gas in their neighbourhood, so the gas radiates at characteristic wavelengths. Such radiating gas clouds are called emission nebulae or H II regions. A lot of such H II regions can be detected in the dust lane of NGC 5128. Spectroscopic observations of H II regions allow conclusions about their physical parameters and chemical composition. For this reason, during spring 1978 and during spring 1979, two observational programmes were carried out on La Silla with the 1 m, the 1.5 m and the 3.6 m telescopes.

Identification of the H II Regions

The most characteristic optical radiation of H II regions is the emission of the hydrogen Balmer lines (Hα 6563 Å, Hβ 4861 Å, Hγ 4340 Å, etc.) and the so-called "forbidden" lines (e.g. [OII] 3727 Å, [OIII] 4959, 5007 Å, [NII] 6548, 6584 Å), which are excited by collisions of the atoms in the nebula. The easiest way to locate H II regions in extra-galactic objects is therefore to photograph them through appropriate optical filters which just let pass the emission lines of the nebulae and suppress everything else. This can be done by using a set of interference filters which are adjusted to the wavelengths of the emission lines.

During five nights in March 1978 a number of such exposures were obtained with the ESO 1 m telescope. As these interference filters let pass only a very small portion of the spectrum, it was necessary to use an image intensifier. The exposure times were typically one to two hours (without filter only a couple of minutes were needed, see e.g. figure 1).

Figure 2 shows an exposure through an interference filter centred around 4775 Å (~50 Å bandwidth). There are no bright nebular emission lines within the transmission range of this filter. What can be seen in the picture is mainly the continuous light of the stars. Therefore, the gas filaments in the dust lane appear rather weak.

Another filter was centred around 6600 Å with a bandwidth of 170 Å. This filter included especially the Hα and [NII] lines (see fig. 3). Therefore, all bright spots on this picture having no counterpart on the continuum picture (fig. 2) are regions in the galaxy which are especially bright in Hα and [NII]. Thus these bright spots must be H II regions, they are marked by small arrows in figure 3. Note also the bright Hα-radiating gas filaments in the dust lane visible in this picture.

Figure 4 is a schematical map of the location of these objects. Most of the emission nebulae were found at the edges of the dust lane or just south of it. They have a typical diameter of 2–4 arcseconds corresponding to 50–100 parsecs in NGC 5128. A remarkable object is the emission region No. 13. In the 4775 Å exposure two distinct bright stellar knots are visible. They appear still brighter on exposures which were taken through filters of shorter wavelengths. However, they are hardly visible on extremely red exposures. Therefore, these two knots are probably very blue (i.e. hot) stars of a remarkable luminosity ($M_B \approx -9$ to -10). They are obviously the exciting stars for the H II region No. 13. In the 6600 Å exposure (fig. 3) the knots are not distinguishable, they are immersed in a much larger region of emitting gas.

The object No. 1 is not a "normal" H II region, it is the nucleus of NGC 5128. This nucleus was discovered in 1969 by S. van den Bergh and in 1971 independently by W. E. Kunkel and H. V. Bradt (*Astrophys. Journ.* **170,** L 7) on infrared plates. The nucleus is a huge cluster of stars, it is probably the "power station" for the giant radio sources outside the optical galaxy. The nucleus comprises a mass of approximately 1,000 million solar masses in a region of ~ 100 parsecs (~ 300 light-years) diameter (this is only a small fraction of the total mass of NGC 5128). Moreover the nucleus contains a lot of excited gas which makes it visible in our filter photographs (fig. 3).

Van den Bergh (1976, *Astrophys. Journ.* **208,** 673) showed by extensive photometric measurements that approximately 25 million years ago a burst of star formation took place in the nucleus. This burst was probably caused by giant explosions in the nucleus, those explosions which are also supposed to be responsible for the formation of the radio sources and jets of excited matter outside the galaxy.

Spectroscopic Observation with the 1.5 m Telescope

In order to get a better understanding of the H II regions in the dust belt a spectroscopic programme was run during

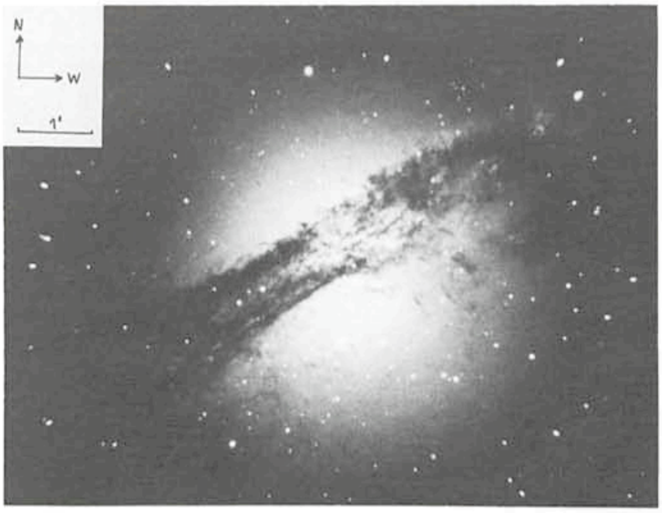

Fig. 1.

Fig. 2.

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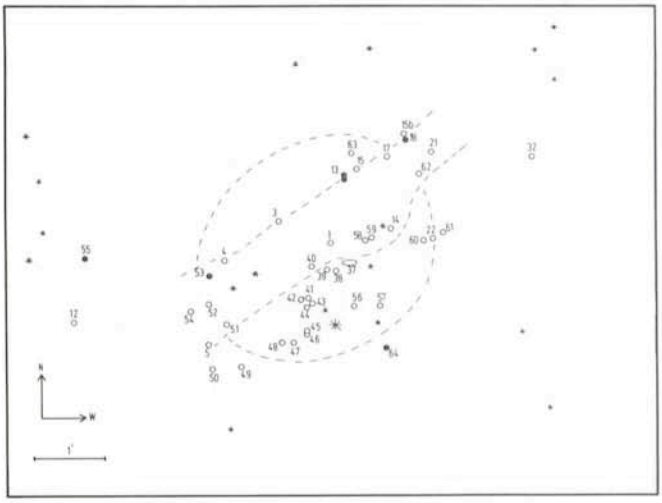

Fig. 4.

Fig. 1: *Unfiltered photograph of NGC 5128 with the ESO 1 m telescope. Since the whole spectrum of visual light could pass, it is not possible to decide from such an integrated picture if a certain bright region in the galaxy is a conglomerate of stars (continuous spectrum) or an emission nebula (discrete line spectrum). Due to the image intensifier the exposure time was only 5 minutes.*

Fig. 2: *Photograph through a narrow-band interference filter of 4775 Å central wavelength, 85 minutes exposure time. Only continuous (stellar) light contributes to this picture. The deformation of the stellar images in the outer regions is due to the image intensifier.*

Fig. 3: *In this case the interference filter was centred at 6600 Å, therefore especially the bright Hα and [N II] lines of excited gas material could pass. Note the bright filaments of excited gas in the dust lane. The arrows mark a large number of bright spots which are not visible in figure 2. They are H II regions which are bright in the Hα* and [N II] lines.

Fig. 4: *Schematical map of the H II regions identified in figure 3. They concentrate mainly at the borders of the dust lane and south of it.*

April 1979 on La Silla. The 1.5 m telescope, equipped with the Boller & Chivens spectrograph and the Carnegie image intensifier was used. The longest slit (3.8 arcmin projected on the sky) allowed the spectroscopy of several H II regions simultaneously, together with the underlying galaxy. The dispersion was 114 Å/mm (1st order) leading to spectrograms from ~ 3500 to 6000 Å.

Figure 5 shows one of these spectrograms. The slit was orientated along the NE border of the dust lane, crossing the H II regions No. 18, 17, 15, 13, 3, and 4 (from top to bottom in figure 5). The spectrogram shows the emission lines of these H II regions together with the absorption line spectrum of the stars in the galaxy. The H II regions threading along the slit appear like pearls on a string at the corresponding wavelengths of their emission lines in the spectrum.

The most prominent emission line (apart from the night sky lines O I 5577 Å and Na I 5893 Å, which of course cover the whole width of the spectrum) is [O II] 3727 Å. It is not only visible (as bright dots) at the location of the H II regions, but covers (however weaker) the whole dust lane. This means that collisionally excited gas is present all over the dust lane. Moreover [O III] 4959, 5007 Å and the hydrogen Balmer lines (Hδ 4102, Hγ 4340, Hβ 4861 Å) are easily visible. The uppermost H II region (No. 18) shows also Hε 3970 + [Ne III] 3968 Å, [Ne III] 3869 Å, and a weak blue continuum. The very bright blue continuum above the middle of the spectrogram is the H II region No. 13. This blue continuum belongs without doubt to the hot stars which excite the gas around them. The continuum is so bright that it outshines a part of the nebular emission lines. It does not show any absorption feature at this spectral

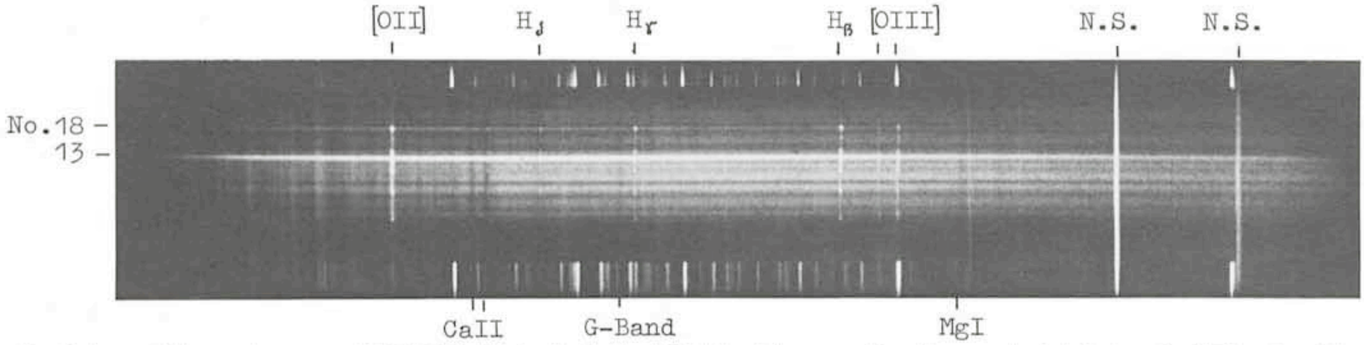

Fig. 5: *Image tube spectrogram of NGC 5128 obtained with the ESO 1.5 m telescope. The slit was orientated along the NE border of the dust lane and crosses a number of H II regions (from top to bottom in the spectrogram). Each H II region produces a bright spot in the spectrum at the wavelengths of the nebular emission lines (indicated on top). The location of two H II regions is indicated at the left margin. The stars of the underlying galaxy can be identified by their most prominent absorption lines (indicated at the bottom margin). The bright emission lines ("N. S.") in the long-wave region of the spectrum are due to the terrestrial night sky.*

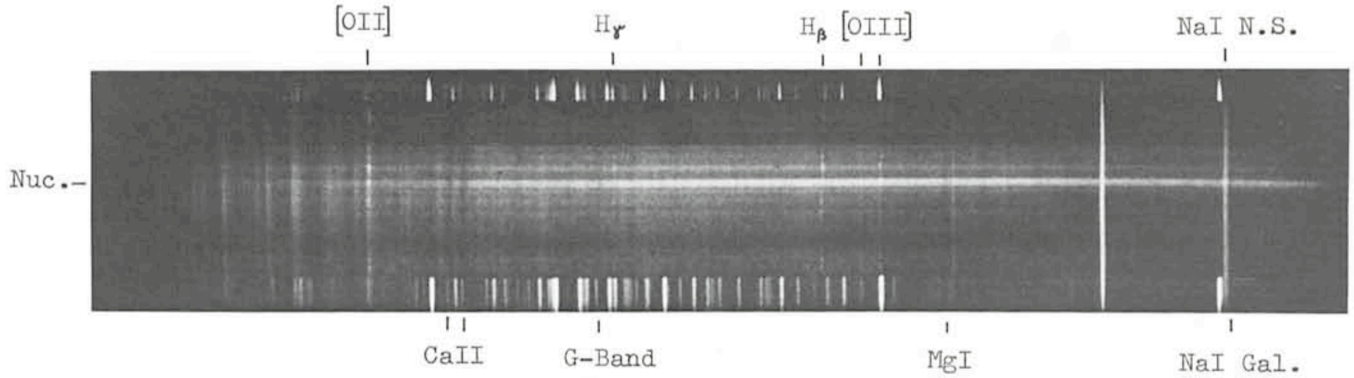

Fig. 6: *Similar spectrogram as figure 5; however, the slit crosses the nucleus of NGC 5128. The bright red continuum of the nucleus is very conspicuous. The broad absorption lines in this continuum (indicated at the bottom margin) show that the nucleus is a giant star cluster. This star cluster also contains excited gas detectable by the typical emission lines (marked at the top). Note the Na I emission line of the terrestrial night sky and the red shifted Na I absorption line of the nucleus of NGC 5128.*

resolution; the nature of the blue stars is therefore not easy to decide. Note the inclination of the nebular emission lines which reflects the rotation of the H II regions around the centre of the galaxy.

The main absorption lines in the spectrum of the underlying galaxy are marked in figure 5: Ca II 3934, 3968 Å, the G-Band (~ 4300 Å), Fe 4383 Å, and Mg I 5167–5184 Å. The structures visible near the short-wave end of the spectrum are the emission bands of the atmospheric airglow (O_2 molecules).

In figure 6 the slit of the spectrograph is again orientated parallel to the dust lane, however, it now crosses the nucleus of NGC 5128. The continuum (bifurcated at the blue end) of the nucleus is very conspicuous in the red. Again [O II], [O III], Hβ and Hγ are visible, but not as bright as in the H II regions at the NE border of the dust lane. It is easily visible that the nucleus contains a cluster of evolved stars: the absorption lines mentioned above are also visible in the continuum of the nucleus. Remarkable is also the very broad Na I 5893 Å absorption of the nucleus (red-shifted against the night sky emission line of Na I). The width of the Na I absorption line is more than 15 Å, which corresponds to a velocity dispersion of 750 km s^{-1}. Such velocities can of course not occur in single stars, what we see is the superposition of the Na I absorption of a whole cluster of stars.

Spectroscopic Observation with the 3.6 m Telescope

In order to get more detailed information about the individual H II regions in NGC 5128, three more nights of spectroscopic observation were spent at the ESO 3.6 m telescope (during March 1979). The spectra were not exposed on a photographic plate but onto the photocathode of the IDS ("Image Dissector Scanner") System. The results of the scanner observations are stored digitally on magnetic tape. The main advantage of the scanner is that the response is absolutely linear to the incident intensity. Therefore, quantitative comparisons between different emission lines or of the continuum are much more accurate than from a photographic plate.

A "normal" astronomer needs some time to get familiar with this really nice scanner system. However, with the helpful introduction of Dr. Schnur and Dr. Pedersen this was not a big problem. The scanner records two spectra simultaneously in two different slits A and B. The standard procedure is now that the object is put into slit A while slit B records the sky background. After approximately 10 minutes of integration the slits are interchanged (star in B, sky in A) in order to get rid of any inhomogeneities of the photocathode. This procedure is repeated several times, all integrations of the corresponding slits are added together, the corresponding sky background is subtracted. The observations end when the summarized spectrum has a sufficiently good signal-to-noise ratio (all results can be monitored on a cathode ray screen). It is extremely helpful that the spectrum can already be seen during the observation. These weak H II regions are sometimes difficult to find (even with the 3.6 m telescope), so the astronomer can see at once if something was wrong. A dispersion of 171 Å/mm was chosen, thus the whole visual region of 3850 to 6800 Å was obtained in the 2048 scanner channels. The total exposure times were typically 60 to 90 minutes.

Figure 7 shows the scanner spectrum of the H II region No. 18. The values from the computer are plotted as a curve. Because of the linearity of the system the diagram shows directly the intensities of the emitted lines. The most important lines are identified in the figure. From the intensity ratios of some emission lines one can directly compute some physical parameters in this H II region. We get a rough temperature estimate of $T \approx 10{,}000$ °K and an electron density of $n_e = 100$ to $200\ cm^{-3}$. These values are typical, also for H II regions in our own galaxy.

Figure 8 shows the scanner spectrum of the H II region No. 13. The emission line spectrum is very similar to that of No. 18, however, a strong blue continuum is superimposed. This continuum results from the blue stellar objects mentioned above. The absorption lines in that spectrum (Ca II 3934, 3968 Å, Mg I 5167–84 Å) do *not* belong to these blue stellar objects. This can easily be verified from figure 5. One has to consider that the slit of the scanner was 6 arcsecond long and therefore the spectrum is contaminated by the surrounding galaxy.

Figure 9 shows the scanner spectrum of the nucleus of NGC 5128. The most conspicuous detail is the strong continuum increasing towards the red end. This continuum shows a number of broad emission lines which are typical for evolved stars (G–K).

The distance of the two slits A and B of the scanner is 20 (or 40) arcseconds. This leads to some problems with the elimination of the night sky from our spectrograms. Since NGC 5128 is such an extended object, slit B will always see some point in the galaxy (and not the pure night sky) while slit A is pointed towards the nucleus. Then the standard procedure of subtraction will of course lead to wrong results. Therefore in the case of figure 9 the night sky was taken from an extra observation well outside the galaxy. However, since the night sky background changes with time and direction, there remain some remnants of the night sky lines (O I 5577, 6300, 6364 Å, marked by N. S.). Especially interesting is the Na I 5893 Å line: The spectrum shows the non-displaced Na I emission of our atmosphere (marked by N. S.) and—red-displaced according to the radial velocity of NGC 5128—the Na I absorption in the continuum of the nucleus (see also fig. 6).

The nucleus is not at all a normal H II region; this can already be seen by a first glance on the emission-line spectrum: Hα is (in contrast to figs. 7 and 8) weaker than [N II] 6584 Å, Hβ and the higher Balmer lines are hardly visible. One simple reason for that may be that the hydrogen emission lines are partly compensated by the absorption lines of the star cluster. However, the physical reasons for the excitation of the lines are probably not those of normal H II regions, the shocks of the explosions are also important here. A more detailed analysis is necessary before a reliable interpretation can be given.

All these spectrograms contain a lot of information about the physical parameters and the chemical abundances in these H II regions. The reduction of these data has just started and will still require much work. And there are also the measurements of the radial velocities which have not been mentioned in this article. All this will hopefully lead to an improved understanding of what is going on in the nucleus and in the dust lane of this spectacular galaxy.

The author is grateful for the patient help offered by the night assistants Mr. Véliz and Mr. Yagnam (3.6 m telescope), and Mr. Ramirez (1.5 m telescope) on La Silla. The support of Dr. Middelburg and Dr. Tarenghi in Geneva during the numerical reduction of the IDS data is gratefully acknowledged.

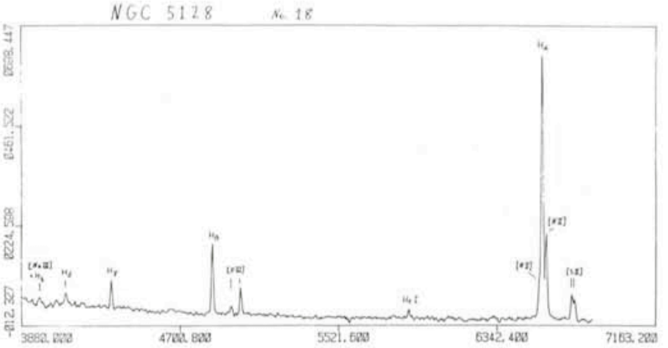

Fig. 7: *Scanner spectrogram of the H II region No. 18, obtained with the ESO 3.6 m telescope. It is a typical spectrum of an H II region, the most prominent emission lines are indicated. Such scanner spectrograms allow direct comparisons of line intensities.*

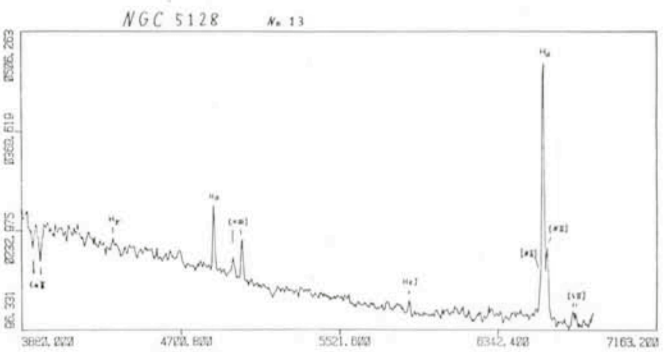

Fig. 8: *Scanner spectrogram of H II region No. 13. The exciting blue stars show themselves by a bright blue continuum. The absorption lines are not from this continuum but originate from the surrounding galaxy (see fig. 5).*

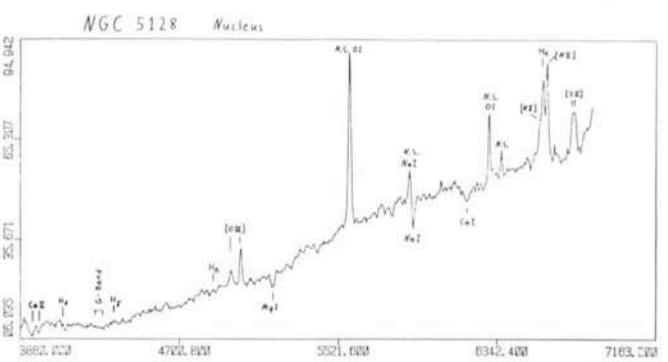

Fig. 9: *Scanner spectrogram of the nucleus of NGC 5128. The extremely red continuum and its absorption lines are very conspicuous. The Balmer lines of the excited gas are much weaker compared to H II region No. 18 (fig. 7). As the night sky was not completely eliminated there remain some remnant emission lines (marked by N. S.). Note especially the Na I night sky emission line and the red-shifted Na I absorption line of the nucleus (see also fig. 6).*

Dark Matter in Southern Open Clusters

Å. A. E. Wallenquist

Is there dark matter in open star clusters? How is it distributed in the cluster? Is this distribution dependent upon the age of the cluster? These are all-important questions, but they are difficult to answer. On the basis of extensive star counts near southern open clusters, Professor Åke Wallenquist of the Uppsala Observatory, Sweden, has found a possible age effect. The result is not fully conclusive, but it opens very interesting perspectives in cluster research.

In a recent paper (Nova Acta Regiae Societatis Scientiarum Upsaliensis, Ser.V:A. Vol. 3 = Uppsala Astronomiska Observatoriums Annaler, Band 5 N:o 10, 1979) the present writer has made an attempt to investigate dark matter in and around open clusters in the southern sky on the basis of star counts made on glass negative copies of plates taken for the ESO B atlas.

Counting Stars

The counts were performed in the following way (see fig. 1): on the cluster was placed a rectangular reseau with a large number of squares of equal size and furnished with a rectangular coordinate system with the origin at the centre of the reseau. The centre of the reseau was made to coincide as far as possible with the centre of the cluster under investigation. The abscissa was oriented along the direction of the right ascension (W–E) and the ordinate axis along the direction of the declination (N–S). In the case of large clusters, the square of the reseau had an area of 2×2 mm^2, whereas in the case of small clusters or very rich clusters the area of a square was 1×1 mm^2. In the richest cluster more than 80,000 stars were counted! The total number of stars counted amounted to about 1.3 million, distributed over 61 cluster regions.

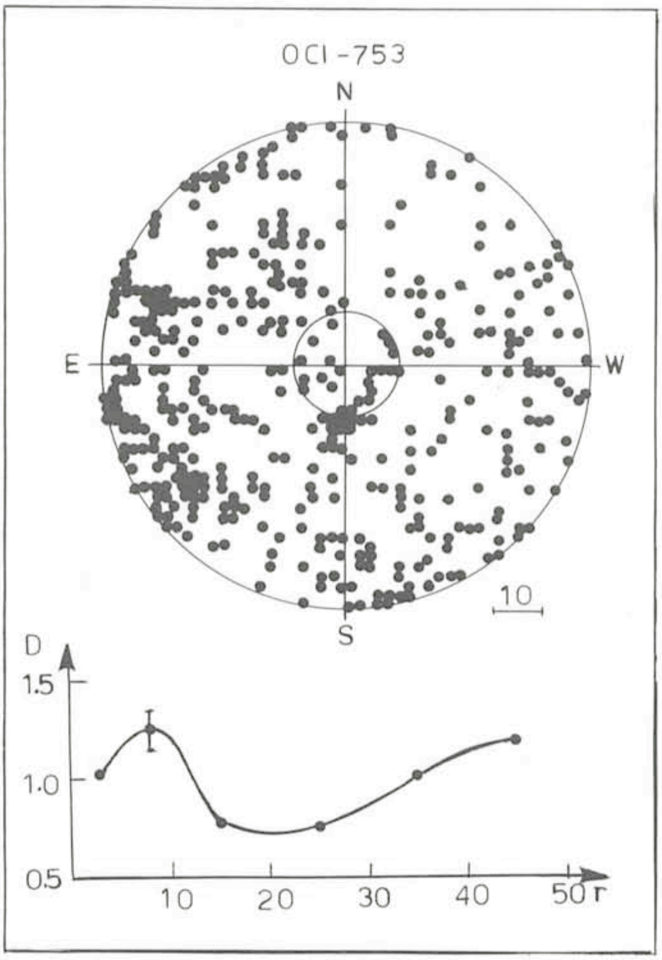

Fig. 2: *The distribution map for the open cluster NGC 2547 (OCl–753).*

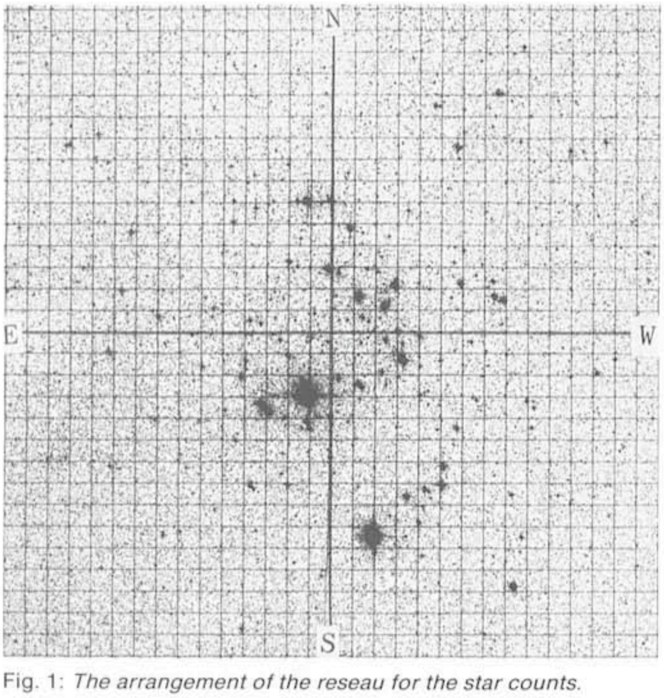

Fig. 1: *The arrangement of the reseau for the star counts.*

The plate under investigation was placed on a special table where it was illuminated from below. The counts were performed with the help of a binocular magnifier with a magnification of about 20 ×. Only well-exposed stars were counted, and faint stars with gray and underexposed images were excluded.

"Dark Squares"

By means of statistical methods the influence of the systematic increase of the surface density of the stars towards the centre of the cluster and the influence of external dark nebulosities or rich star clouds were, as far as possible, eliminated. For each cluster a distribution map was constructed where those squares where the number of stars was at least 25 % less than the average number of stars within the squares in the region investigated were regarded as "dark squares" and were denoted by black dots on the maps.

In order to obtain a clearer view of how the dark squares (dark matter) were distributed with regard to the centre of the cluster, the surface densities of the dark squares were computed for successive distances from the centre of the cluster. Below each distribution map is the surface density curve for the dark squares; it shows, consequently, the variation of the surface density (D) with the distance from the centre of the cluster expressed in mm on the plate (r).

In figure 2 the distribution map for the cluster NGC 2547 (OCl–753) is reproduced. The circle in the centre of each map indicates the apparent extension of the cluster and the scale of each map is indicated by a horizontal line having the length of 10 mm on the ESO plates (~ 11 arcmin).

Dust and Cluster Age

For the statistical investigation only 28 clusters could be used. The *intensity* of absorption (a), expressed in an arbitrary measure, the *distance* of the absorption zone (that is the maximum of the surface density curve) from the centre of the cluster, with the radius of the cluster as the unit (d) and the *relative* absorption within the cluster, expressed as the ratio between the average surface density for the dark squares within the cluster and that for the whole region (D_c), were studied in the relation to the age of the clusters.

The clusters were, consequently, divided into four groups according to age (log t; t in years) and for each group the mean values of the above-mentioned quantities were computed. The results are given in figure 3, which is self-explanatory. The mean value of each group is represented by a black dot and error bars represent the mean error of the mean.

As shown in the figure, there is a slight indication that the intensity of absorption as well as the distance of the absorption zone from the centre of the cluster increases with the age of the cluster, whereas the absorption within the cluster decreases with increasing age. (The same result was found in an earlier investigation on dark matter in open clusters mainly situated in the northern sky.

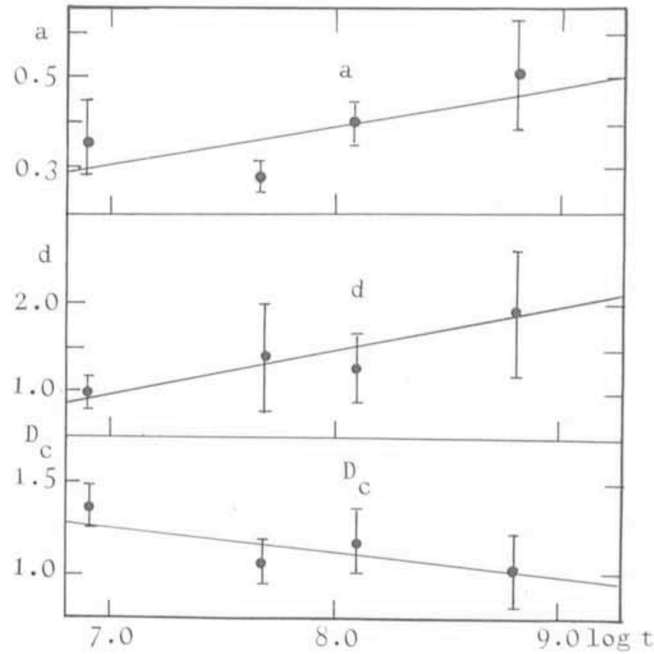

Fig. 3: *The variation of the intensity of absorption (a), the distance of the absorption zone from the centre of the cluster (d) and the absorption inside the cluster (D_c) with the age of the clusters (log t).*

Taking into account the small number of clusters investigated as well as the large mean errors, the result cannot be regarded as fully conclusive. It nevertheless gives an indication that the dark matter (dust) has been driven away from the cluster and that the remaining dark matter inside the clusters has decreased with increasing age.

Astrometry of the Optical Images of Some Southern Radio Sources

H. G. Walter and R. M. West

Radio interferometry has enriched positional astronomy with extremely accurate celestial coordinates of extragalactic sources. As these objects are ideal points for an inertial reference frame, the problem of measuring the positions of optical counterparts with high accuracy is of central importance. Drs. H. G. Walter, Astronomisches Rechen-Institut, Heidelberg, Fed. Rep. of Germany, and R. M. West, ESO, recently measured 41 objects in the southern sky with the ESO S-3000 measuring machine. Several new identifications and improved optical positions resulted from this undertaking.

Radio Sources and their Optical Counterparts

Like stars of bright and intermediate magnitudes, selected extragalactic objects are very useful objects in astrometrical observing programmes aiming at the establishment of a general reference system of positions and proper motions. Due to their large distances, galaxies have proper motions which amount to 0.″00002 per year at most and which are therefore negligible over centuries, even in case of precise observations with present high-performance instruments. The absence of proper motions makes galaxies and other very distant objects the natural representatives of a stable reference system.

The astrometrical, optical observing programmes of galaxies that were executed during previous decades did not arrive at results which were satisfactory in every respect, because most galaxies are diffuse and extended objects and are therefore difficult to measure. For this reason, the astrometric connection of galaxies to the stars of the Fourth Fundamental Catalogue (FK4)—which constitutes the traditional, fundamental positional reference system—did not result in an accuracy exceeding that of the fundamental stars.

However, more favourable conditions for the connection of extragalactic objects to the FK4 now exist since coordinates of radio sources with *point* structure, located at large distances, are measurable with an accuracy of about 10^{-2} arcsec by means of *radio interferometry*. A careful estimate of the state of the art predicts that accuracies of 10^{-3} arcsec may be obtained in the near future, after improvement of the measurement techniques and of the data reduction methods. Thus, the radio emission at a few cm wavelength now promotes certain radio galaxies and, in particular, the radio-emitting quasi-stellar objects (QSO's) to ideal objects for the establishment of an extragalactic reference frame.

With the radio interferometrical determination of radio source positions, however, only a partial result is achieved until the optical identification of these objects has been ascertained. The identification of optical counterparts of radio sources serves the following purposes:

(1) examination of the morphological structure of the objects in order to decide their nature and whether they are suitable as reference points;

(2) tying the radio reference frame to the traditional fundamental system of positions by measuring the positions of the optical counterparts relative to stars of the fundamental system (closely related to this task are the attempts to improve the optical and dynamical reference frames on the basis of the excellent position accuracies attainable by radio interferometry);

(3) estimates of distances to extragalactic radio sources from the measured redshift of optical counterparts. (Note that so far there is no general method which yields distances from radio observations only.)

These three objectives have largely provided the motivating force for astrometry of extragalactic radio sources with point structure.

Position Measurements

At present, hardly more than two hundred extragalactic radio sources have been observed, for which the optical counterparts are known with positions accurate to a few tenths of a second of arc. Since the share of the southern sky in this number is comparatively low, we selected a group of 42 extragalactic radio sources with excellent radio positions in the southern hemisphere. When the sources had been identified with an optical counterpart, we measured their positions relative to reference stars of the Perth 70 Catalogue which is based on the system of FK4, cf. *Messenger* No. 11, p. 4.

For one of the radio sources no optical identification was found. The remaining 41 sources include three new optical identifications which are associated with the sources 1144–379, 1245–197 and 1313–334, as shown in figure 1. Finally, we succeeded in determining an improved optical position of the radio source 0438–436 which is the quasar with the highest known radio luminosity.

The measurements were made by means of ESO (B) Atlas (Schmidt) plates for sources south of declination –17°.5 and POSS Atlas plates for sources north of –17°.5. After identification of *all* (25 to 30) stars of the Perth 70 Catalogue on the plate, the (X, Y) positions of these stars and the optical image of the radio source in question were

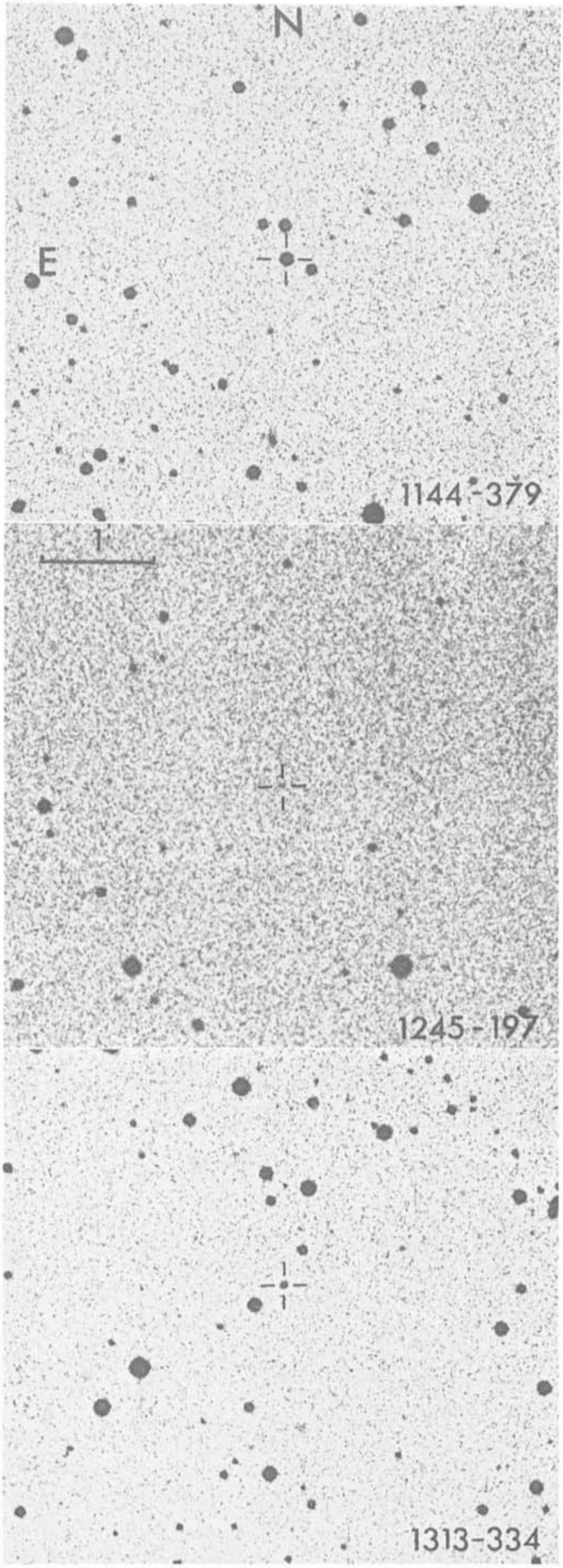

Fig. 1: *The optical images of three radio sources which were first identified in this programme.*

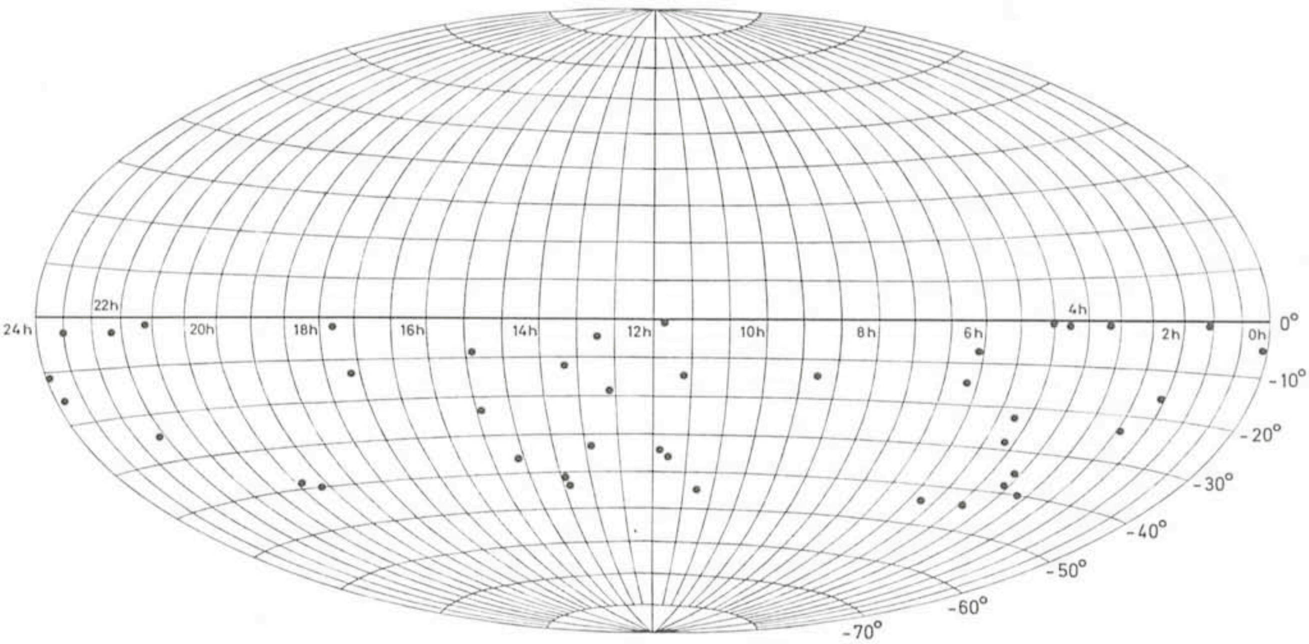

Fig. 2: *The distribution of 41 extragalactic radio sources which were measured in this programme.*

measured on ESO's S–3000 plate measuring machine. The (X, Y) positions of the reference stars were reduced to equatorial coordinates by using seven terms in both coordinates for the determination of the plate constants. Then the sky coordinates of the optical counterparts were derived with an internal average standard deviation of 0.″3 in right ascension and declination. The distribution of the measured objects over the southern sky is illustrated in figure 2. The measured optical positions agree very well with the radio interferometric positions; a full discussion is given in ESO Preprint No. 59.

Future Prospects

As most of the optical counterparts are fainter than $m_v = 16$ and since the reference stars of the Perth 70 Catalogue are brighter than $m_v = 10$, the accuracy of the present method that directly relates the counterparts to Perth 70 reference stars is limited by the large brightness difference (i.e. the appearance of the images on the plates). Superior accuracies of ± 0.″1 may be reached through a different method which ties optical counterparts to a catalogue of bright stars in a defined system by a step procedure that uses secondary reference stars in the magnitude range $12 < m_v < 14$ and long-focus, small-field plates (e.g. Chr. de Vegt, U. K. Gehlich, *Astron. and Astrophys.* **67**, 1978, p. 65). The effort, however, is disproportionately larger than direct tying on large-field Schmidt plates as we did, because the accurate positions of 50 to 100 secondary reference stars in the vicinity of each of the optical counterparts are required. So far the facilities for position measurements of secondary reference stars in the southern sky have been poor, and our method of direct tying is more expedient.

In the framework of the Space Astrometry Project sponsored by the European Space Agency (ESA), photoelectric determination of the positions, proper motions and parallaxes of about 100,000 faint stars down to the magnitude $m_v = 12$ is planned by means of an artificial earth satellite (HIPPARCOS); cf. *Messenger* No. 16, p. 35. Positional accuracies of 0.″002 are likely to be achieved. These stars would establish a comprehensive and impressively precise reference frame for position determination of optical counterparts by yielding accuracies comparable with those of radio interferometry. For practical applications, however, it is important that sufficient reference stars are measured in the fields of optical counterparts of point-like radio sources. A selective observing programme of the astrometry satellite is therefore necessary.

Main Results

The new astrometric observations of optically identified radio sources constitute a significant contribution to the network of reference points in the southern sky; we also believe to have demonstrated in practice the great utility of the Perth 70 Catalogue as reference frame for extragalactic objects and, last but not least, the reliability of ESO's plate-measuring system and the associated software (see also this issue, p. 21).

NEWS AND NOTES

Minor Planet Discovered by ESO Night Assistants

During a recent visit to Europe by the astronomer-in-charge, H.-E. Schuster, the smooth running of the ESO Schmidt telescope was assured by night assistants Oscar and Guido Pizarro. Checking through a night's plates they came upon a comparatively bright planet trail. They marked the trail and were able to find trails of the same planet on further plates that were taken for the same programme the following nights.

The first plate was taken on May 19, 1979 and the new planet has been given the preliminary designation 1979 KA. Further observations were obtained on three otherwise useless nights in June and a preliminary orbit has been computed by the Minor Planet Bureau. The mean distance from the Sun is about 400 million kilometres and the size of the new planet is probably about 10 kilometres in diameter.

Observational Tests for H II Region Models: A "Champagne Party"

D. Alloin and G. Tenorio-Tagle

The theoretical model outlined in this article being referred to as the "champagne" model (rather than the "coca-cola", the "ginger-ale", etc.) is not just a question of country of origin or even style: what happens when one or more stars in a molecular cloud start to ionize the gas is not too different from what you would experience if you—with a singular lack of common sense and respect—would place your "Dom Pérignon" in an oven. Drs. Danielle-Marie Alloin and Guillermo Tenorio-Tagle of the ESO Scientific Group in Geneva have just observed an H II region at the edge of a molecular cloud with the 3.6 m telescope. Here are some preliminary results and further details about the sparkling theory.

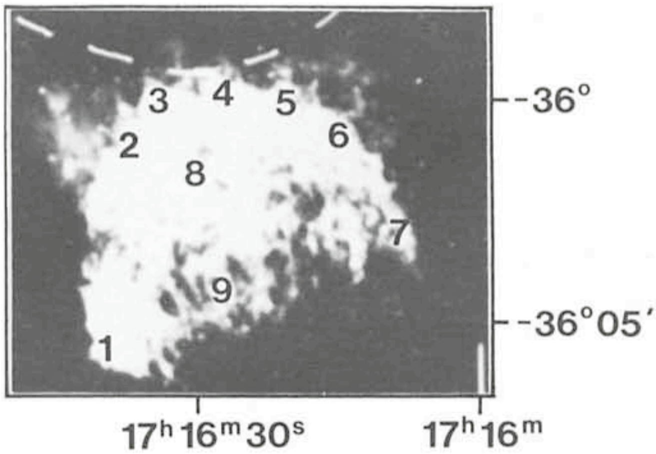

Fig. 1 a: *Hα*, [H II] plate of Gum 61. The selected observed positions are shown through numbers.

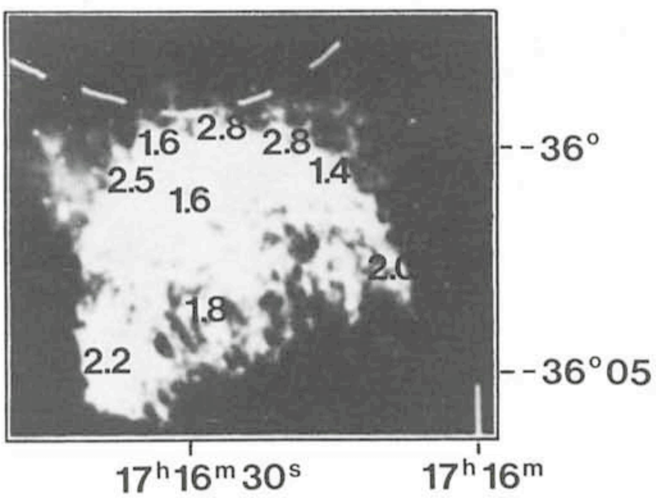

Fig. 1 b: *Gum 61, electron density distribution in units of 10^3 cm^{-3}.*

It is our aim to study *as a single entity* several neighbouring H II regions associated with a molecular cloud. In this way, we believe, one can obtain information about the progressive star formation within the cloud, and about the disruption of the parent cloud through its ionization.

Therefore, we selected as a good candidate NGC 6334 which lies at the edge of the Milky Way at galactic coordinates b = 30′ and l = 351° 30′. One of its components to the south-west, Gum 61, presents a quite unusual aspect: it shows numerous filaments which extend in the south-west direction from the edge of the molecular cloud, as clearly seen on the Hα, [N II] plate displayed in figure 1 a. According to the recent distance estimate of 1.7 kpc (Neckel, 1978) this H II region is about 4 parsec in diameter. An OH maser is also known to be present within the molecular cloud to the north of Gum 61, implying recent star formation all around.

Then, this particular nebula Gum 61 was chosen for our observations on June 30 and July 1st, 1979.

3.6 m Observations of Gum 61

We used the ESO Image Dissector Scanner (Cullum and Fosbury, 1979) attached to the Cassegrain focus of the 3.6 m telescope at La Silla (ESO). A resolution of about .6 nm (= 6 Å) was achieved, using a dispersion of 5.9 nm mm^{-1} over the wavelength range 390–680 nm. Nine different positions were selected: along the boundary of the H II region, in the centre and across a few filaments. These positions are indicated by numbers in figure 1 a.

Preliminary results show that we are dealing here with a low excitation, high density nebula. The electron density distribution can be worked out from the [S II] 671.6/673 nm line intensity ratio, and these results are displayed in figure 1 b in units of 10^3 cm^{-3}. As expected, the density appears to be larger all along the boundary of the ionized gas, while, in the centre, we do find a lower value increasing slightly towards the end of the filaments to the south-west.

On the other hand, the excitation parameter, represented as usual by the observed [O III]/Hβ line intensity ratio appears to be twice as large in the northern part of the nebula, next to the molecular cloud, as at the end of the filaments (position 1). This implies the existence of other exciting stars, hidden in the molecular cloud.

The Champagne Model

Recent numerical calculations (Tenorio-Tagle, 1979) have shown us how an H II region enters the "champagne phase" when the discontinuity between cloud (the star formation site = the champagne) and intercloud gas becomes ionized. The ionization front moving into the intercloud gas with supersonic velocities creates and leaves behind a large discontinuity in pressure (between the now ionized cloud and the intercloud gas). This discontinuity sets a "champagne-like effect" by generating a strong isothermal shock and a rarefaction wave. The shock wave

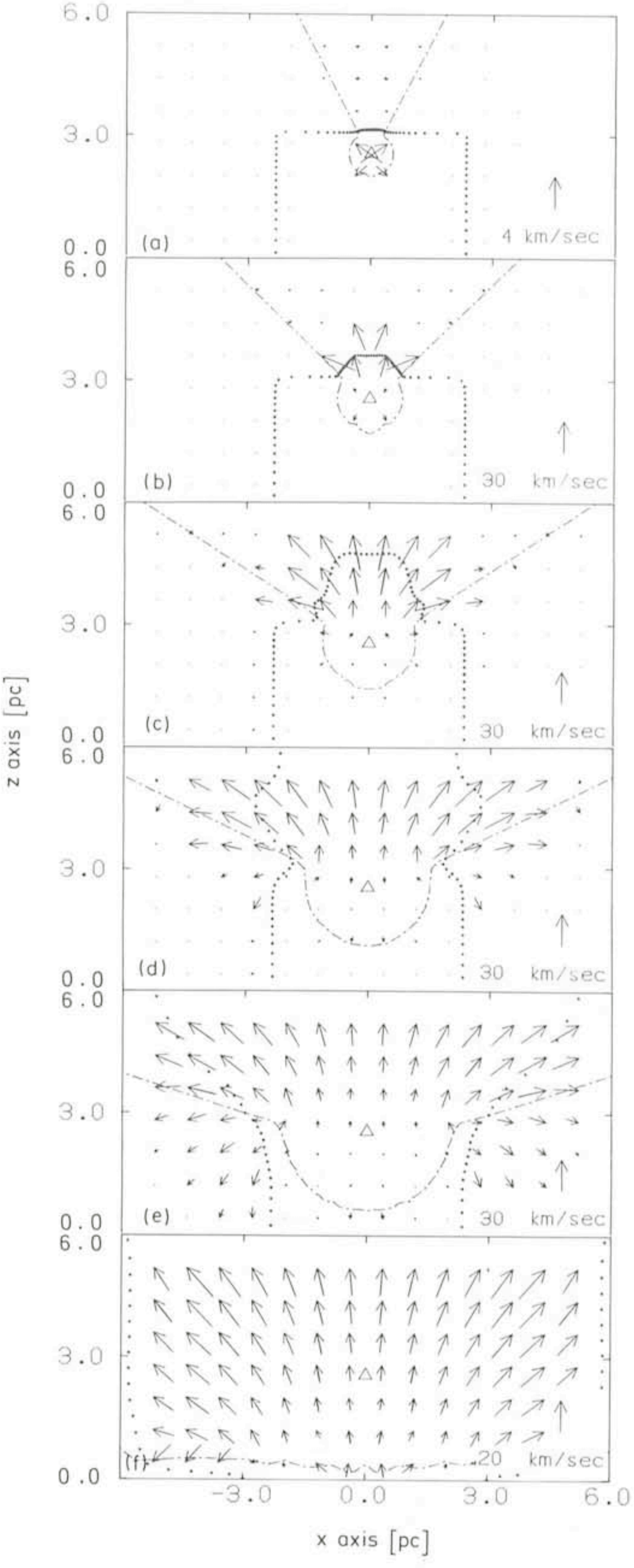

Fig. 2: *The Champagne-flow model at different stages:*

- *crosses delineate the molecular cloud in which the star (a triangle) is born. Dashed-dotted line = ionization front.*
- *arrows indicate the gas velocities in the units given on each figure.*
- *t = 9.5 × 10³ yrs (a); = 4.13 × 10⁴ yrs (b); = 8.9 × 10⁴ yrs (c); = 1.6 × 10⁵ yrs (d); = 2.8 × 10⁵ yrs (e); = 5.67 × 10⁵ yrs (f). (Bodenheimer* et al., *1979).*

propagates into the ionized intercloud gas and becomes the edge of the density-bounded side of the nebula, while the rarefaction wave enters the ionization-bounded side and moves towards the bottom of the bottle. In this way, "champagne" begins to stream away from the cloud, reaching supersonic velocities (u > 3 sound speed), while it spreads over a large volume, as shown in figure 2. Many observers will recognize this event as a blister at the edge of a cloud, how rude!

In order to explain our observations, we should bear in mind that, during the champagne phase, the other ionization front which moves in the cloud, i.e. to the bottom of the bottle, doesn't know anything about the champagne shower occurring on the other end. This holds until the rarefaction wave crosses the position of the star and a larger amount of photons speed its propagation. However, before this occurs, the ionization-bounded side of the nebula expands as postulated by the classical formulation (Spitzer, 1968). Consequently another weaker rarefaction wave is also present in the flow, moving from the bottom of the bottle towards the exciting star. Thus, between the two rarefaction waves, one should expect an enhancement both in pressure and density, as shown in figure 3.

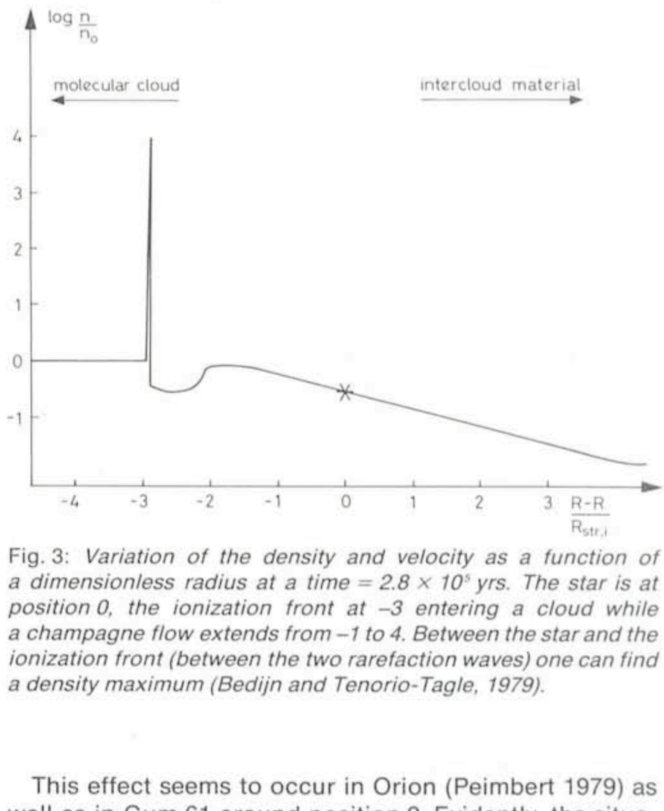

Fig. 3: *Variation of the density and velocity as a function of a dimensionless radius at a time = 2.8 × 10⁵ yrs. The star is at position 0, the ionization front at –3 entering a cloud while a champagne flow extends from –1 to 4. Between the star and the ionization front (between the two rarefaction waves) one can find a density maximum (Bedijn and Tenorio-Tagle, 1979).*

This effect seems to occur in Orion (Peimbert 1979) as well as in Gum 61 around position 9. Evidently, the situation might be more complicated than the simple one described in those models which assume a single ionizing star. We have already seen from the [O III]/Hβ line intensity ratio that other exciting stars partly contribute to the ionization.

We wonder if the other H II regions which constitute the NGC 6334 complex might represent different stages of the champagne phase: some of them are more extended while others are smaller in size but not in brightness. The study of the whole complex would certainly give us a better idea about the progress and site of star formation.

Finally, we would like to stress the fact that the velocity field determination in the whole area would provide the key to understand the formation and evolution of such a complex.

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ESO/SRC Conference on APPLICATIONS OF CAMAC TO ASTRONOMY

The Proceedings of this conference, held in Geneva in September 1978, are now available. Copies can be obtained, free of charge, from:

European Southern Observatory
c/o CERN
Attn. M. J. Cullum
1211 Geneva 23
Switzerland

NEWS AND NOTES

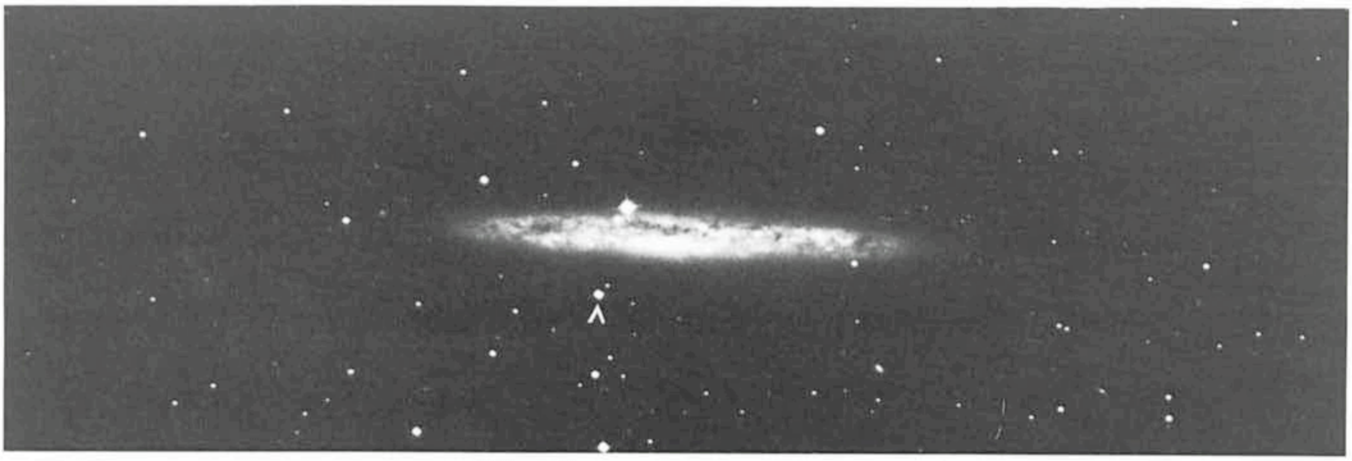
The Supernova That Was Not . . .

The ESO 1 m Schmidt telescope is a major supplier of observational material to many European astronomers. The plates are taken by the ESO observers on La Silla, sent by diplomatic bag to the Sky Atlas Laboratory in Geneva, registered and checked and then forwarded to the astronomer who asked for the plates to be taken.

Two plates were taken during the month of May 1979 for one of these programmes, showing the galaxy NGC 4517. It so happened that the ESO astronomer who checked the plates in Geneva (R. West) noticed that there was an additional, apparently stellar image (see arrow) on one of the plates, near the galaxy.

A supernova was strongly indicated, although the position in the galaxy, far from the main plane, was somewhat peculiar. And suddenly it became clear that the image was on the plate that was taken *first,* but not on the *second!* Who has ever heard about a supernova that disappears in the course of ten days?

The mystery was quickly solved. A print-out of the minor planets in the field showed that at the position of the supposed supernova, the 13ᵐ5 minor planet (268) ADOREA would have been virtually stationary (i. e. not moving as seen from the Earth) at the exact time of the first plate, but well away from the galaxy on the second plate. A careful inspection of the image also shows that it is slightly elongated, confirming the explanation.



Two photos of galaxy NGC 4517, both 2-hour exposures on IIIa-J emulsion behind a GG385 filter, obtained with the ESO Schmidt telescope on May 18 (upper) and May 28 (lower), 1979.

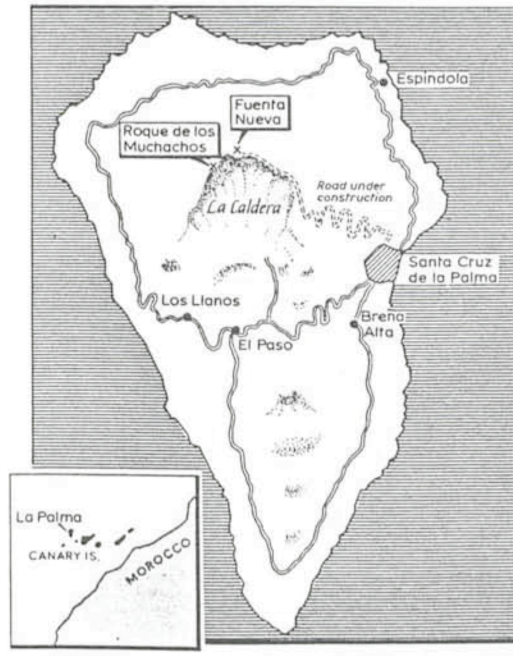
Roque de los Muchachos Observatory

After six years of site-testing and another four of diplomatic activity, an agreement has been reached between Spain, the United Kingdom, Denmark and Sweden about the construction of an international observatory on the island of La Palma in the Canary group. The observatory will be placed on the rim of an extinct volcanic crater, 2,400 m above sea level. It is expected that long spells of exceptional weather will be available here.

The agreements call for the installation of powerful instruments, and a British 4.2 m telescope should come into operation after a number of years. The Isaac Newton 2.5 m telescope will soon be moved from England and a British 1 m telescope is planned. The automatic meridian circle of the Brorfelde Observatory in Denmark will be installed in 1981 and a Swedish solar station is being moved from Capri (Italy) to La Palma.

European astronomers have long been on the lookout for good observing sites in or near Europe. The observatories in Australia and Chile certainly offer excellent conditions for observing the southern sky, but it has always been felt that the distance from Europe contributes significantly to the cost and creates problems for the smooth running. As a result, several sites nearer to Europe have been tested and for instance the Max Planck Observatory at Calar Alto in Spain is a recent, impressive addition to European observational astronomy.

No doubt, many of the astronomers that regularly visit ESO-La Silla will now start thinking about supplementing their observations with future programmes on La Palma!



The Roque de los Muchachos site (reproduced from New Scientist*).*

XVIIth IAU General Assembly in Montreal

The triennial general assembly of the International Astronomical Union took place in Montreal, Canada, from August 13 to 23. More than 2,000 astronomers and specialists from more than 40 countries were present and about 770 new members were admitted to the Union, bringing the membership to about 4,600. One new country, Indonesia, joined the IAU.

Several hundred meetings were held in the various IAU commissions, the scopes of which range from "Astronomical Telegrams" to "Cosmology" and "Protection of Astronomical Sites". Among the highlights must be mentioned the impressive results that have recently been obtained by spacecraft near Venus and Jupiter and the exciting discoveries with the new X-ray satellite EINSTEIN.

A number of ESO astronomers participated in the assembly and in some of the symposia that took place in USA and Canada, just before or after the assembly. A wide variety of talks were given, for instance about interstellar absorption (A. Danks, ESO/Chile), observations of early-type galaxies (G. Schnur, ESO/Chile), the use of parallaxes and proper motions (P. O. Lindblad, ESO/Geneva), and Seyfert galaxies (M.-H. Ulrich, ESO/Geneva). Observations of X-ray sources were reported by H. Pedersen (ESO/Chile) and M. Pakull (ESO/Geneva). The ESO Director-General, L. Woltjer, reviewed the cosmological significance of recent X-ray observations and R. West (ESO/Geneva) presented plans for a future Space-Schmidt telescope. He was also elected Assistant General Secretary of the IAU.

ESO Users Manual Now Available!

ESO is pleased to announce the availability of the ESO Users Manual. It has recently been distributed to astronomical institutes and contains all the necessary information to enable visiting astronomers to apply for observing time. If your institute has not received a copy, please contact the Visiting Astronomers Section Garching. The manual will be updated periodically, and any errors that should be corrected or information you would like included should be communicated to the editor, Anthony Danks.

A Strange Galaxy

More than 10,000 new galaxies have been discovered on the ESO (B) Atlas of the Southern Sky and catalogued in the ESO/Uppsala lists that are regularly published in *Astronomy and Astrophysics Suppl. Series*. Many of these objects are highly peculiar.

The object shown in the photo was designated as 215-G?14, i.e. No. 14 in field 215, probably a galaxy. Two "nuclei" can be seen in the centre of a diffuse "nebulosity". Since the galactic latitude is only 8°, the possibility of a planetary nebula could not be excluded.

A spectrum has now been obtained with the ESO 3.6 m telescope. It shows that the right "nucleus" is nothing but a normal star, but the one to the left (which is slightly diffuse) is a galaxy nucleus with a radial velocity of 5,600 km s^{-1}. There is therefore little doubt that the underlying nebulosity is a real galaxy. The semi-stellar nucleus has a strong emission-line spectrum and is of the Seyfert type.

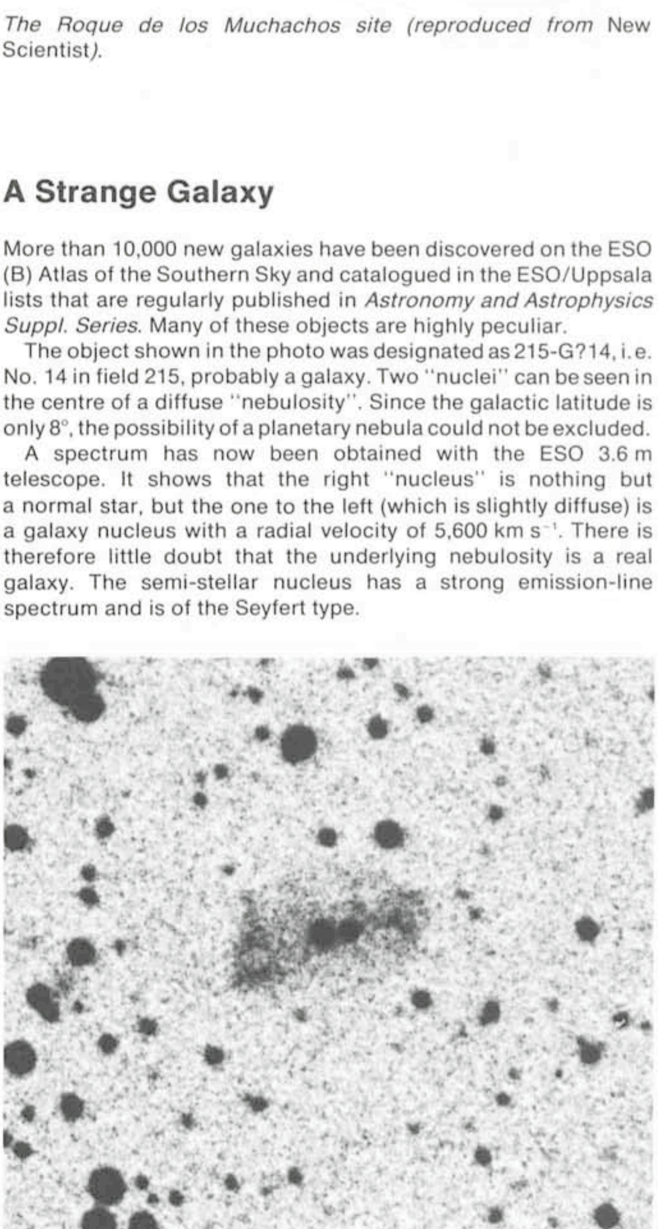


Image Processing: The Software Gap

R. Albrecht

An enormous amount of work has been invested in astronomical computer programmes. Dr. Rudy Albrecht of the Vienna Observatory explains how much time and effort has unfortunately been wasted because of duplication and lack of documentation. The situation may change, however, with the publication of the "Circular of the IAU Working Group on Computer Processing of Astronomical Data" which attempts to coordinate astronomical programme writing.

Everybody who has ever used a computer for the reduction of a large amount of data is familiar with the situation: one is confronted with the intricacies of an operating system, which works according to the strangest rules. The astronomical problems implied in the data almost disappear out of sight when compared to the alien demands of command string syntax and job control. Trying to use existing software is even more frustrating: there are countless programmes around that do almost what you want—but none of them exactly so. The only promising one was written by a graduate student, who since left, and no documentation of any kind can be found anywhere!

So finally you settle down and produce yet another programme that just does the job for your data. It will not work for anybody else, nor for other data. It is certainly not documented, because "it would have been a waste of time".

This type of inefficient software generation is going on right now in many observatories around the world. The mere fact that it is a waste of human intelligence should be reason enough to try to change the situation. The other, more convincing reason is the new astronomical tools that are becoming available to the astronomical public: IUE and the Space Telescope.

The type of data produced by panoramic (two-dimensional) detectors cannot be handled with traditional methods, because the reduction algorithms, commonly known as "Image Processing", are too sophisticated, and generating (and regenerating) them would exceed a single man's time. Back in the early days of photography and later for photoelectric photometry it was possible for one man to understand the theory behind the detector, build the device, carry out the observations and finally interpret the data astronomically. This is clearly not possible any more.

The situation in Europe with respect to the reduction of ST-generated data is by now foreseeable: There will most probably not be a central institution, where all the data reduction facilities are concentrated, but rather a network of national and local centres, each having their own processing facilities and probably concentrating on different aspects of the data, depending on the astronomical interest.

Some sort of software sharing has been proposed, either via firm links, facilitated by identical hardware, as will be the case in the United Kingdom. Or the exchange of programmes on magnetic tape between institutions with no compatible hardware. This approach is a necessity for ST, but it should certainly not be restricted to it.

Clearly, certain rules must be followed in order to make the software easily exchangeable among the institutions. It is a fact that the programming style of most astronomical application programmes never goes above the level of introductory programming courses. Top-down development and programme structuring is very rarely being used. This makes it difficult to implement programmes on other installations, even if the programming language is completely compatible. However, it will be difficult to get good people to write good programmes, designing and documenting them according to certain rules as long as they will not get "payed back". In other words, as long as the only drawback of not adhering to the rules is that you will never be asked again to submit a programme, these rules cannot be enforced.

It has to be recognized that the development of a programme, although it is really a tool, represents a lot of work in terms of time and effort. However, it is obviously not possible to publish a programme in an astronomical journal. Since astronomical problems are not very interesting for the world computer community, it cannot be published in a computer journal either.

In an effort to provide a publication medium for just such matters, we are trying to make use of the *Circular of the IAU Working Group on Computer Processing of Astronomical Data*. This "Circular", originally edited by C. T. Bolton of David Dunlap Observatory, was intended to be a communication device for PDS users on technical matters and it should still serve as such. Since software problems are the logical extension of technological problems, the publication of programmes and software-related matters is not contradictory to the original intentions. Moreover, the comparatively informal publication in a working group circular provides the possibility to report on things that have not taken final shape and may provide some helpful advice for other readers, who are working on a similar problem.

The "Circular" is now being edited jointly by Drs. Massimo Capaccoli of the Padova Observatory and Rudolf Albrecht! Contributions are invited on topics of software standards, compatibility, etc. Please follow the rules for camera-ready manuscripts. Programmes that are useful to others should be published with full documentation *plus* source listing.

Please send your contributions to:

R. Albrecht
Institute for Astronomy
Tuerkenschanzstr. 17
A-1180 Vienna, Austria

Tentative Meeting Schedule

The following dates and locations have been reserved for meetings of the ESO Council and Committees:

November 13	Scientific/Technical Committee, Geneva
November 14-15	Finance Committee, Geneva
November 16	Committee of Council, Geneva
November 29-30	Council, Munich
December 4-6	Observing Programmes Committee, Geneva

Millimetric Photometry of Planets on La Silla

R. Courtin, N. Coron, R. Gispert, J. M. Lamarre, J. Leblanc and J. Haro

Most people think of the ESO La Silla observatory as a place that is exclusively dedicated to optical (and infrared) observations. Now, however, what can perhaps best be termed as very short wavelength radio *observations have been carried out at the 3.6 m telescope by a group of French specialists, headed by Dr. Régis Courtin and based at the CNRS Laboratoire de Physique Stellaire et Planétaire (LPSP), Verrières-le-Buisson in France. Although the weather was somewhat uncooperative, good observations were obtained in four wavebands (0.7–4.0 mm) of Venus, Jupiter and Saturn. This is their preliminary report.*

Planetary Atmospheres

During the last decade, far-infrared photometry of planets has become a most powerful tool in the determination of their atmospheric thermal structures. Because of the rather strong variation of the opacity of their gaseous components with respect to wavelength, these atmospheres can be sounded in the altitude range by achieving either spectral measurements or multiband photometric observations. For instance, the knowledge of the thermal structure at high pressure levels in the giant planets is of great importance since it leads to an estimate of the internal source of power which constitutes one of the essential parameters in the modelling of solar system evolution. Furthermore, once the temperature profile is known, it becomes possible to investigate the abundances of minor constituents such as ammonia, phosphine or water.

The millimetric and submillimetric spectral ranges are particularly suitable for the sounding of deep atmospheric layers since the opacity has a trend to decrease at these wavelengths.

In the case of the outer planets, the dominant opacity is the result of absorption by molecular hydrogen, except for Jupiter where non-condensed ammonia is the main absorber beyond 40 microns. What concerns Venus, the atmospheric opacity is dominated by the properties of sulfuric acid droplets mixed with water vapour. For the giant planets, the maximum of the weighting functions calculated at $\lambda = 1$ mm locates between 2 and 3 atm, within the convective regions which extend below the tropopause (minimum temperature layer). In Venus, the sounded zone corresponds to the bottom of the dense cloud cover composed of sulfuric acid and water.

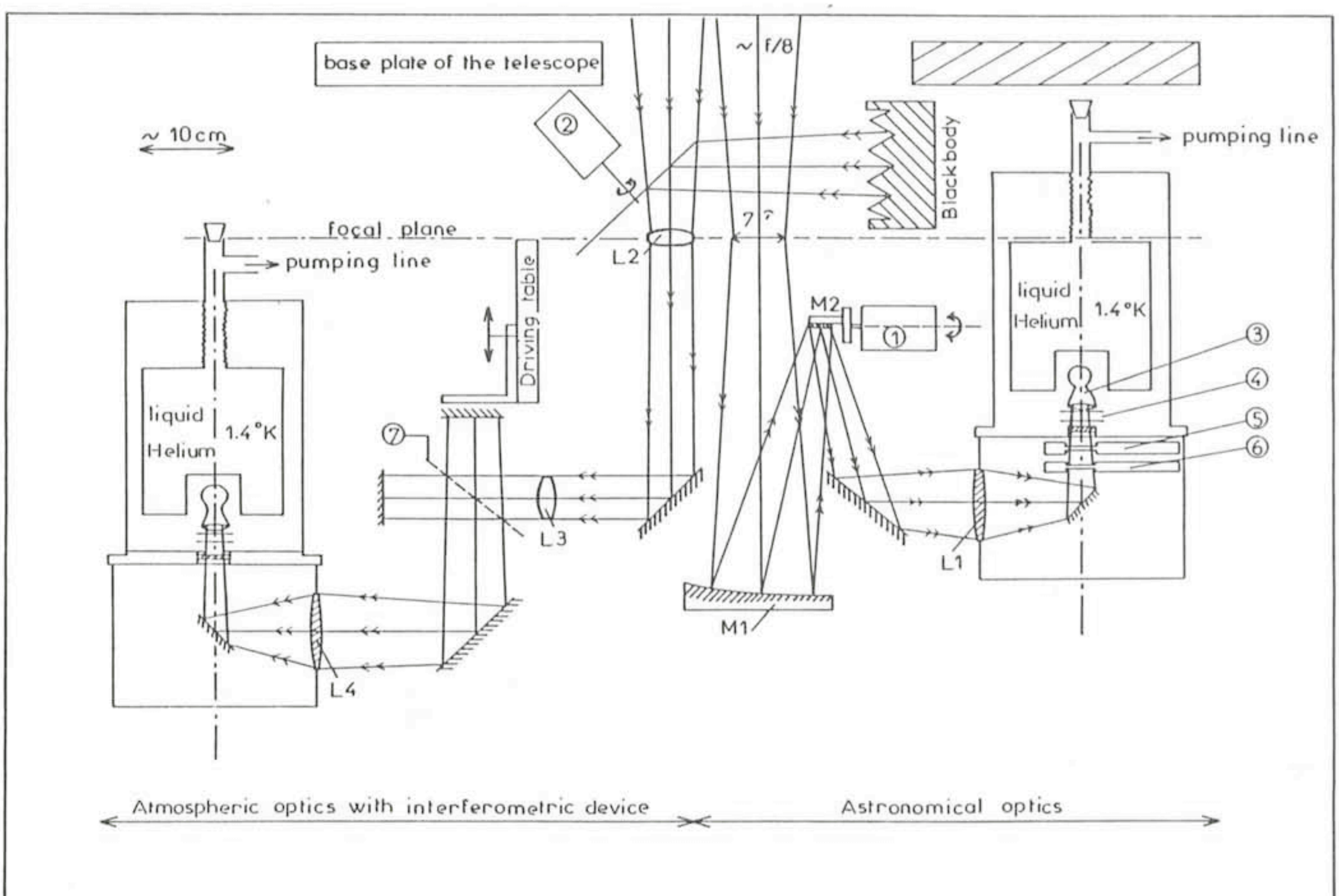


Fig. 1: *Optical schema of the millimeter photometer with sky emission spectral measurement. ① Scanner motor for sky modulation; ② Chopper; ③ Detector with light-cone; ④ Cold filters; ⑤ & ⑥ Filter wheels; ⑦ Beam splitter; M1 Parabolic mirror; M2 Wobbling mirror for sky modulation; L1 & L4 Quartz lenses; L2 & L3 TPX lenses.*

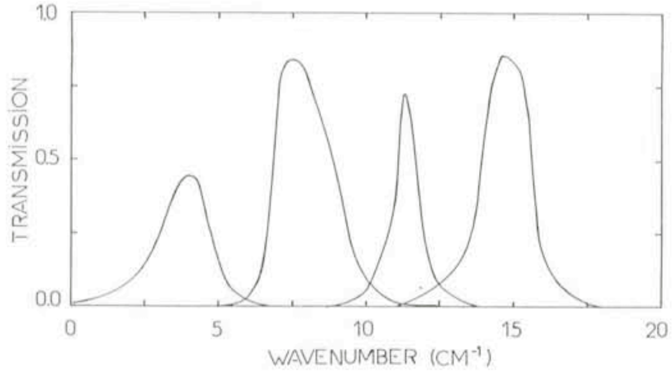


Fig. 2: *Spectral shape of the band-pass filters used for astronomical sources.*

Instrumentation and Observations

The fundamental problem in far-infrared photometry is to eliminate the intense atmospheric thermal emission superposed on the radiation coming from any astronomical source. Moreover, in the submillimetric and millimetric wavelength range, the presence of strong absorption bands of water vapour severely restrains the spectral ranges accessible from the ground and also produces large fluctuations of transmission related to meteorological conditions.

For these reasons, our instrument is designed as a dual-channel system, one channel being devoted to the measurement of astronomical fluxes using a sky modulation technique, the second one being restricted to the spectral monitoring of the sky emission modulated with the radiation of a blackbody source. The schematic optical design of the instrument, operating at the Cassegrain focus (f/8), is shown in figure 1. Focal plane sky chopping is achieved through the wobbling mirror M2 at a frequency of 20 Hz. The field of view in the astronomical channel is 7 arcmin. Spectral analysis of sky emission is made with a Michelson interferometer using a thin metallic grid as a beam splitter. Both detectors are composite Germanium bolometers (developed at LPSP) cooled by a liquid Helium bath at 1.4°K.

At the altitude of the La Silla Observatory, four atmospheric transmission windows can be utilized between 700 microns and 4 mm. The shapes of the corresponding

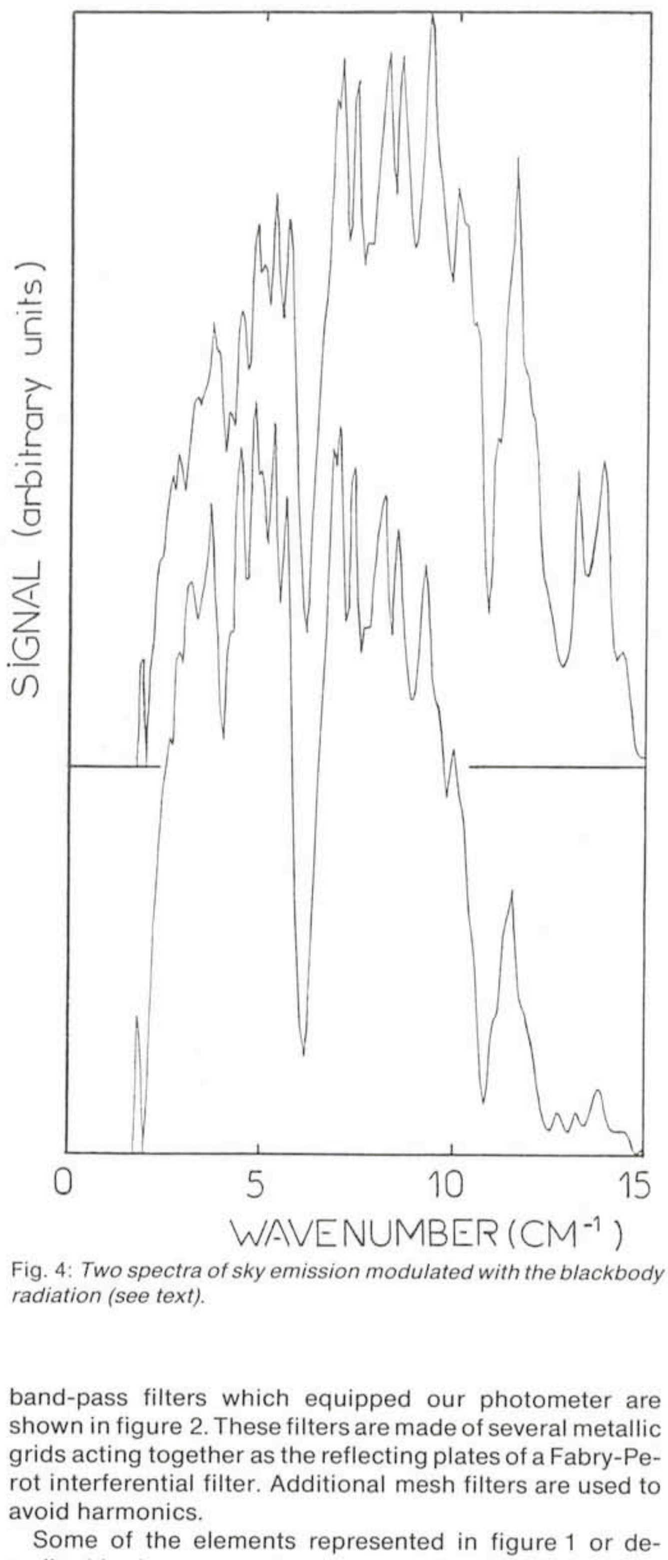


Fig. 4: *Two spectra of sky emission modulated with the blackbody radiation (see text).*

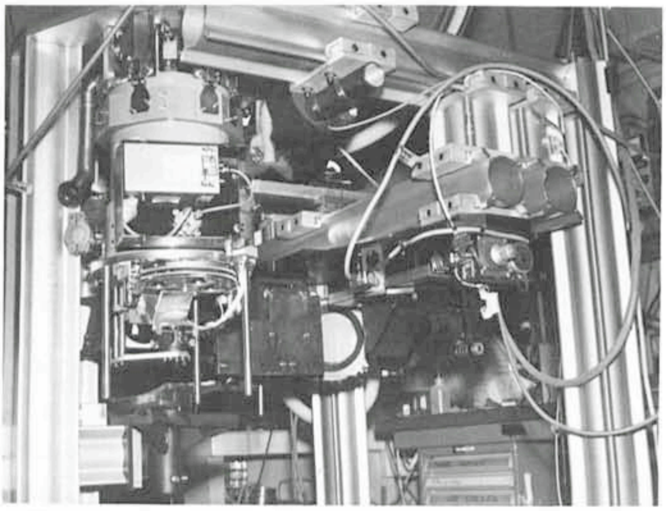


Fig. 3: *The instrument being tested in the laboratory.*

band-pass filters which equipped our photometer are shown in figure 2. These filters are made of several metallic grids acting together as the reflecting plates of a Fabry-Perot interferential filter. Additional mesh filters are used to avoid harmonics.

Some of the elements represented in figure 1 or described in the text can be seen on the photograph of figure 3: Parabolic mirror M1 (lower left), Astronomical photometer with preamplifier and filter wheels (left), Blackbody source and chopper (top), Interferometer with driving table and beam splitter (centre).

The observations were carried out with the 3.6 m telescope on La Silla at the beginning of March 1979. The meteorological conditions were very good during the few days preceding our run and on the first 24 hours of our observing period. Unfortunately, the water vapour content in the atmosphere steadily increased from the second day and consequently the average transmissions in the four filters dramatically dropped. This effect is much more pronounced in the two bands at shorter wavelengths ($\bar{\lambda}$ = 730 and 860 microns) for which the atmospheric zenithal transmissions varied from about 0.35 and 0.70 to about 0.03 and 0.15. This may be illustrated by the two spectra shown in figure 4. These curves represent the variation of the following quantity:

$$S_\nu = K\,[T_A(\tau_\nu)\,e^{-\tau_\nu} + (T_{BB} - T_A(\tau_\nu))]$$

where K is a constant,
$T_A(\tau_\nu)$ is the emission temperature of the sky depending on the optical depth τ_ν, and
T_{BB} is the blackbody temperature.

Thus, after the appropriate baseline correction and with the assumption of the atmospheric thermal profile, these spectra give access to the transmission. The upper spectrum was recorded on the first night at zenith, whereas the lower one corresponds to an air mass m = 1.29 at the end of the second night. The drastic changes seen between the spectra arise from both the changes in air mass and in the humidity content since the relative humidity at the ground level varied from 25 % to 52 % between the measurements.

Despite the unfavourable climatic conditions, we have acquired numerous high signal-to-noise ratio measurements of the fluxes of Venus, Jupiter and Saturn in the four bands. Uranus and Neptune, which are much fainter sources, hardly showed up in the 7–9 cm^{-1} filter.

Because of the simultaneous monitoring of sky emission in the direction of each source, and the intrinsic quality of the raw data, an improved precision on short millimetric brightness temperatures of the bright planets can be expected from these observations. This is of great interest in relation with the present and future space probe missions to Jupiter and Saturn (Voyager missions) and to Venus (Venera project) which will provide accurate measurements of the fluxes in the intermediate and near infrared (from 2 to 50 microns for Voyager and from 70 to 200 microns for Venera). The exploration of such a wide spectral range is obviously of great benefit to our knowledge of the atmospheric structures of these planets.

Simultaneous Spectroscopic and Polarimetric Observations of Be Stars

K. Metz and G. Pöllitsch

Some of the most enigmatic objects in our galaxy are the Be stars. They display a remarkable variety of features, ranging from variable emission lines to high degrees of polarization. How do they look like? Drs. Klaus Metz and Gerd Pöllitsch from the München Institute for Astronomy and Astrophysics visited La Silla in 1977 and this year and observed southern Be stars. They do not provide the final answer to the problem, but they here report interesting new results.

In 1866 A. Secchi reported that the stars γ Cassiopeae and β Lyrae showed very brilliant spectra which seemed to be inverse to those of other blue stars. This was the first discovery of emission in stellar spectra, but almost twenty years had to pass until E. C. Pickering started an objective-prism survey in that field. In 1911, R. H. Curtiss followed with the first observations and classification of emission-line stars. As a consequence of his work, the International Astronomical Union introduced the name *Be star* in 1922 at its first General Assembly.

More than half a century has now passed and many famous astronomers, among them a surprisingly high number of women, have been working on the problems of Be and shell stars. During the last years they extended the classical observations to the far UV and IR using high-speed photometers and polarimeters as well as spectral line scanners.

The result of these efforts is that none of the various models proposed for Be stars can now satisfy all different aspects which have been brought in by the new observations.

This is due not only to difficulties in understanding the physics of extended shells, but also to the fact that many Be stars act like prima donnas: Sometimes they behave eruptively. Or they can, nobody knows why and when, completely lose their shell and then look like a normal B star. They have proven to be variable in spectrum and polarization within a relatively short time or even within hours. For an astronomer it is really fascinating to look at this performance and to see how it is developing with time (figs. 1, 3).

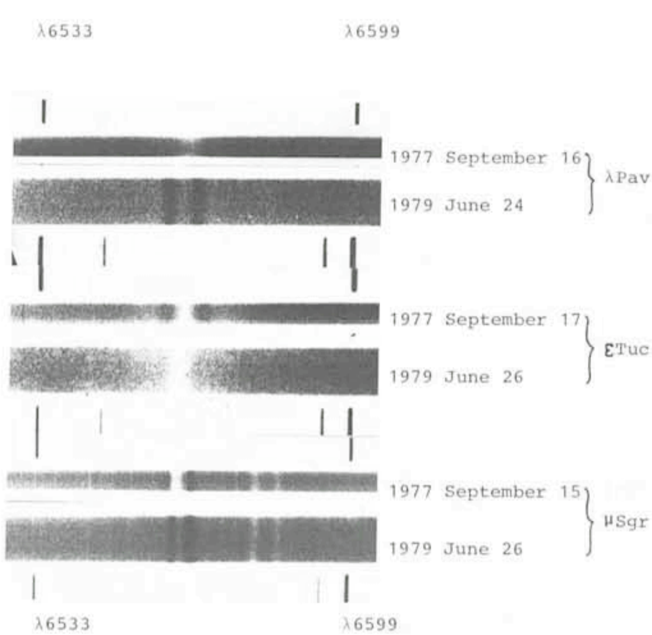


Fig. 1: *Hα line variation of three Be stars. The spectra have been taken with the ESO 1.5 m telescope, coudé, 12.3 Å/mm, 127-04 and IIIa-F emulsion respectively.*

Models of Be Stars

The first approach to an understanding of Be star phenomena was made by O. Struve. He suggested that the broadening of emission lines is due to rotation of a thin shell. Many objections have been made against this hypothesis and a long public dispute arose between Struve and Ambarzumian, in particular about how widths of emission lines shall be measured, a problem which does not yet seem to be solved. In Struve's model the high rotational velocity of a Be star should cause an equatorial break-up and the ejected material will form an emitting ring or disk, similar to our planet Saturn. In this case, broadening of emission lines would only be a function of the inclination of the rotational axis. If the disk is viewed edge-on, sharp absorptions will occur and therefore this model also explains the shell spectra[1] by inclination. Quantitative calculations have been carried out by Marlborough, Hutchings and others and they have been able to compute fairly realistic hydrogen line profiles.

However, there are other emission-line objects, like novae and planetary nebulae, the geometry of which can be resolved by telescopes. As a matter of fact, most of them show rather spherical geometries. This led one of us to compute line profiles of Be stars which were based on spherical envelopes. In this thesis he actually showed that spherical envelopes rotating differentially can also reproduce the observed Balmer lines, both with and without central absorption features.

The question is then: which shape do Be stars really have? Are they spheres or disks? An accurate knowledge of the geometry could help to draw conclusions about the mechanism forming the circumstellar shell. For example, an equatorial break-up or interacting binaries would form a disk or a ring-like shell. In turn, if radiative pressure or other symmetric forces account for the massflow, one would expect rather spherical shells. However, it should be emphasized that the study of line profiles only yields rough information about the geometry. See for example figures 2 a, 2 b: In figure 2 a three calculated line profiles are plotted. Figure 2 b shows the different geometries for which the calculation has been carried out. By comparison with the measured line profile (crosses) one can see that the fit is pretty good in all three cases. By variation of the relevant parameters within the limits given by physical conditions we finally derive:

(1) The observed Hα line profile may be produced by a shell extending at least 5 but not more than 25 stellar radii.

(2) The ratio of polar radius to equatorial radius lies between 0.5 and 1.

Polarization of Be Stars

As was first shown by A. Behr in 1959 for γ Cas, Be stars can exhibit a strong and variable polarization. Polarization of starlight, which is not generated by scattering of light within the interstellar medium, but is produced by the star itself or by scattering of radiation within an asymmetric stellar envelope, is called *intrinsic*.

The fact that normal Be stars do not show any significant intrinsic polarization, whereas Be stars do so, very soon led to the supposition that the envelopes must be responsible for the intrinsic effect. Indeed, the observed degree and wavelength dependence of polarization in Be stars can best be explained by electron scattering (independent of wavelength) but modified by absorption in a hydrogen plasma both before and after scattering.

It is clear that a resulting polarization will be produced only by an asymmetric distribution of scattering particles. Therefore the determination of the intrinsic polarization produced in the envelopes of Be stars should be a powerful

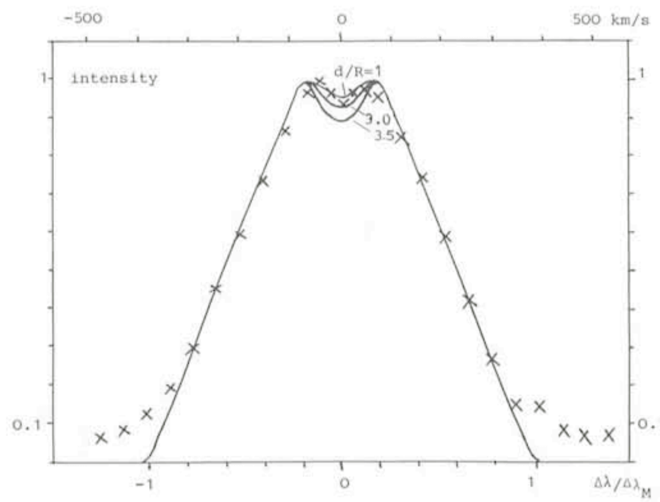


Fig. 2a: *Measured H α profile of π Aqr normalized to maximum intensity 1 for maximum emission (1977, Sept. 19, ESO 1.5 m coudé, 3.3 Å/mm). Solid line derived from model calculations for spherical and flattened shells as plotted in figure 2b.*

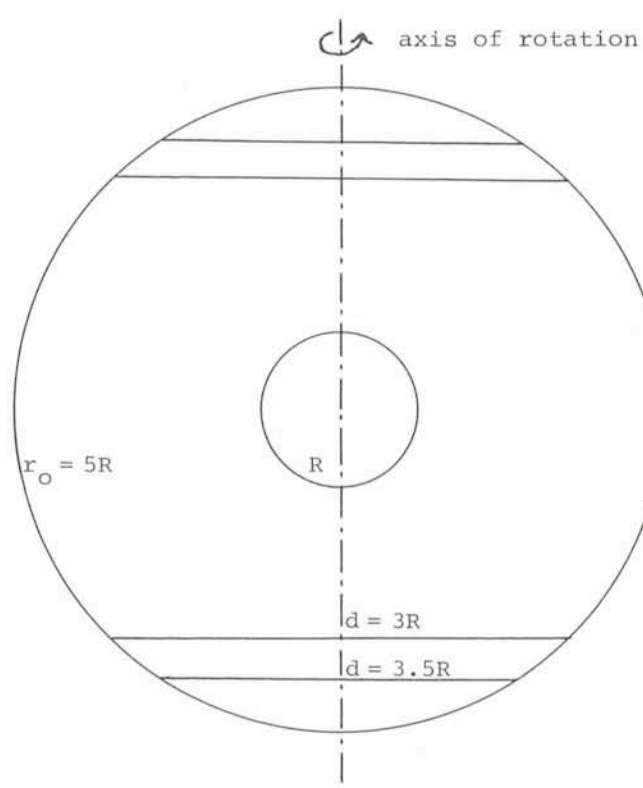


Fig. 2b: *Geometry of the shell of π Aqr as adopted for model calculations in figure 2a. Three cases have been considered: A spherical shell and a sphere cut off at a distance $d = 3R$ and $d = 3.5R$. Hydrogen density is proportional $(1/r)^{2.5}$. Rotation is differential but with conservation of angular momentum ($v_\varphi [r] \cdot r = const.$)*

[1] Spectra showing both broad photospheric lines and very narrow lines are called shell spectra. Most of them also show emission.

means of studying the geometry of the envelopes themselves. At least this will be valid in the case where the electron density as well as the density gradient may be determined independently by simultaneous spectroscopic observations.

Simultaneous Observations at La Silla

In 1977 we started at La Silla a programme of simultaneous spectroscopic and polarimetric measurements for which ESO is able to offer excellent facilities. Discussing our observational routine, we had to decide whether to select a sample of only a few stars, each of them being observed over a long period, or to observe a larger number of stars, but spending only a relatively short observation time on each. Considering the great variety among Be stars, we decided upon the latter.

However, the long integration time, which is necessary for high-dispersion spectra, and also a narrow-band filter polarimetry, then restricts the observations to objects brighter than 6th magnitude. About 160 stars remain. Due to the concentration of young stars to the galactic plane, most of them can be observed at La Silla.

In our first run in 1977 we could observe 15 Be stars simultaneously. In 1979 we observed a further 15 stars and in addition 6 of the stars we had already observed two years earlier.

The repetition of observations turned out to be very illuminating because all six stars exhibited pronounced variations. For example, in 1977 λ Pav showed a normal B-type spectrum whereas in 1979 a marked double emission appeared. ε Tuc varied its spectrum quite contrary and the other stars changed their line profiles remarkably (see fig. 1).

Very surprising was the fact that five of twenty-one programme stars, known as emission-line stars, did *not* show any emission in Hα!

The Shell of π Aqr

Everyone who is concerned with calculations of extended envelopes knows by experience that it would be too optimistic to believe that the Be star problems can be solved quite simply by simultaneous spectroscopic and polarimetric observations. We soon had to learn this lesson from the shell star π Aqr. As was pointed out, the Hα line profile shows that the ratio of polar radius to equatorial radius lies within 1/2 and 1. On the other hand, we have the results of the polarization measurements (see fig. 3):

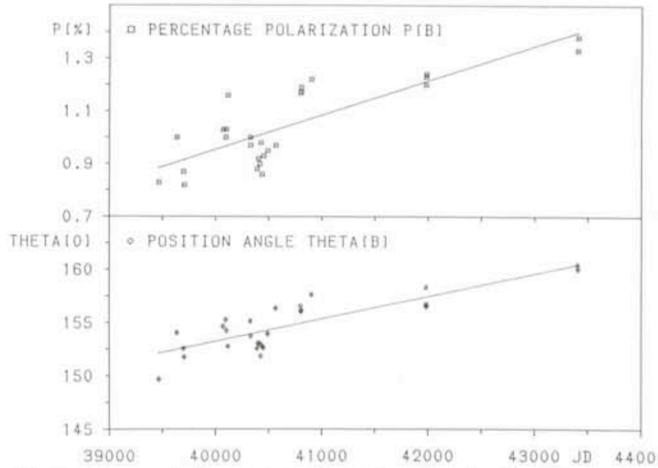


Fig. 3: *The variable polarization of π Aqr in the blue colour observed over a period of 12 years by different authors.*

Assuming simple electron scattering, the extremely high polarization of π Aqr requires this ratio to be between 1/3 and 1/5. What is wrong here? Perhaps the models used for both the line-profile calculations and also the continuum polarization are too simplified. Perhaps the polarization is caused not only by electron scattering but also by aligned grains. A confirmation may be the strong variability as well as the increase of polarization during the period of observation. However, which particles should be aligned and what is the physical mechanism responsible for an alignment of particles?

We have no answers to these questions at the moment. Therefore we are now trying to start calculations which take into account the known fact that the photosphere of a rapidly rotating star, like π Aqr, cannot be a sphere but must be flattened. This asymmetry of the geometry of the photosphere will cause a radiation flux which is also asymmetric in its geometry. Therefore, an additional polarization will result by electron scattering even within a spherical shell.

Acknowledgements

We wish to express our appreciation to all staff members at La Silla for their assistance during the simultaneous observations on two telescopes.

NEWS AND NOTES

Identification of Minor Planets

All over the world, every night, photographical plates are exposed with astronomical telescopes. And astronomical photography has become a great hit among amateurs who, for comparatively little money, can buy rather large, high-quality instruments.

As is well known to the readers of the *Messenger*, such photos may frequently show trails of minor planets. The fainter the limiting magnitude, the more trails are likely to be seen. Many professional astronomers are full-time "minor planet hunters" and with larger telescopes and better photographic emulsions more and more objects are being picked up. Many amateurs are now capable of reaching magnitude 15 or even 16 and have the fun of discovering new minor planets.

One of the major problems that confronts the astronomer who works in this field is to determine whether a trail belongs to a planet that is already known or whether it is new. The necessity of being able to answer this important question quickly and efficiently in connection with the research that is carried out at the Schmidt telescope on La Silla has led ESO astronomers H.-E. Schuster and R. M. West to develop a method that may be of interest to others.

ESO has several computer systems in Chile and in Geneva. Some of these control the telescopes on La Silla and others control the measuring machines in Geneva. There are, of course, also some systems that are used for "regular" computations. Some years ago, ESO decided to standardize its computer equipment, and after a careful study the Hewlett-Packard 21MX was chosen. This has the great advantage that programmes can be immediately transferred from one ESO computer to another, without time-consuming software rewriting.

A set of programmes has been written that takes care of almost all problems in connection with minor planet work, from identification to measurement of accurate positions, but not (yet) computation of orbits from observed positions.

The basic feature is a computer file with the orbital elements of all numbered minor planets which is regularly brought up to date. As of August 1979, there are 2,167 entries. The file originates from a card catalogue that was generously made available to ESO by Dr. Lutz Schmadel of the Astronomical Computing Centre in Heidelberg. A second file contains the elements of all minor planets that were discovered at ESO. Since the elements vary with time because of planetary perturbations, a programme is available that carries the epoch of the elements forward or backward in time. This programme is based on a subroutine that was also delivered by Dr. Schmadel and which has proven to be very accurate.

To identify a minor planet trail is now rather easy. All the astronomer has to do is to use a "search" programme. He first tells the computer the central coordinates of the plate on which the trail is seen, the epoch of the plate (i.e. the exact time it was exposed), the size of the plate (in millimetres) and the plate scale ("/mm). The programme then, in about one minute, runs through the element files and prints out which planets can be seen in the plate field, the rectangular (X, Y) coordinates of the corresponding trail and the magnitude. By placing a transparent millimetre grid on the plate, it is very easy to verify whether the trail in question corresponds to one of the known planets. In practice, very few planets that are brighter than 16^m are unknown, but most of those fainter than 17^m are new discoveries.

Accurate measurements of the trail positions can be done for instance on the ESO S-3000 measuring machine in Geneva that is capable of taking plates of 14 × 14 inch size. Positional measurements have now become a matter of routine and ease, because a high degree of automation has been achieved. Astrometrical standard stars in the field shown by a plate are acquired automatically from the Perth 70 catalogue which is stored on the computer disc. Similarly, the earlier-mentioned programme may be used to find the minor planets on a plate without having to search for them through a microscope. Thus, when trails of supposedly new planets are measured, it takes very little effort to add measurements of all known planets on the plate.

The measured (X, Y) coordinates are transformed into celestial (α, δ) coordinates by means of another programme. All in all, it now takes about 15 minutes to measure a few minor planet trails on a Schmidt plate and obtain accurate positions ($\pm$ 0."3). Most of the time is spent on the measurement of the standard stars that serve as reference.

The positions are sent to the Minor Planet Bureau of the IAU that, under the leadership of Dr. B. Marsden, has achieved a high degree of perfection in orbital calculation and identification of "new" planets with "unidentified" observations from earlier epochs. This enormous task is facilitated by a computer catalogue of about 200,000 minor planet observations which can be searched once the approximate orbit of the "new" planet is known. It is not rare that the efforts of Dr. Marsden and his associate Dr. Conrad Bardwell lead to several identifications, sometimes dating back to early in this century. The requirement that a planet must have been observed in at least three oppositions before it can be numbered can therefore sometimes be met immediately.

R. M. West

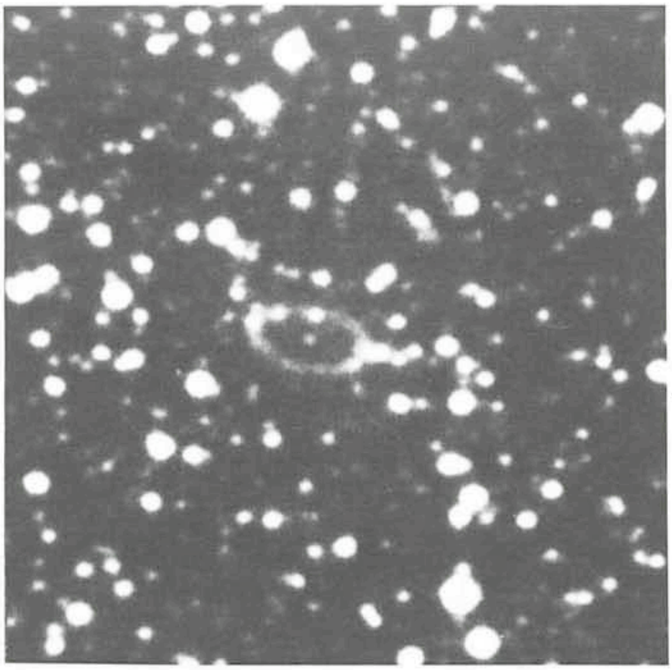
Galaxy or Nebula?

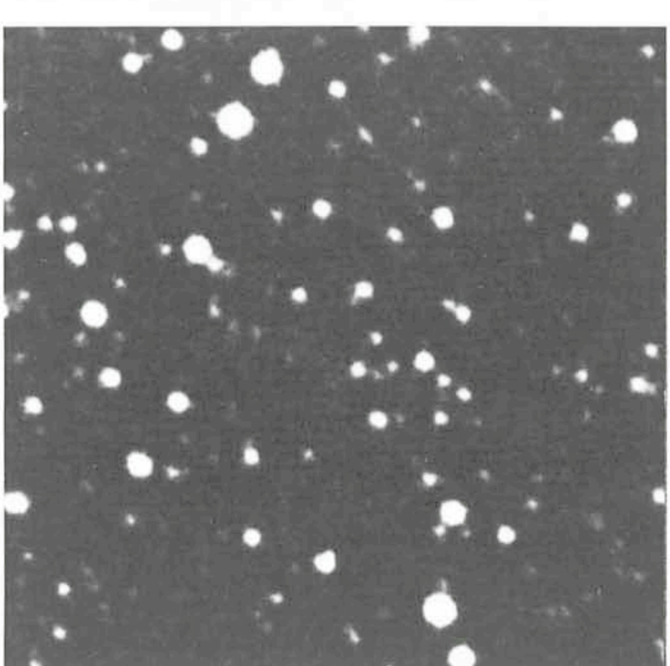
The ESO (R) half of the joint ESO/SRC Atlas of the Southern Sky is now going well ahead (2-hour exposures on IIIa-F + RG630 plates with the ESO Schmidt telescope).

It is obviously of great interest to compare these red plates (wavelength interval: 6300–7000 Å) with corresponding blue plates, for instance the ESO (B) plates (3900–4900 Å) in order to discover objects that are either very blue or very red. During the quality control of a red plate, ESO astronomer H.-E. Schuster recently noticed a very peculiar object near one of the edges. The object, which is shown enlarged here, has the form of an oval ring; the longest diameter is about 28 arcseconds. The object is not at all visible on the ESO (B) plate (also shown here).

One would suspect that it is a planetary nebula or perhaps a ring galaxy. The central star of a planetary nebula is normally blue, but a comparison of the two photos does not show a particularly blue object in the centre. Nor is it usual to encounter an extragalactic object at this low galactic latitude (+ 3.°7).

It is faintly visible on the Whiteoak extension to the Palomar Atlas but is not included in the lists of planetary nebulae that have so far been published. Spectroscopic observations are now eagerly awaited; for those who want to try themselves, here are the accurate coordinates (1950.0) of the central "star": R. A. = 16^h 40^m 57.s44; Delt. = –39° 57' 48."4.





A mysterious object, reproduced from a rejected ESO (R) plate (upper, 120 min IIIa-F + RG630, bad seeing) and an ESO (B) plate (lower, 60 min IIa-O + GG385), both obtained with the ESO Schmidt telescope. North is up and east to the left.

Visiting Astronomers

(October 1, 1979—April 1, 1980)

Observing time has now been allocated for period 24 (October 1, 1979 to April 1, 1980). The demand for telescope time was again much greater than the time actually available.

This abbreviated list gives the names of the visiting astronomers, by telescope and in chronological order. The complete list, with dates, equipment and programme titles, is available at request from ESO/Munich.

3.6 m Telescope

Oct. 1979:	Querci, Foy, Alcaíno, Tarenghi/Crane/Ellis/Kibblewhite/Peterson/Malin, Lequeux/Laustsen/West/Schuster, Fricke/Schleicher/Biermann, Gyldenkerne/Taylor/Axon, Wamsteker/Danks, Hunger/Kudritzki.
Nov. 1979:	Sibille/Perrier, van den Heuvel/Van Paradijs/de Loore, Grosbol, Crane/Materne/Tarenghi/Chincarini, Röser, Dennefeld/Boksenberg, Norgaard-Nielsen/Niss.
Dec. 1979:	Schnur, Reipurth/Wamsteker, Wlérick/Bouchet, Ekman, de Ruiter/Lub, Pottasch/Piersma/Goss, Shaver/Danks/Pottasch, Mundt.
Jan. 1980:	Weigelt, Alloin/Boksenberg/Tenorio-Tagle, Lindblad/Boksenberg/Alloin, Danziger/de Ruiter/Kunth/Lub/Griffiths/Wilson/Ward, West/Kurtanidze/Frandsen/Thomsen, Westerlund/Pettersson, Schnur/Kohoutek/West, Schnur, Sibille/Perrier.
Feb. 1980:	Epchtein/Guibert/Q-Rieu/Turon/Puget, Koester/Weidemann, Véron, M. P. and P., Pakull, Bergeron/Kunth, Ilovaisky/Chevalier, Adam, Knoechel.
March 1980:	Moorwood/Shaver/Salinari, Huchtmeier/Materne/Wielen, Schnur/Kohoutek/West, Boksenberg/Danziger, Boksenberg/Danziger/Fosbury, Boksenberg/Danziger/Fosbury/Goss, Goss/Boksenberg/Danziger/Bergeron, Ulrich/Boksenberg, Wehinger/Boksenberg/Lub/Wyckoff, Bensammar.

1.52 m Spectrographic Telescope

Oct. 1979:	Holweger, Ahlin/Sundman, Querci, Foy, Spite, Wolf/Sterken.
Nov. 1979:	Wolf/Sterken, Thé/van Genderen/Kwee, Röser, Grosbol, Crane/Tarenghi/Materne/Chincarini, Dennefeld/Boksenberg.
Dec. 1979:	Krautter, Lauberts, Bastian, Gahm/Hultqvist/Liseau.
Jan. 1980:	Gahm/Hultqvist/Liseau, Gehren/Hippelein/Münch, Macchetto, Gustafsson/Welin, Schnur, Westerlund/Pettersson, van Dessel.
Feb. 1980:	van Dessel, Kudritzki/Simon, Monnet/Georgelin/Boulesteix/Marcelin, Hua/Nguyen Doan, de Loore/Burger/van Dessel/van den Heuvel.
March 1980:	de Loore/Burger/van Dessel/van den Heuvel, Ahlin/Sundman, Materne/Richter/Huchtmeier, Schnur, de Vries.

1 m Photometric Telescope

Oct. 1979:	Schmidt/Engels/Schultz, Wamsteker, Moorwood/Salinari, Azzopardi/Vigneau, Geyer/Hänel/Nelles.
Nov. 1979:	Geyer/Hänel/Nelles, Wamsteker, Thé/van Genderen/Kwee, Motch, van Woerden/Danks, Schoembs, Motch.
Dec. 1979:	Motch, Wamsteker, Danks/Wamsteker, Lauberts, Wlérick/Bouchet, Ekman, Gahm/Lindroos, Hippelein/Münch/Melnick.
Jan. 1980:	Hippelein/Münch/Melnick, Westerlund, Westerlund/Pettersson, Metz/Häfner, Danks/Wamsteker, Epchtein/Guibert/Q-Rieu/Turon.
Feb. 1980:	Epchtein/Guibert/Q-Rieu/Turon, Tarenghi/Tanzi, Koester/Weidemann, Véron, M. P., Adam, Knoechel.
March 1980:	Knoechel, Swings, Swings/Bouchet, Moorwood/Shaver/Salinari, Wlérick/Bouchet, Mianes, van Woerden/Danks, Bensammar.

50 cm ESO Photometric Telescope

Oct. 1979:	Divan/Zorec, Motch, Spite.
Nov. 1979:	Spite, Barbier, Geyer, Hensberge.
Dec. 1979:	Hensberge, Gahm/Lindroos.
Jan. 1980:	Hensberge, Debehogne, Metz/Häfner, Zwaan.
Feb. 1980:	Zwaan, Schober, Motch, Wolfschmidt.
March 1980:	Wolfschmidt, Lagerkvist, Thé/Wesselink.

40 cm GPO Astrograph

Oct. 1979:	Azzopardi/Vigneau, Gieseking.
Nov. 1979:	Gieseking.
Dec. 1979:	Gieseking, Debehogne.
Jan. 1980:	Gieseking.
Feb. 1980:	Gieseking.
March 1980:	Gieseking.

1.5 m Danish Telescope

Dec. 1979:	Nissen, Weigelt.
Feb. 1980:	Schnur/Sherwood, Véron, P., Alcaíno, Haug.
March 1980:	Haug.

50 cm Danish Telescope

Dec. 1979:	Ardeberg/Gustafsson.
Jan. 1980:	Barbier.
Feb. 1980:	Barbier, Haug, de Loore/Burger/van Dessel/van den Heuvel.
March 1980:	de Loore/Burger/van Dessel/van den Heuvel, Renson.

90 cm Dutch Telescope

Oct. 1979:	de Loore/van den Heuvel/van Paradijs, Thé/van Genderen/Kwee.
Dec. 1979:	de Ruiter/Lub.
Feb. 1980:	Pakull, Wlérick/Bouchet.

61 cm Bochum Telescope

Dec. 1979:	Celnik, Zeuge.
Jan. 1980:	Zeuge, Motch, Schober, Klutz.
Feb. 1980:	Klutz.

Speckle Interferometry and Speckle Holography with the 1.5 m and 3.6 m ESO Telescopes

J. Ebersberger and G. Weigelt

That great arch-enemy of all observing astronomers, the seeing, *can be pacified with a method called* speckle interferometry. *For some years it has provided us with "real" pictures of close binary systems and even of the surfaces of some stars, e.g. the well-publicized image of Betelgeuze. So far, however, the speckle technique—which is based on very short exposures and very long focal lengths—has been limited to comparatively bright objects. Drs. Johannes Ebersberger and Gerd Weigelt, from the Physics Institute of the Erlangen-Nürnberg University, Fed. Rep. of Germany, review recent speckle work at La Silla. It will be good news to many that they are reasonably confident that objects of magnitude 16 or even fainter may soon be within reach of speckle interferometry!*

The theoretical resolution of a 3.6 m telescope is about *0.03 arcsecond* (at $\lambda = 400$ nm). This limit is caused by diffraction. Of course, ordinary astrophotography does not yield diffraction-limited resolution. The turbulent atmosphere restricts the achievable resolution to about *1 arcsecond.*

However, it is possible to achieve *0.03 arcsecond* resolution if one evaluates *short-exposure photographs* by speckle interferometry or its modification, speckle holography. Speckle interferometry was first proposed by A. Labeyrie (*Astron. Astrophys.* **6**, 85). Up to now speckle interferometry was mainly applied to the measurement of binary stars and star disks. In the future speckle interferometry will certainly also be applied to more complicated objects such as for instance galactic nuclei.

For speckle interferometry it is necessary to evaluate short-exposure photographs, because only short-exposure photographs carry diffraction-limited information. The exposure time has to be about 0.03 sec or shorter in order to "freeze" the turbulent atmosphere. Such short-exposure photographs, called speckle interferograms, consist of many small interference maxima, called "speckles". The size of each speckle is in the case of a 3.6 m telescope about 0.03 arcsecond. Speckle interferograms are the diffraction patterns of the refractive index variations in the atmosphere. The life time of the fine structure of a speckle interferogram is about 0.03 sec. A typical speckle interferogram is shown in the upper part of figure 2.

Why is it possible to extract by speckle interferometry high resolution information from speckle interferograms? Figure 1 gives the answer. The two stars of a close binary star produce at the same time nearly the same speckle patterns or point spread functions. This fact is called the space-invariance (isoplanicity) of the atmospheric point spread function. If the separation of a binary star is closer than 1 arcsecond, then the total speckle pattern consists of *two identical, overlapping* speckle patterns.

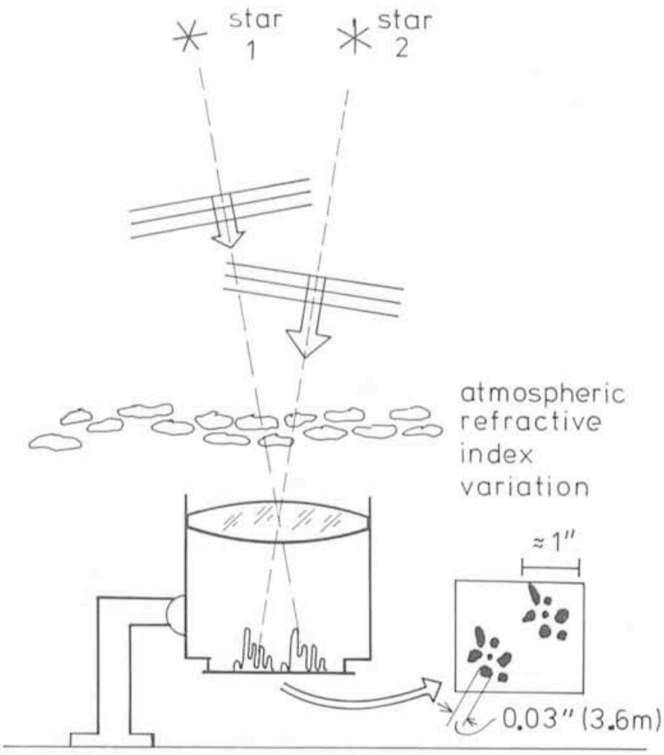


Fig. 1: *The two stars of a close binary star produce at the same time nearly identical speckle patterns. This is due to the fact that the light from both stars propagates through nearly the same part of the atmosphere.*

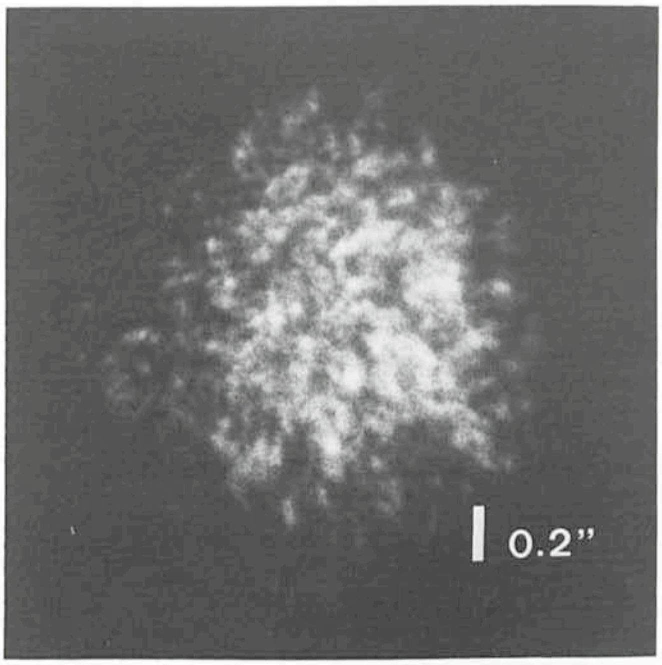
This knowledge is the key for extracting high resolution object information. In the case of a more complicated object, the total produced speckle pattern is equal to the convolution of a single star speckle interferogram and the object intensity distribution.

In speckle interferometry high resolution information is extracted from speckle interferograms by averaging the modulus square of the Fourier transforms of all recorded speckle interferograms. This procedure and the compensation of the speckle interferometry transfer function yield the power spectrum (= modulus square of the Fourier transform) of the object. This is what Michelson observed as "visibility". From there one continues to process the information by performing another Fourier transformation. The outcome is the autocorrelation of the object, with a resolution limited only by diffraction, not anymore by the turbulent atmosphere.

In the following sections some examples of speckle interferometry measurements with the 1.5 m and with the 3.6 m telescope are shown. We describe: (1) speckle interferometry measurement of the close spectroscopic binary Epsilon HYA, (2) speckle interferometry of the newly resolved, close binary Zeta AQR A-C (separation = 0".064), (3) speckle interferometry of two faint binaries (brightness $9^m_.4/9^m_.6$ and $9^m_.5/10^m_.4$; probably the faintest binaries resolved by speckle interferometry up to now), (4) speckle interferometry with a simulated Multiple Mirror Telescope, and (5) reconstruction of a high resolution *image* (instead of the autocorrelation) from speckle interferograms. The latter image-forming method is called *speckle holography.*

Example 1: Speckle Interferometry Measurement of the Spectroscopic Binary Epsilon Hydrae

Spectroscopic binaries are very interesting objects for speckle interferometry, because the combination of speckle measurements and spectroscopic measurements can yield new points in the empirical mass-luminosity relation. One of the spectroscopic binaries that is resolvable by speckle interferometry is Epsilon HYA. At the bottom of figure 2 the reconstructed autocorrelation of Epsilon HYA is shown. The autocorrelation of a binary star consists of three dots. The distance from the centre to one of the off-centre dots is the separation. The separation of Epsilon HYA was measured (epoch 1978.964) to be 0."239 ± 0."004. The position angle was measured to be 141°.7 ± 2° (180°-autocorrelation ambiguity). The autocorrelation was reconstructed from 400 speckle interferograms. One of them is shown at the top of figure 2. The speckle interferograms were recorded under the following conditions: 3.6 m telescope; effective focal length = 460 m; exposure time = 0.01 second; interference filter: λ_0 = 550 nm and $\Delta\lambda$ = 20nm; compensation of atmospheric dispersion by non-deviating prisms.



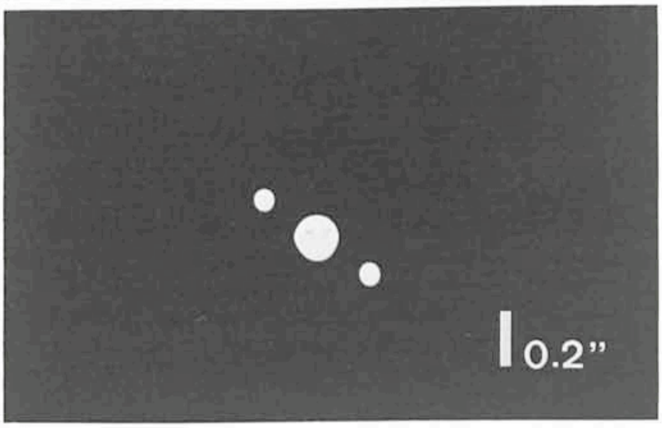


Fig. 2: *Speckle interferometry measurement of the spectroscopic binary Epsilon HYA. The photograph at the top shows one of 400 speckle interferograms recorded with the 3.6 m telescope. The photograph at the bottom is the reconstructed high resolution autocorrelation of Epsilon HYA (separation = 0."239 ± 0."004).*

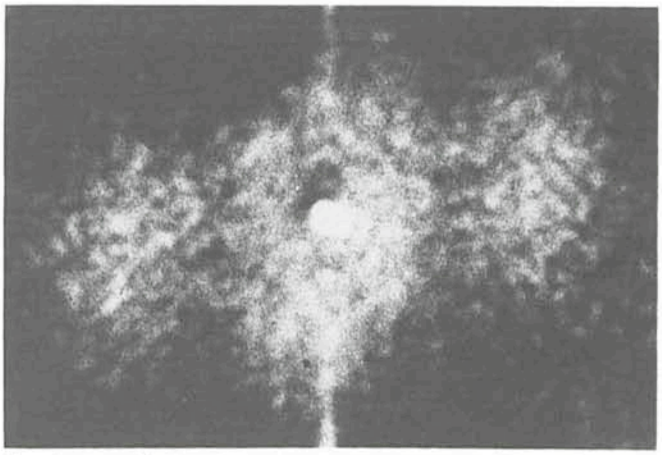


Fig. 3: *Speckle interferometry measurement of Zeta AQR A–C (separation = 0."064 ±* 0."005). Object power spectrum.

Example 2: Speckle Interferometry Measurement of Zeta Aquarii A–C

Zeta AQR A–B is a famous binary star with about 1.7 arcsecond separation. When we evaluated the speckle interferograms of this object we were very surprised. Zeta AQR A was again resolved in two stars having a separation of only 0."064 ± 0."005 (1978.964). Figure 3 shows the power spectrum of Zeta AQR A–C, which was reconstructed from 100 speckle interferograms recorded with the 3.6 m telescope.

Example 3: Speckle Interferometry Measurement of Faint Binaries

In order to study the limiting magnitude of speckle interferometry we recorded speckle interferograms of objects down to 14^m.8! Most of these measurements have not yet been reduced. Already evaluated are the speckle interferograms of ADS 1865 (9^m.4/9^m.6) and D + 14.696 (9^m.5/10^m.4). The speckle interferograms of these objects were recorded with the 1.5 m ESO telescope. Separation and position angle of ADS 1865 were measured (1978.956) to be 0."214 ± 0."010 and 181° ± 4°, respectively. Figure 4 a shows the power spectrum of ADS 1865 reconstructed from 500 speckle interferograms. Figure 4 b and 4 c show the power spectrum and autocorrelation of D + 14.696 (1978.956: separation = 0."640 ± 0."02; position angle = 160°.7 ± 2°). The autocorrelation of D + 14.696 was reconstructed from 400 speckle interferograms. Based on extrapolations we believe that objects of 16th to 18th magnitude may be observable during very good seeing and with a sufficiently large number of short exposures.

Example 4: Speckle Interferometry with Simulated Multiple Mirror Telescopes

ESO and the Kitt Peak National Observatory are studying a large Multiple Mirror Telescope. Therefore we have simulated MMT speckle interferometry. For that purpose we mounted a MMT mask in front of the 1.5 m telescope. The mask consisted of 4 holes. The diameter of each of the four apertures was 50 cm. The goal of these experiments was to collect information about the signal-to-noise ratio and the speckle interferometry transfer function. We have

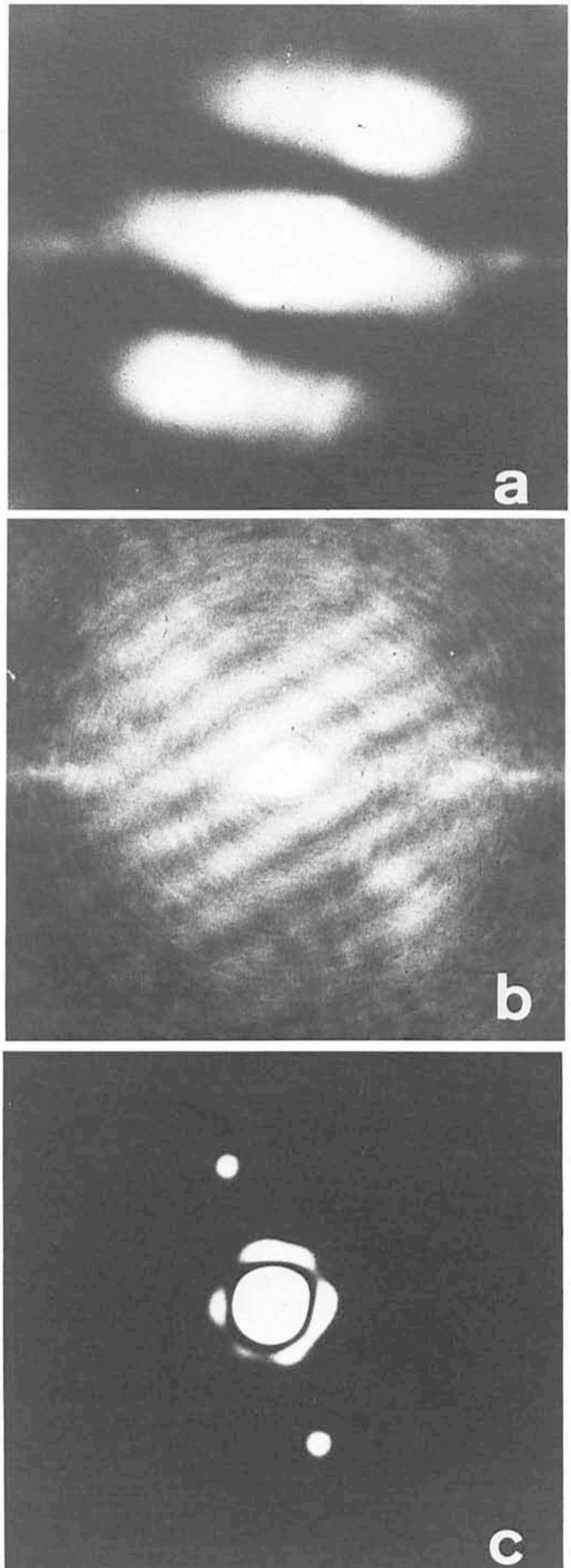


Fig. 4: *Speckle interferometry measurement of the binaries ADS 1865 ($9\overset{m}{.}4/9\overset{m}{.}6$) and D + 14.696 ($9\overset{m}{.}5/10\overset{m}{.}4$).*

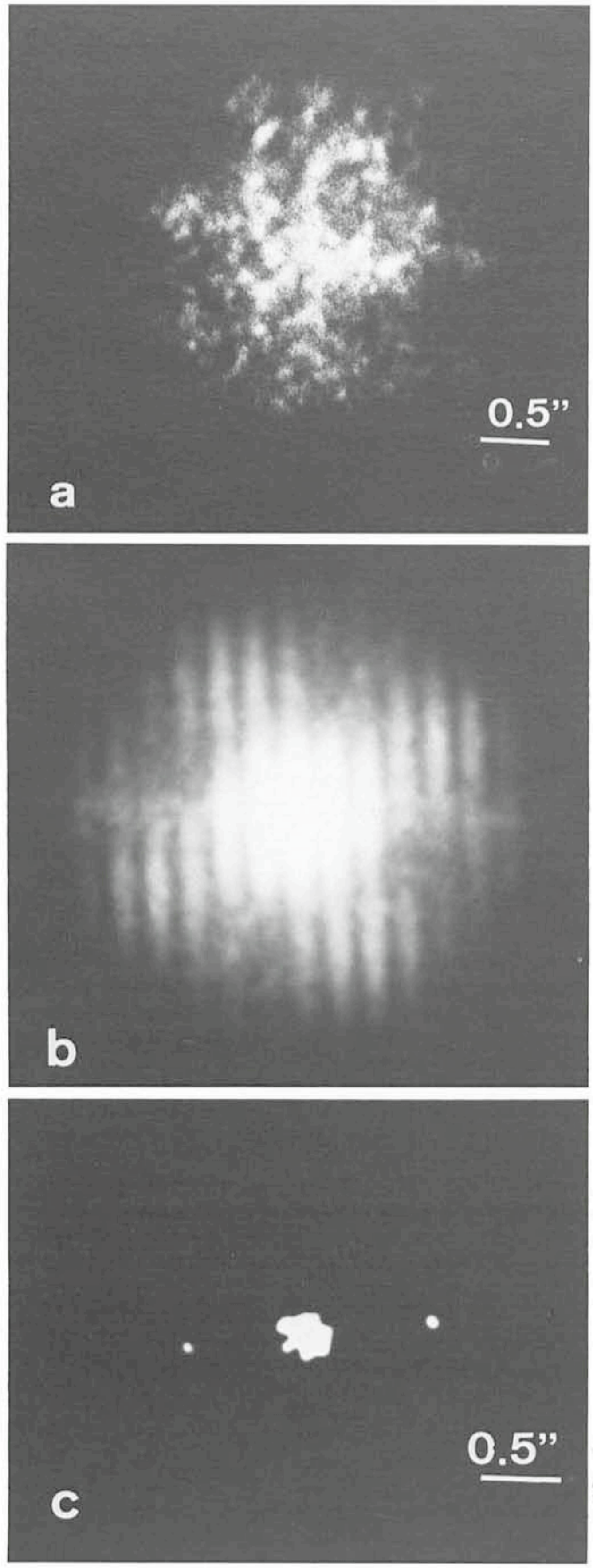


Fig. 5: *Speckle interferometry with a simulated Multiple Mirror Telescope (MMT). Figure 5 a is one of 625 MMT speckle interferograms of Zeta CNC A–B. Figure 5 b shows the average power spectrum of the 625 speckle interferograms and Figure 5 c is the reconstructed autocorrelation of Zeta CNC A–B (separation = $0\overset{''}{.}81$).*

found that the S/N ratio of the MMT measurement was nearly the same as in the case of the full aperture.

Example 5: Reconstruction of Actual Images by Speckle Holography

Speckle interferometry yields the high resolution autocorrelation of the object. It is also possible to reconstruct actual images from speckle interferograms. For that purpose one has to record speckle interferograms of the object one wants to investigate, *and simultaneously* speckle interferograms of an *unresolvable* star close to the object. The speckle interferograms of the unresolvable star (point source) are used as the deconvolution keys. It is necessary that the object and the point source are in the same "isoplanatic patch". The isoplanatic patch is the field in which the atmospheric point spread function is nearly space-invariant. We found under good seeing conditions the size of the isoplanatic patch to be as large as 22 arcseconds, which was at the limit of our instrument (article in press).

The technique of using as the deconvolution keys speckle interferograms of a neighbourhood point source is called speckle holography. Speckle holography was first proposed by Liu and Lohmann (*Opt. Commun.* **8,** 372) and by Bates and co-worker (*Astron. Astrophys.* **22,** 319). Recently, we have for the first time applied speckle holography to astronomical objects (*Appl. Opt.* **17,** 2660). Figure 6 shows an application of speckle holography. In this experiment we reconstructed a diffraction-limited image of Zeta Cancri A–B by using as the deconvolution keys the speckle interferograms produced by Zeta CNC C, which is 6 arcseconds apart from A–B.

The measurements reported here are only a small part of the measurements that were performed with the 1.5 m and 3.6 m telescopes. We also measured various spectroscopic binaries, six Hyades binaries, other interesting binaries, the diameter of Mira, the central object of 30 Doradus nebula and other interesting objects. We plan to report these measurements when the evaluation is completed.

Finally, we would like to thank A. W. Lohmann for initiating the speckle project and for many stimulating discussions. We would also like to thank the staff at La Silla, especially the night assistants, for their valuable cooperation. The development of the speckle interferometer was financed by the German Science Foundation (DFG).

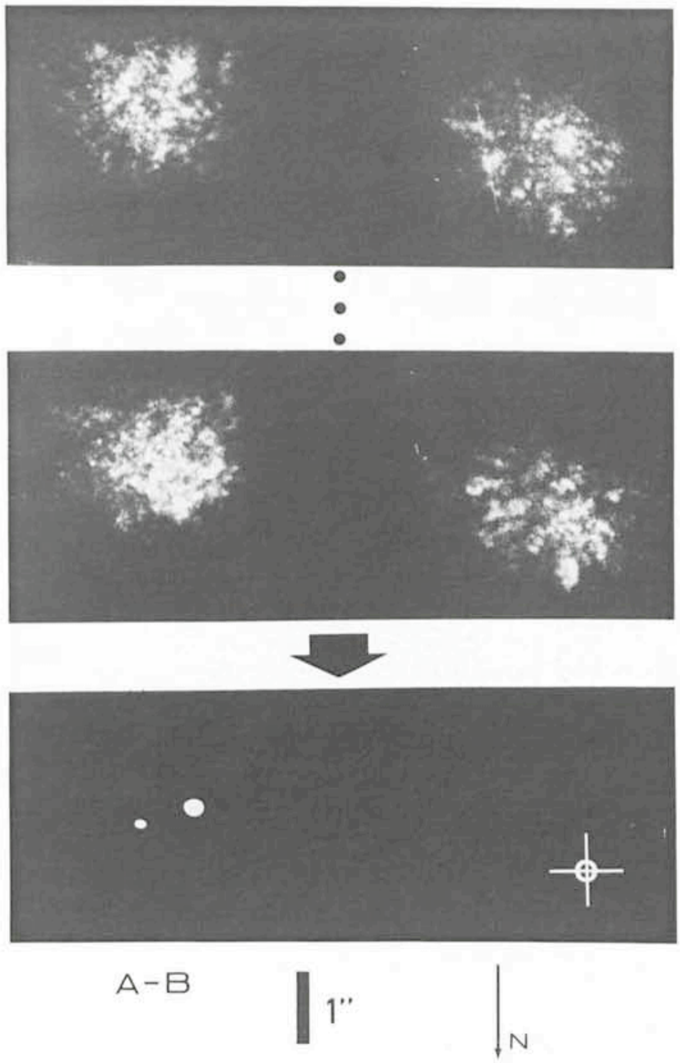


Fig. 6: *Speckle holography measurement of the binary star Zeta Cancri A–B. The diffraction-limited* image *of Zeta Cancri A–B (at the bottom left; separation = 0.″81) was reconstructed from 600 speckle interferograms. The cross at the bottom right has been drawn to indicate the position of Zeta CNC C. Two of the speckle interferograms are shown at the top. The speckle clouds on the left-hand side are produced by Zeta Cancri A–B. The speckle clouds on the right-hand side are due to Zeta Cancri C. The speckle clouds of Zeta Cancri C were used as the deconvolution keys. The speckle interferograms were recorded with the 1.5 m ESO telescope (the photograph in figure 6 is from the article "High resolution astrophotography: new isoplanicity measurements and speckle holography applications", G. Weigelt, submitted to* Optica Acta*).*

Photometric Observations of Minor Planets at ESO (1976–1979)

H. Debehogne, Royal Observatory, Brussels, Belgium

The study of the light variation of minor planets allows an estimate of their form and rotation (direction of axis and period). If it is furthermore possible to obtain a measure of their apparent magnitude over as long a time interval as possible, then the knowledge of the albedo and orbit gives the absolute magnitude and dimension. A table exists that connects the diameter and the magnitude/albedo; it has been compiled by the method of least squares applied to asteroids for which the diameters have been determined by other methods.

Minor planet photometry is in itself an important science and many astronomers work in this area only. However, many astrometrists and computers of orbits are overcome by their desire to improve their knowledge about minor planets and begin to do photometric observations. As indicated above, both astrometry and photometry are important for the study of these objects. The ESO observatory at La Silla offers the possibility to do both, by means of the 40 cm GPO astrograph (astrometry) and the ESO 50 cm telescope (photometry). Moreover, the GPO provides plates that facilitate the 50 cm observations.

There are two types of plates. The first type, which is later used for measurements of positions and improvements of the orbit, may also be used for quick (but less accurate) correction to the available ephemeris and therefore serves to facilitate the identification of the object in the 50 cm finder. The second type provides finding charts which increase the speed and reliability of the photometric observations. The two types of plates differ by the way they are made. The first may be referred to as "normal" for astrometric work; one makes three exposures (the exposure time is determined by the magnitude of the minor planet to be observed), separated by 6–10 minutes (to give a sufficient motion of the object) and slightly displaced, preferably in the δ-direction. This method, which has been used for many years, improves the accuracy of the measurements and makes the correct identification of the minor planet virtually fool-proof. Contrarily, the second type of plate consists of a single, 3–6 minute exposure which serves as finding chart for the 50 cm observations and does not give rise to any confusion because of multiple images as on the plates of the first type.

It is desirable to have a time interval between the GPO observations and those with the 50 cm. The photometric work requires a certain amount of preparation and it is important that the available observing time is well used and not wasted because of problems of identification, etc.

Observations at La Silla

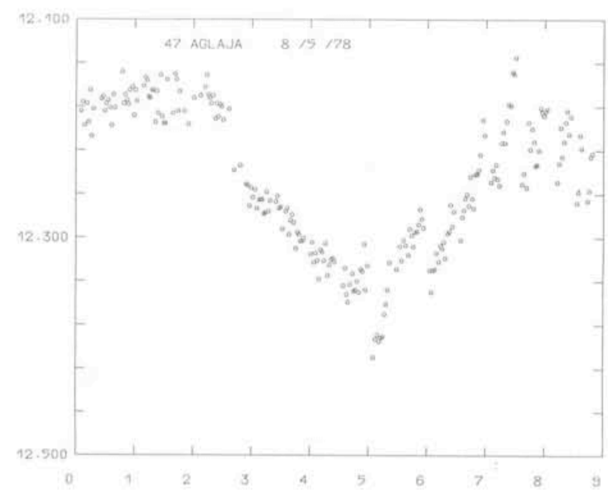
I have carried out photoelectric observations at La Silla, in 1976 with J. and A. Surdej (ESO), in 1978 together with V. Zappala (Turin) and in 1979 with L. and G. Houziaux, V. Zappala, E. van Dessel (Royal Obs., Brussels) and J. F. Caldeira (Valongo, Rio de Janeiro)—this year the variable carbon star V 348 Sgr was also on the programme.

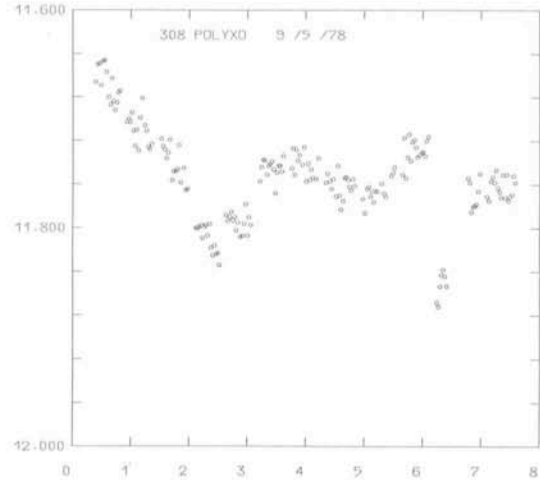
In 1976, the lightcurves of (59) ELPIS, (599) LUISA, (29) AMPHITRITE, (185) EUNIKE, (121) HERMIONE and (128) NEMESIS were observed and the corresponding periods of the first four determined as 13^h41^m, 9^h34^m, 5^h23^m and 10^h50^m, respectively. An interesting study has been carried out by J. and A. Surdej (cf. *Messenger* 13, page 4) which permits to draw conclusions about the form and rotation of asteroids from their observed lightcurves. In the case of (128) NEMESIS, our observations indicated a slow light change and therefore a slow rotation. This incited H. J. Schober (Graz) and F. Scaltriti and V. Zappala (Turin) to continue the observations of this object. A record period of 39 hours was finally found. For (121) HERMIONE a lower limit for the period was established at 9 hours and the period must be a fraction of 97.6 hours. (29) AMPHITRITE showed no less than three minima, a feature that has only been seen in six asteroids (H. J. Schober, 1978). So, all in all, the nine nights of observations in 1976 can be said to have been fruitful.

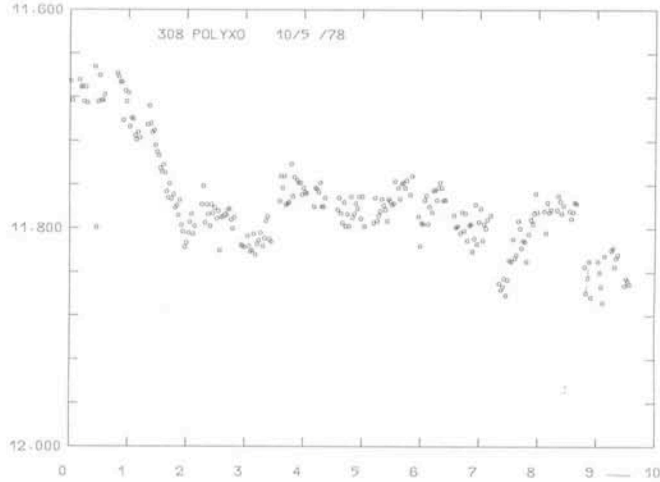
In 1978, observations were carried out during the first half of May. (47) AGLAJA was observed during two entire nights and the periods for (45) EUGENIA (three nights) and (308) POLYXO (three nights) were determined as 5.7 and 12 hours, respectively. This was done in collaboration with V. Zappala and H. van Diest. I feel, however, that the period of POLYXO is longer (32 hours), taking into consideration the observed gradients in the lightcurves and the high accuracy of the ESO 50 cm measurements, as well as the dispersion.

As a result of this experience, it was decided to observe two asteroids at the time this year (25. 4.-4. 5. 1979): (344) DESIDERATA and (110) LYDIA, and (139) JUEWA and (161) ATHOR. It is felt that this method is advantageous: a better assurance about the dispersion and about the reality of small differences in the brightness gradient. For instance small differences now force us to accept a longer period for (161) than believed before. A study is under way with Italian and Belgian colleagues.

The illustrations show observations of (47) AGLAJA and (308) POLYXO which were obtained in 1978. They were drawn by the UNIVAC computer in Uccle (H. van Diest).







Some Remarks about V 348 Sgr

A few words about our attempt to observe this star. It was not possible, but the explanation has now been found by examining the GPO plates. On a plate from April 22, 1979, its magnitude was 11.5. However, on a plate that was obtained four days later by C. F. Caldeira, it was no longer visible, i.e. it was fainter than 16^m! The period of this variable star is about 200 days and it is neither constant, nor regular, or even well known. It is therefore no wonder that it eluded us this time.

It is a pleasure to thank ESO, the night assistants and the La Silla Computer Centre for all help received.

New ESO Slide Sets

The first of the two new ESO slide sets announced on page 3 of *Messenger* No. 17 has just become available.

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

The second slide set—containing 20 of the best black-and-white photographs obtained with the ESO 3.6 m telescope—will become available in late autumn this year.

Spectra of the Variable Star RY Sgr Near Minimum Light

M. Spite and F. Spite

Very interesting spectral observations were obtained by Drs. Monique and François Spite (Paris Observatory, Meudon) of the southern variable star RY Sgr, near a minimum. The observations were carried out with the Lallemand-Duchesne electronographic camera at the ESO 1.52 m telescope, and for the first time the O–O Swan band was detected in a R CrB star.

The variable stars of the R Cr B type are in a very interesting phase of stellar evolution, since they are supposed to be progenitors of type I *supernovae* (Wheeler, 1978). In their atmospheres, hydrogen is scarce or absent and the abundance of carbon and helium is large. They sometimes display small quasi-regular variations and deep minima at irregular intervals. This irregularity does not facilitate the observations of these stars during the minimum phase. Moreover, the stars become rather faint at minimum. The physical processes producing the deep minima are not yet understood. Clouds of carbon grains play a role, but when and where such clouds are formed are still unanswered questions, because the temperature of the photosphere seems too hot for a condensation of carbon into grains.

In order to make some progress in our understanding of the deep minima, spectra should be obtained, with good resolution, at critical phases. This is why we decided to observe, at the 1.52 m telescope, the star RY Sgr, the brightest star of this type after R Cr B, when a decay of its light was announced in 1977.

We had the opportunity to take advantage of the high sensitivity, high resolution and high photometric quality of the Lallemand-Duchesne electronographic camera, associated with the Echelec coudé spectrograph (Baranne, Duchesne, 1976) and we obtained two 60 Å/mm spectra covering the violet, blue and green regions. An untrailed photographic spectrum in the yellow range was obtained at the ESO coudé spectrograph.

Near minimum light, the spectra display the same main features as those observed at a preceding minimum (Alexander et al. 1972):

(1) narrow bright emission lines, called "chromospheric lines" after Payne-Gaposchkin (1963) who analysed the 1960 minimum of R Cr B itself;

(2) three broad bright emission lines in the violet (Ca II and He I λ3888);

(3) absorption lines.

The absorption lines show that the temperature of the photosphere is high, even during the minimum. This remark is backed up by a few measurements of the R–I colour index, obtained at the ESO 50 cm telescope: even neglecting the reddening by carbon clouds, the R–I index points to a rather high temperature.

Due to the good sensitivity of the electronic camera in the green region, the O–O Swan band is clearly visible: it is the first time that this band was ever observed in R Cr B type stars.

It is interesting to note that, for the moderately deep minimum of 1977, the main features of the spectrum

Spectrum of RY Sgr near minimum light in the blue-violet range, obtained with the Lallemand-Duchesne electronographic camera. In the underexposed (violet) part, the broad emission lines of Ca II (H and K lines) and of He I (λ 3888 line) may be recognized: they are evidences for violent motions of atoms.

are, qualitatively, the same as those noted by Alexander et al. (1972) for the deeper minimum of 1967, and this similarity shows that these features are essentially independent of the amplitude of the minimum and independent of its duration.

Some differences exist, however. The "broad bright lines" are displaced towards the red during the 1977 minimum, and they were displaced towards the violet during the 1967 minimum.

A possible interpretation of these differences is an unsymmetrical ejection of carbon clouds. An ejection mainly directed towards the observer would be linked with a deeper minimum *and* violet-shifted broad bright lines. An ejection mainly directed backwards would be linked with a less deep minimum *and* red-shifted lines.

Many observations are still necessary to elucidate the physical phenomena which take place in the course of a minimum. Although obviously difficult, such a programme could well be rewarding.

The observations with the electronographic camera were prepared, as usual, with great care, by J. Breysacher and his team. We are happy to thank them all.

The ESO Workshop

Methods of Abundance Determination for Stars

will take place in Geneva 25–27 March, 1980. Participation is by invitation only, but those interested in more information should contact Prof. P. O. Lindblad, ESO c/o CERN, 1211 Geneva 23, Switzerland.

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NEWS AND NOTES

ESO Planets Named

A number of new minor planets have been discovered with the ESO Schmidt telescope on La Silla. Some of these were named in a recent issue of "Minor Planet Circulars" from the Minor Planet Bureau of the International Astronomical Union.

One of the names has a special connection to ESO:

"(2145) BLAAUW = 1976 UF

Discovered 1976 Oct. 24 by R. M. West at the European Southern Observatory.

Named by the discoverer in honour of Adriaan BLAAUW, Director of ESO (1970-74), President of the IAU (1976-79) and professor at the Leiden Observatory since 1975. He has made many important contributions to stellar kinematics, the structure of the Galaxy and the study of stellar associations. He has been very active in the furthering of collaboration in European astronomy. He is one of the founders of the European journal *Astronomy and Astrophysics* and has been chairman of the Board of Directors since 1969."

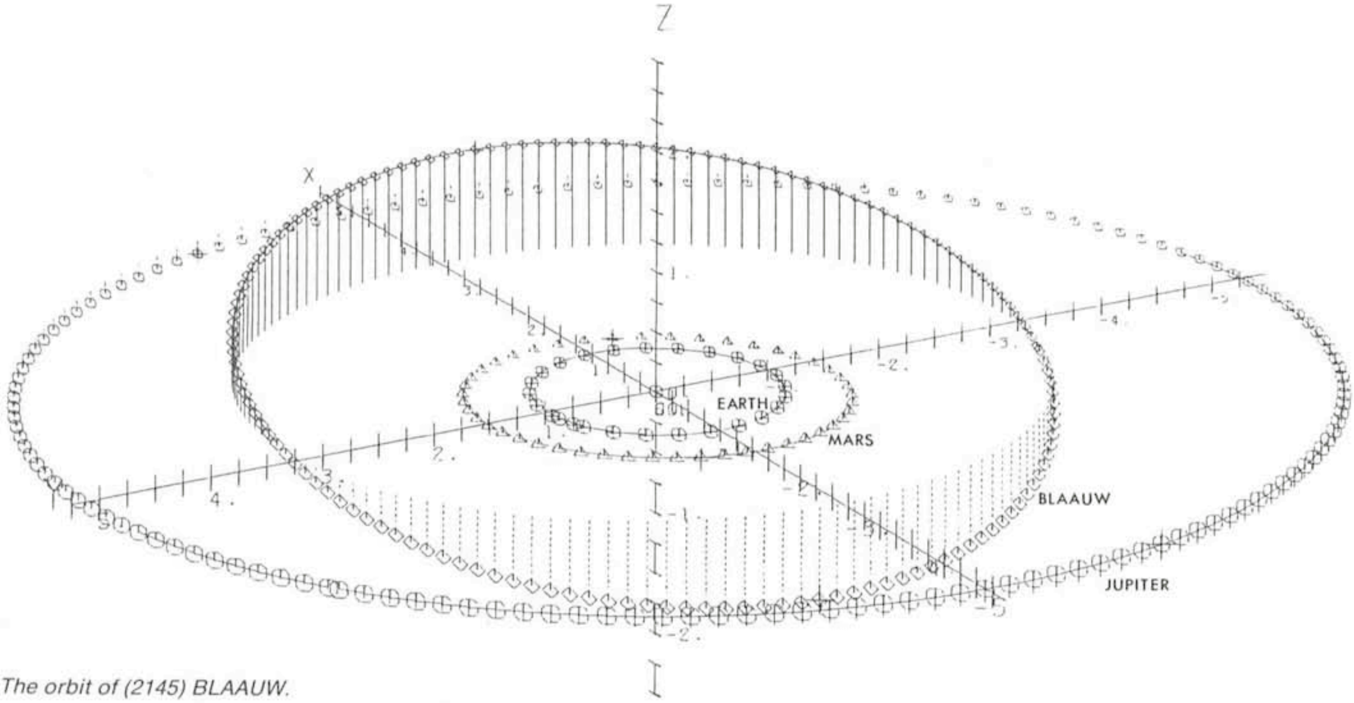
Two Trojan planets that were also found at ESO in 1976 have been given numbers (2146) and (2148). The first one is particularly interesting, because it has the highest known inclination among Trojans, more than 39°. The dedication reads:

"(2146) STENTOR = 1976 UQ

Discovered 1976 Oct. 24 by R. M. West at the European Southern Observatory.

This Trojan planet is named for the Greek warrior with the famous voice, as loud as fifty men together."

Further details about these discoveries were given in *Messenger* No. 8, page 3.



The orbit of (2145) BLAAUW.

The X-Ray Bursters

W. Wamsteker

Astronomical observations from satellites, rockets, balloons and aircraft have given us a completely new image of the universe and its strange inhabitants. Not since the first telescopes were put together, almost 400 years ago, has there been such a burst of new discoveries. The astronomical "zoo" of peculiar objects is steadily growing and the "X-ray bursters" belong to one group of animals that poses fundamental problems. Dr. Willem Wamsteker from ESO/Chile reviews this fascinating subject.

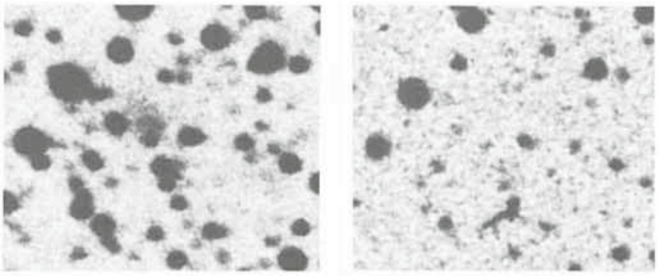


Fig. 1: *A red (left) and a blue (right) plate of the field of the rapid burster (MXB 1730–335) taken with the ESO Schmidt telescope by H.-E. Schuster. (Plate scale: 1 cm = 24 arcsec; north is at the top, east to the left). The diffuse blob on the left-hand picture is the unresolved core of the highly-reddened ($A_V \approx$ 15 mag) globular cluster Liller-1. One also notices a higher density of stellar background images, probably the brighter giants in the cluster. The rapid burster is thought to be a member of this cluster. Although a central black hole cannot be excluded, it is more likely to be a star that, having completed its evolution, has collapsed into a neutron star.*

The successful launches of the first-generation X-ray satellites has generated interest in a field of astronomy which previously was inaccessible because of the complete blocking of the earth atmosphere. The first-generation satellites consisted of UHURU, ANS, Ariel, SAS-3 and OSO-8. The discoveries of these satellites cover a wide range of objects, from quasi-stellar sources to neutron stars. The observed phenomena are of great interest because they allow the study of black holes, neutron stars and other forms of condensed material.

The conditions prevailing at such objects have been anticipated by theoretical investigations, but no evidence for the existence of such bodies had ever been seen before. We shall here discuss only the aspects of *one* particular class of objects: *the X-ray burst sources;* these are considered to be part of a larger class, the so-called galactic bulge sources.

Discovery of X-ray Bursters

The first X-ray burster (we hereafter refer to these objects as "bursters") was found from an inspection of the records of the ANS (Astronomical Netherlands Satellite). The positional identification of these sources with optical stars was only made feasible when for most of these sources accurate (i.e. a few minutes of arc) positions became available from the SAS-3 satellite. The first burster was found to be associated with the globular cluster NGC 6624. Although the source is definitely associated with the globular cluster (because of the positional coincidence), no real optical counterpart has yet been identified with it. Later, six more globular clusters were found to be also X-ray sources, of which four had burst characteristics.

One of these was of particular interest because it led to the additional discovery of a new, highly obscured globular cluster, which was until then unknown. The burster MXB 1730–335—MXB means MIT X-ray burster—which is also referred to as "the rapid burster", stands apart from other bursters because of its peculiar characteristics, to which we shall come back later. When the position of this X-ray source became known with sufficient accuracy, Dr. W. Liller found on a deep red photograph an extended object which was resolved into stars. Later, an infrared source was found independently by Kleinmann at CTIO and Wamsteker at ESO. The analysis of these results showed that one was indeed looking at a globular cluster which is now normally referred to as Liller 1 in the expectation that Dr. Liller will find more of these objects. However, the association of MXB 1730-335 with a globular cluster, as well as the other burster coincidences with globulars, made the likelihood of studying these objects at optical wavelengths rather small. The density of stars in the central regions of globular clusters is very high and it is therefore extremely difficult to study individual stars, especially when they are also faint.

Fortunately this situation changed when some of the galactic bulge sources showed burst characteristics. At present about 30 X-ray sources are known which have shown at some time burst characteristics. Of these, 12 have a more or less certain optical counterpart. However, only 5 of these are single stars which allow the possibility of separate optical investigations.

What are Bursters?

Burst sources are X-ray sources which maintain a more or less stable brightness level—sometimes variable within time scales of the order of days—upon which infrequent and irregular brightenings of about 10 times the normal emission level are superposed. These bursts show an extremely short rise time; within 1–2 seconds the brightness increases approximately tenfold and after this the brightness decays more or less exponentially in a time of 5–10 times the rise time. Although the bursts represent an extremely spectacular phenomenon, they contain only a fraction of the total energy emitted by these objects. This is simply due to their short duration and infrequent occurrence. (Energy in bursts $\approx 10^{-2}$ x energy in constant source.) Most bursters show this type of behaviour where bursts occur with intervals which are separated by 10^3–10^4 times the decay time of 5–20 seconds of the bursts. The spectrum of these sources softens during the decay; this means that the temperature associated with the X-ray spectrum becomes cooler while the source gets back to its quiet X-ray brightness level. These bursts are said to have type-I characteristics.

The second type of bursts (type-II bursts) are only seen in the "rapid" burster and are the reason for its name. In addition to type-I bursts, this source shows at times what appears to be "Sten-gun" fire in the X-rays. Up to 1,000 bursts per day have been seen for this source! These type-II bursts are less energetic and do not show the spectral cooling seen in the type-I bursts, as was found by the MIT astronomers.

Burster-generated International Collaboration

The presence of these enigmatic objects has stimulated a large number of collaborative efforts involving astronomers at many observatories all over the world. Upon the independent suggestions of various astronomers, ESO astronomer Holger Pedersen, Professor Walter H. G. Lewin and his collaborators at MIT, among others, took it upon themselves to organize observations from ground-based sites simultaneously with monitoring at X-ray wavelengths by satellites. The satellites involved are SAS-3 (now defunct), the British UK-6 satellite and the Japanese satellite HAKUCHO. The first campaign, two years ago, did not give many significant results. One of the reasons for this was that at that time no real optical counterparts had been unambiguously identified, so many observations were done with large diaphragms to match the X-ray error circles. One of the most significant results of the first campaign was an upper limit to the optical activity derived from a photograph of a television monitor where no optical activity was seen at the time an X-ray burst occurred (by a soviet group). It was understandable that under those conditions chances of success were slim. The situation changed with the smaller error boxes generated by the SAS-3 RMS experiment. The much smaller number of stars in the error boxes made unambiguous identification of single stars with the bursters possible.

In 1978—during the second campaign—the first coincidence event (in X-ray jargon: HIT) was obtained by McClintock of MIT at CTIO on the burster MXB 1735-44. The stars associated with the bursters are very faint. The counterpart of MXB 1735-44 has a visual magnitude of $V \approx 17\overset{m}{.}5$ and is the brightest of all. Therefore, observations at optical wavelengths of phenomena associated with the X-ray bursts can only be made with large telescopes during the dark of the moon, for which many programmes supply competing pressure on the telescope time allocating committees. At telescopes with apertures of less than 2 metres it is imperative to work with the full sensitivity of a detector (photomultiplier), to obtain sufficient photons and to detect bursts in the noise. It is then not feasible to get information about the spectrum of a burst in the optical wavelength region. Although the X-ray bursts are much brighter than the stable flux, in the

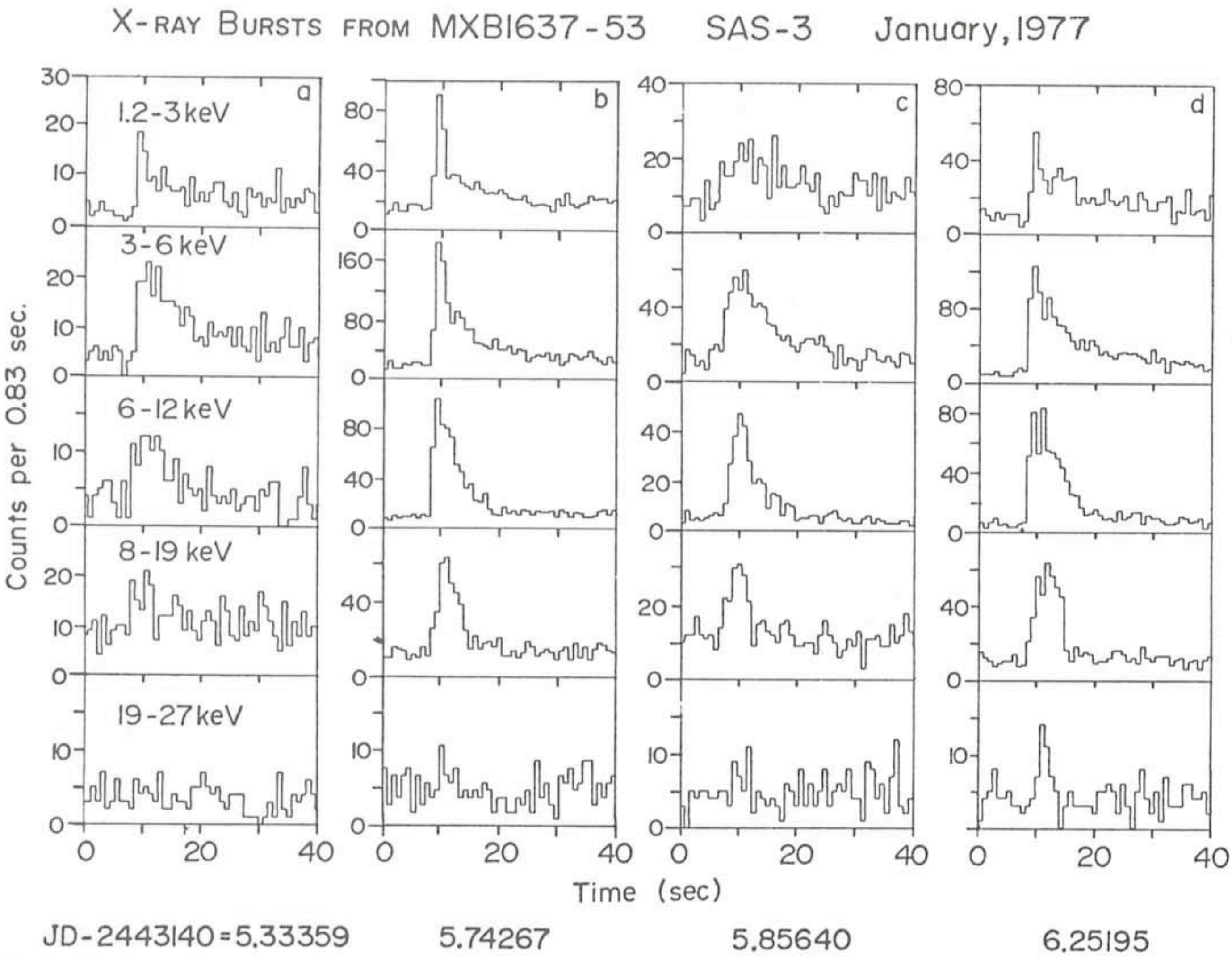


Fig. 2: *This figure shows the raw counts plots for some X-ray observations of the burst source MXB 1637–53. As indicated, the observations are shown for five different energy levels. For the burst on day 5.74267 the very rapid rise is quite obvious—the data brins are 0.8 sec in duration. Note also the much longer tail in the decay at lower energies (1.2–3 keV) in comparison with the foster decrease at higher energies (19–27 keV). This indicates the cooling of the source. (Figure adapted from Hoffman, Lewin and Doty,* Ap. J. **217**, *L23, 1977.)*

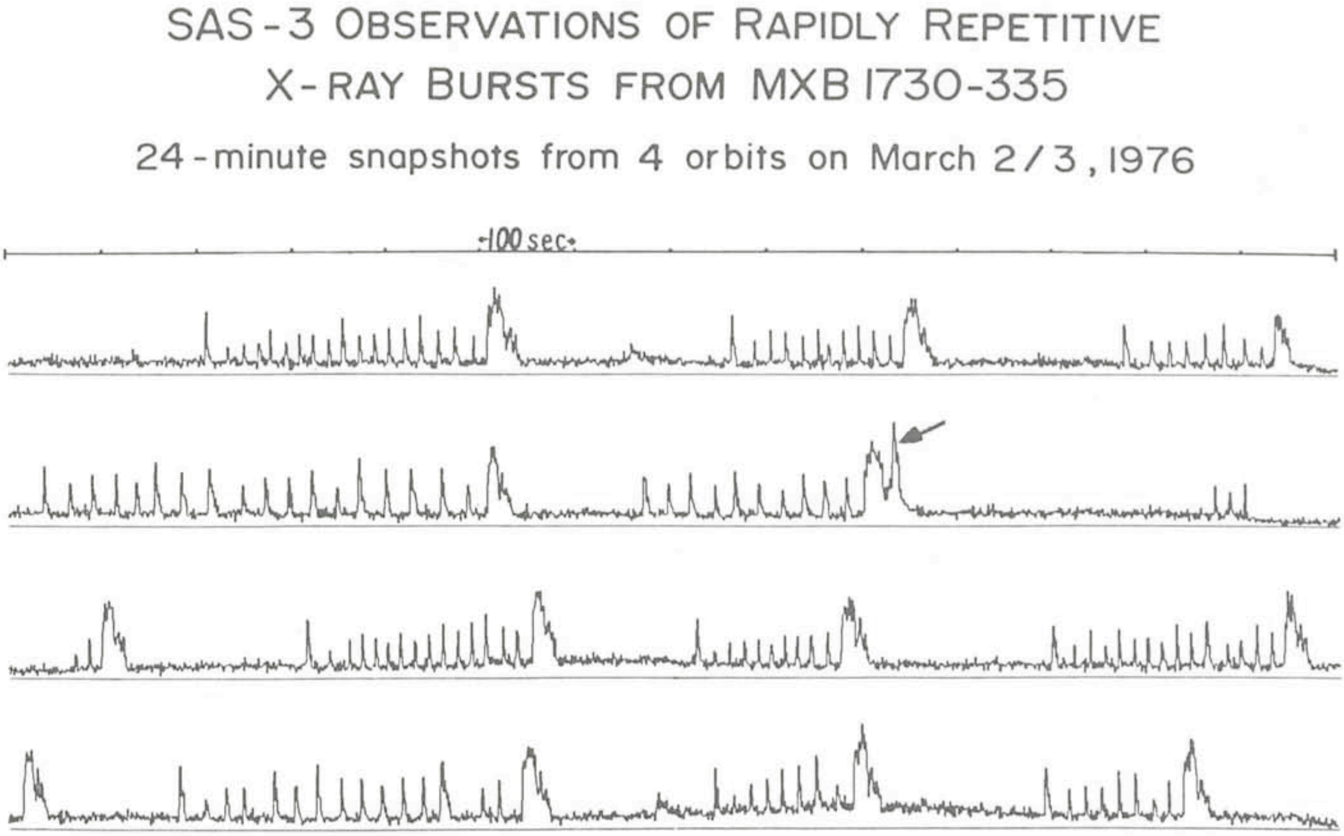


Fig. 3: *These observations of the "rapid burster" clearly show how this source got its nickname. After the stronger bursts usually follows a period in which the source is burst-inactive. It appears that the length of the quiet period is dependent on the strength of the preceding burst. The arrow indicates a burst seen by the same detector coming from another nearby burst source. Through the comparison of data from different detectors researchers are usually able to separate such effects out of the data. (Figure adapted from Lewin,* Annals of the New York Acad. of Sciences, **302,** *210.)*

optical one expects—extrapolating the earlier mentioned spectral softening—the reverse to be the case. The burst will only be seen as a relatively small fluctuation in the steady signal. One of the few existing instruments which would allow us to obtain colour information on the optical bursts is the ESO 4-channel photometer used at the 3.6 m telescope.

Observations at ESO

In August 1978 the 3.6 m telescope was scheduled for an attempt to crack this problem. During four nights I had the possibility to observe MXB 1735-44 with the 4-channel photometer. A preliminary fast photometry mode was generated for the photometer by the Chilean electronics engineer Mr. Juan Fluxa. It was during those four nights that the "astronomer's luck" still proved to play an important role when observing. The telescope did not show any problems, although still in testing phase, the weather—unusual for this season—was of excellent photometric quality, so all human endevours had succeeded. However, although the source was X-ray active—some 8 bursts were seen by the SAS-3 satellite—none of these occurred at night time! The large amount of data—60,000 integrations of 1 sec each—did however allow an analysis of possible variations with a longer time base. These results, which are now being analysed, will therefore still give important information about the nature of these sources. It is gratifying to note that the programme, which was followed up during the third campaign this year by Holger Pedersen at ESO, has now given the desired results (see page 34).

It is expected that all this activity will lead finally to a better understanding of the processes taking place in these objects. They represent a form of matter under conditions which cannot be simulated in the laboratory at similar temperatures, pressures and stable conditions. It is therefore very well possible that understanding these objects will give us new insights into the fundamental properties of matter.

Possible Mechanisms

Although various mechanisms have been proposed for these sources, most astronomers in this field favour the so-called *thermonuclear flash* model. In this model, matter is accreted onto the surface of a neutron star (accretion = the process through which matter is slowly spiraling onto the surface of very dense objects). The material falling on the surface of the neutron star is "burned" into helium, in a process similar to that of a hydrogen bomb. This continuous conversion of hydrogen into helium then gives rise to the steady X-ray flux of these sources. When the pressure and the temperature of the helium become sufficiently high, an unstable condition results and a helium bomb is detonated. This last process gives rise to energy which we see later in the form of X-ray bursts and optical bursts. The question of whether we see the primary radiation, or whether all radiation we see in the bursts is reprocessed radiation through the local heating of the atmosphere of a normal companion star, is one important aspect of this problem which we hope to solve through our observations.

Optical Bursts from MXB 1636-53

H. Pedersen

Dr. Holger Pedersen of ESO/Chile recently was privileged to witness optical "bursts" from an X-ray source. With only a very limited number of such observations ever made, he conveys in this note a very important aspect of observational astronomy: the immense joy of making discoveries!

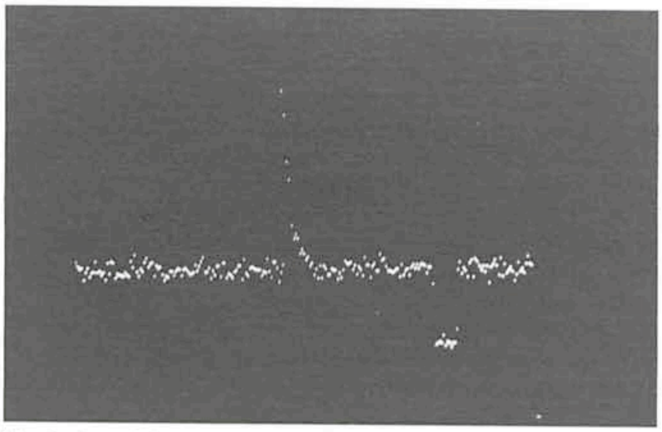


Fig. 2: *One of the strongest optical bursts from MXB 1636-53. The photograph was taken from an oscilloscope display showing the last 12 minutes of observations. The stellar intensity increased nearly by a factor of four in less than 2 seconds. The level of the sky brightness is also indicated.*

Until recently, only two of the five known optical counterparts of the X-ray bursters were known also to emit optical bursts. In both cases, the association between the X-ray data and the optical bursts were based on only one event.

The optical counterparts are very faint, around 30,000 times fainter than visible to the naked eye. This is probably one of the reasons why so few events have been observed so far. Moreover, the bursts are quite unpredictable and come with intervals of hours or days.

Therefore, the astronomer who wishes to do this kind of observation needs three things: a large telescope with a highly effective photometer, a dark, moonless sky and then either good luck or a lot of observing time. All these conditions were fulfilled when I had the opportunity to use the newly finished Danish 1.5 m telescope at La Silla in June and July this year. The work was only a small part of an international "Burst Watch" campaign coordinated by Professor W. Lewin and co-workers at the Massachusetts Institute of Technology. Several other optical observatories did similar observations and the X-ray data were taken by no less than two recently launched satellites: the Japanese HAKUCHO (the Swan) and the British UK-6.

The first two nights on La Silla were used mostly to solve various technical problems and rehearsing the observing routine. Finally I got started on the night June 20/21. Seventeen minutes after the beginning, the star (called MXB 1636-53) had to be recentred in the diaphragm. An extra mirror was inserted into the beam in order to image the star and its surroundings on the TV camera. Suddenly the field on the TV monitor looked strange and unrecognizable. It took some moments to realize that the object was in outburst, now being much brighter than normal! A few more seconds were lost when doing the final position correction and taking the TV mirror out of the beam. Therefore, the measurements showed only the tail of the burst. Bad luck. No doubt the burst had been very bright compared to the two previous optical bursts observed last year from Cerro Tololo and Wyoming. However, later the same night two more bursts were recorded and, this time, also "secured" on magnetic tape. That was nearly too good. Could they perhaps be due to some instability in the electronics? In any case, a telex was sent to MIT stating that "optical events" had been seen. A couple of days later came the confirmation. The Hakucho team, headed by Professor Minoru Oda, hat found X-ray bursts at all three moments (the British satellite was observing another object, MXB 1735-44).

During the rest of the observing period eleven more bursts were recorded. All were noticed as the data slowly crossed an on-line oscilloscope display. Figure 2 shows one of the strongest bursts: the intensity increased by a factor of 3.7 in less than 2 seconds. Seeing such a phenomenon while it was going on was a great experience. Now remains a joint effort with the Hakucho team and MIT in order to correlate and interpret the data. Hopefully these observations will help to give an answer to some of the still open questions regarding the physics of these strange objects.

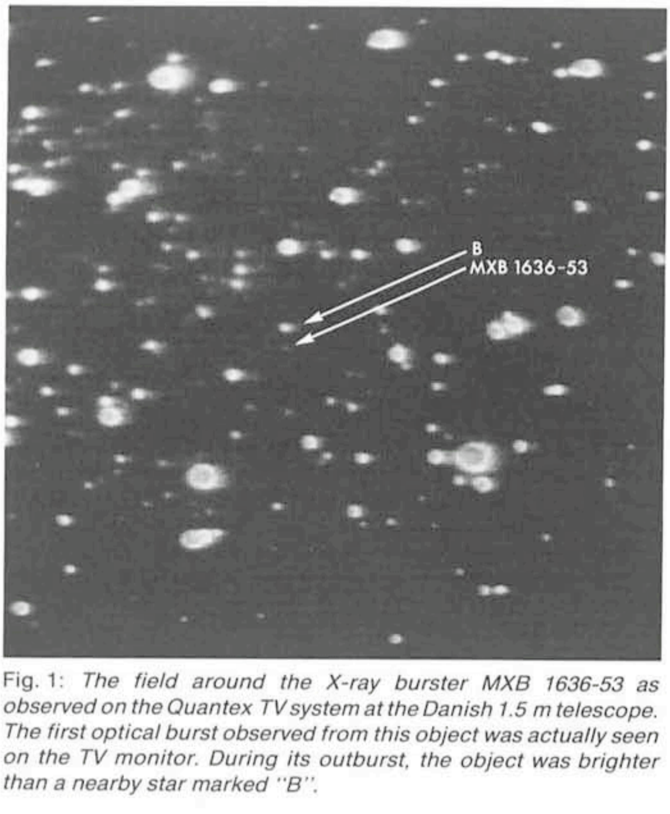
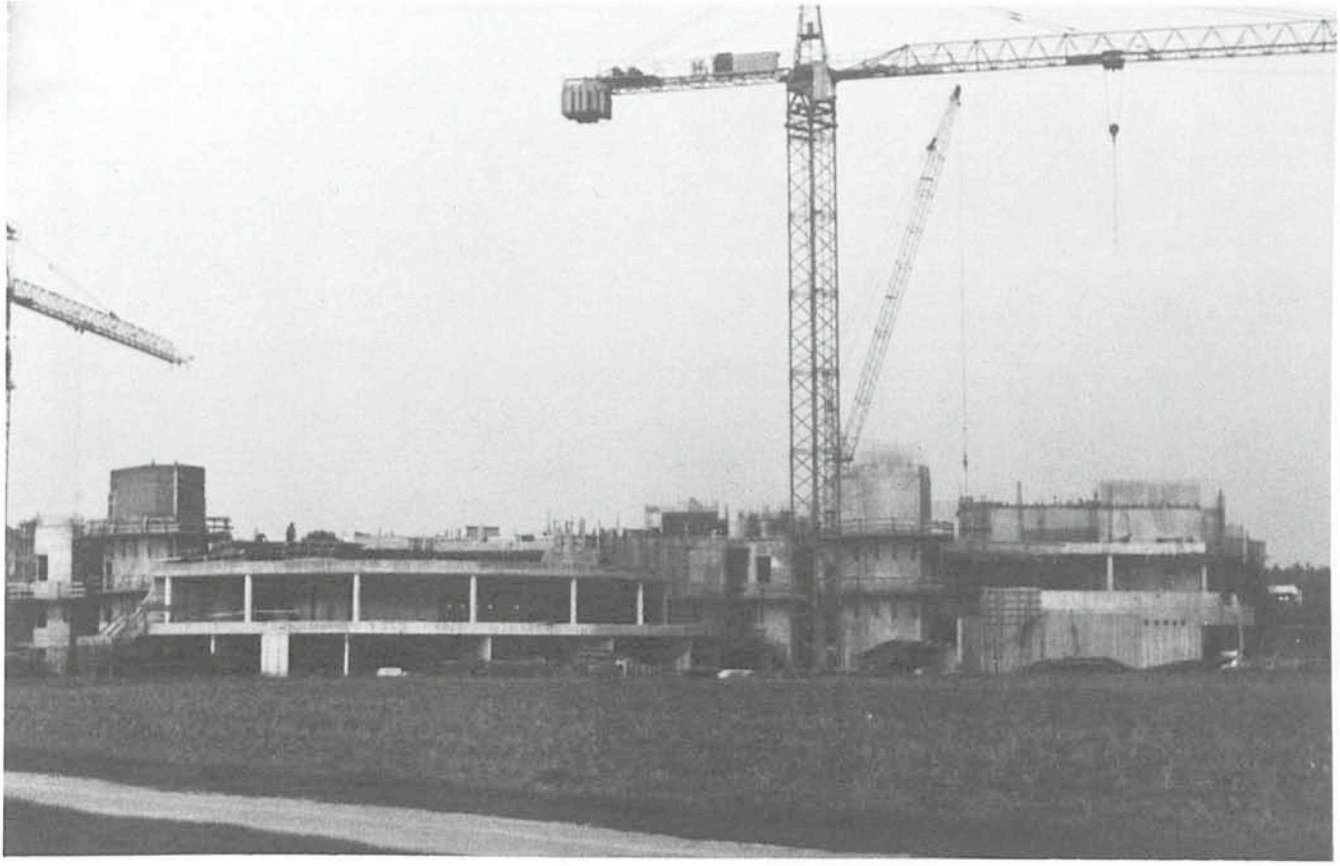


Fig. 1: *The field around the X-ray burster MXB 1636-53 as observed on the Quantex TV system at the Danish 1.5 m telescope. The first optical burst observed from this object was actually seen on the TV monitor. During its outburst, the object was brighter than a nearby star marked "B".*



ESO Headquarters Construction Site

The construction work on the ESO Headquarters building at Garching has been proceeding well during the past few months and it now seems certain that the building will be terminated in summer next year. The photograph was taken on September 10, 1979.

PERSONNEL MOVEMENTS

Staff

ARRIVALS

Garching:

Denis PIERRE (French), Accounts Clerk, 17.9.1979

Geneva

Arne ARDEBERG (Swedish), Astronomical Director La Silla, 1.8.1979. For about 2 months in Geneva and then La Silla

La Silla

Michel MAUGIS (French), Electronics Technician, 1.10.1979
Nikolaus VOGT (German), Astronomer, transferred from Santiago, 1.12.1979

DEPARTURES

Garching

Willem VAN WEEGHEL (Dutch), Accountant, 31.12.1979

Geneva

Jürgen MATERNE (German), Astronomer/Physicist, 30.6.1979
Torben ANDERSEN (Danish), Mechanical Engineer, 24.8.1979

La Silla

Günter SCHUBA (German), Electronics Technician, 30.6.1979
Charles TISSOT (French), Projects and Works Coordination Assistant, 30.9.1979
Marinus DE JONGE (Dutch), Head of Technical Research Support Group, 31.12.1979
Willem WAMSTEKER (Dutch), Astronomer, 31.12.1979

Paid Associates — Fellows — Coopérants

ARRIVALS

Geneva

Preben GROSBØL (Danish), Fellow, 1.9.1979
Edwin VALENTIJN (Dutch), Fellow, 1.9.1979
Roger FERLET (French), Fellow, 1.10.1979
Jeremy SELLWOOD (British), Fellow, 1.11.1979

La Silla

René BARBIER (Belgian), Coopérant 1.10.1979
Christian MOTCH (French), Coopérant 1.10.1979

DEPARTURES

Geneva

Hernan QUINTANA (Chilean), Paid Associate, 31.8.1979
Philippe VERON (French), Paid Associate, 30.9.1979

New Appointments of Staff Already in Post

Geneva

Massimo TARENGHI (Italian), Astronomer, 1.9.1979

La Silla

Patrice BOUCHET (French), Astronomer, 1.9.1979
Jan LUB (Dutch), Astronomer, 1.9.1979
Holger PEDERSEN (Danish), Astronomer, 1.9.1979

ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy . . . It is supported by six countries: Belgium, Denmark, France, the Federal Republic of Germany, the Netherlands and Sweden. It now operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where ten telescopes with apertures up to 3.6 m are presently in operation. The astronomical observations on La Silla are carried out by visiting astronomers—mainly from the member countries—and, to some extent, by ESO staff astronomers, often in collaboration with the former.

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

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

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

Editor: Richard M. West
Technical editor: Kurt Kjär

EUROPEAN
SOUTHERN OBSERVATORY
Schleißheimer Straße 17
D-8046 Garching b. München
Fed. Rep. of Germany
Tel. (089) 3204041-45
Telex 05215915 eso d

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ALGUNOS RESUMENES

Planeta menor descubierto por asistentes nocturnos de ESO

Durante la reciente visita a Europa del astrónomo responsable, H.-E. Schuster, los asistentes nocturnos Oscar y Guido Pizarro estaban a cargo de los trabajos en el telescopio Schmidt. Al controlar las placas que habían tomado durante la noche descubrieron rastros de un planeta comparativamente brillante. Lo marcaron y lograron encontrar rastros del mismo planeta en las placas que fueron tomadas para el mismo programa durante las siguientes noches.

La primera placa fue tomada el día 19 de mayo de 1979 y preliminarmente el nuevo planeta fue nombrado 1979 KA. Se efectuaron observaciones adicionales durante tres noches en junio, y el Minor Planet Bureau computó una órbita preliminar. El nuevo planeta tiene un diámetro de aproximadamente 10 kilómetros y su distancia media al sol es de alrededor de 400 milliones de kilómetros.

Erupciones ópticas descubiertas en MXB 1636–53

La identificación de objetos en los cuales se producen erupciones de rayos X con objetos ópticos es solamente posible cuando sus posiciones son conocidas con suficiente precisión. Los detectores de rayos X acarreados por satélites han comprobado de ser sumamente eficientes para determinar sus posiciones, y especialmente el satélite americano SAS-3 ha sido útil, reduciendo las posiciones inciertas a círculos con un diámetro de 20 segundos de arco.

Se sabe que dentro de algunos segundos después de una erupción de rayos X se puede observar un evento similar en la contraparte óptica. El astrónomo que desea hacer esta clase de observaciones necesita tres cosas: un gran telescopio con un fotómetro de alto alcance, un oscuro cielo sin luna, y mucha suerte o muchas noches de observación.

Todas estas condiciones se cumplieron cuando el Dr. H. Pedersen de ESO/Chile tuvo la oportunidad de usar el recién terminado telescopio danés de 1,5 m en La Silla durante junio y julio del presente año.

El trabajo era parte de una campaña internacional coordinada por el MIT. Varios otros observatorios ópticos hacían observaciones similares y los datos de rayos X fueron registrados por dos satélites recientemente lanzados: el japonés HAKUCHO (el cisne) y el británico UK-6.

Durante la noche del 20 al 21 de junio, el campo en el monitor de televisión repentinamente se vio extraño e irreconocible. Fue necesario un momento para darse cuenta que el objeto (llamada MXB 1636-53) se encontraba en erupción, siendo mucho más brillante que de costumbre. Más tarde en la noche se registraron dos erupciones adicionales.

Fue enviado un telex al MIT informando que se habían observado «eventos ópticos». Algunos días más tarde se tuvo la confirmación. El equipo de HAKUCHO, dirigido por el Profesor Minoru Oda, había observado erupciones de rayos X precisamente en los momentos indicados (el satélite británico observaba otros objetos).

Durante el resto del período de observación se registraron varias otras erupciones. Fue una gran experiencia ver tal fenómeno en los momentos de producirse.

Interferometría «speckle» en La Silla

Recientemente los Sres. J. Ebersberger y G. Weigelt del Instituto de Física de la Universidad de Erlangen-Nürnberg, República Federal de Alemania, llevaron a cabo un programa de interferometría «speckle» en los telescopios de ESO de 1,5 y 3,6 metros.

La interferometría «speckle», una técnica relativamente nueva, se basa en exposiciones muy breves y largos focales muy extensos, permitiendo disociar estrellas dobles y discos estelares.

Hasta ahora esta técnica se ha limitado a estrellas relativamente brillantes, pero los Sres. Ebersberger y Weigelt están convencidos que en un futuro próximo ella será aplicada también a objetos más complejos, como ser núcleos galácticos débiles.

Observatorio Roque de Los Muchachos

Entre España, el Reino Unido, Dinamarca y Suecia se ha llegado a un acuerdo para la construcción de un observatorio internacional en la isla de La Palma del grupo de Las Canarias.

Los acuerdos preven la instalación de instrumentos de gran alcance, y dentro de algunos años deberá funcionar allí un telescopio británico de 4,2 m. Dentro de poco el telescopio Isaac Newton de 2,5 m será llevado desde Inglaterra y se está planeando un telescopio británico de 1 m. El círculo meridiano automático del Observatorio de Brorfelde en Dinamarca será instalado en 1981 y una estación solar sueca será cambiada desde Capri (Italia) a La Palma.